Società Chimica Italiana

XXVIII Congresso Nazionale

MILANO, 26 - 30 Agosto 2024

SCI 2024

Chimica

ELEMENTI DI FUTURO

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Medaglie della Società Chimica Italiana

- **MD-01. Medaglia d'Oro Cannizzaro**: Prof. Gianfranco Pacchioni
- **MD-02. Medaglia d'Oro Natta**: Prof. Aldo Roda
- **MD-03. Medaglia d'Oro Illuminati**: Dott. Carlo Fiorentini
- **MD-04. Medaglia d'Oro Pisani**: Prof.ssa Maria Cristina Menziani
- **MD-05. Medaglia d'Oro Piria**: Prof. Maurizio Prato
- **MD-06. Medaglia d'Oro Paternò**: Prof. Luca Prodi
- **MD-07. Medaglia d'Oro Tiezzi**: Prof. Damià Barceló Culleres
- **MD-08. Medaglia d'Oro Marotta**: Dott.ssa Armida Torreggiani

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MD-01

From Li clusters to nanocatalysis: a personal tour of 40 years of cluster chemistry

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I will trace the history of 40 years of research in cluster chemistry from my personal point of view recalling experiences and anecdotes in my numerous stays in Berlin, Munich, and at IBM in California. I will describe how my research activity began in the early 1980s with studies on the electronic structure of Li clusters in the gas phase. Since then, research on the chemistry and physics of clusters has made enormous progress, thanks to the development of new experimental techniques, advanced theoretical methods and a continuous growth in computing power. The structure and properties of bare clusters, ligand-stabilized organometallic clusters, and supported nanoparticles were elucidated with the ultimate goal of creating strong links between cluster science, surface chemistry, and heterogeneous catalysis. This has led to a better understanding of catalysis using supported nanoparticles down to individual atoms and the possibility of designing new nanostructured catalysts (including single atom catalysts) with desired properties. The presentation will conclude with some considerations on how the way of doing science has changed from when I started to today.

MD-02

Analytical chemistry in front of the curtain: a personal experience of the last 40 years

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Analytical chemistry has continuously evolved over the last 40 years, leveraging advancements in related fields such as materials science, instrumentation, nanotechnology, biotechnology, "omics," and molecular biology. This evolution has positioned analytical chemistry as an 'enabling science' for numerous disciplines, including life sciences, medicine, environmental science, and food science. Despite its significant contributions, the general public often perceives the work of analytical chemists as routine service rather than scientific innovation. During this transformative period, my scientific activity has been at the forefront of analytical chemistry's metamorphosis. Beginning in the late 1970s, my research in bioanalytical clinical chemistry benefited from the availability of pure enzymes and the development of enzymatic assays that replaced nonspecific and time-consuming chemical methods. We developed highly sensitive coupled enzymatic reactions with co-immobilized enzymes in continuous flow systems, utilizing bio-chemiluminescence (BL/CL) detection. The groundbreaking work of Nobel laureate R. Yalow on radioimmunoassay (RIA) inspired significant advancements in analytical immunology. This led to the production of antibodies against almost any molecule, revolutionizing medicine by enabling the measurement of biomarkers and steroid hormones at picomolar levels. The substitution of radioisotopes with enzymes and BL/CL substrates expanded the use of immunological methods to veterinary medicine, food, and environmental analysis. The specificity of BL/CL, due to the absence of nonspecific signals, facilitated this expansion. Innovations included the development of various BL/CL microfluidic-driven miniaturized devices, validated for point-of-care testing and LFIA biosensors using 3D printing technology. Light measurement advancements, using CCD and smartphone CMOS detectors, enabled simple, affordable portable devices utilized in the ISS space station by astronaut Paolo Nespoli. Additionally, cell-based biosensors using luciferase from various species, including the cloned Luciola Italica, advanced in vivo imaging for cancer models and motility studies in intact animals. Recent research introduced thermochemiluminescence combined with energy transfer principles, offering reagent-free biosensor advantages over CL. Parallel to this, my research on bile acids (BA) since 1975 involved measuring thermodynamic properties such as pKa, water solubility, Surface tension: critical micellar concentration, and Log P in representative BA series. This work led to a productive collaboration with Roberto Pellicciari, studying over 100 new BAs and developing models to predict pharmacokinetics, activity, and metabolism. Ultimately, this research contributed to the pharmaceutical market entry of Obeticholic acid, a new potent FXR agonist. The fruitful collaboration with physical chemistry, synthetic and medicinal chemistry was the main key of the success.

MD-03

Reflection on Chemistry Educational Research: the example of the pathway on combustion in elementary school

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The didactic research of chemistry should have, in my opinion, as a fundamental task that of building a vertical curriculum from elementary school to upper secondary school capable of achieving meaningful teaching, capable, that is, of guaranteeing to all students, with deep and lasting learning, the knowledge and skills necessary for conscious citizenship: a task, a very demanding one, the realization of which cannot arise except from the coming together of multiple competencies, from epistemological and didactic disciplinary ones, from psychological and pedagogical ones, to those related to a critical reflection on the teaching experience. To use a term much in vogue today, it can be said that curriculum research stands on the terrain of complexity; it excludes any reductionist approach, which can only be meaningless or deleterious in educational outcomes. In the above considerations on the meaningfulness of knowledge there is an inescapable aspect that is implicit, but for the sake of clarity it is good to make it explicit: in order to be meaningful, knowledge, in addition to being fundamental and essential, must be adapted to the cognitive and motivational structures of students. Indeed, we think that it is impossible to make knowledge that is too far removed from the possibility of being understood become meaningful, despite all the attempts made to promote understanding through laboratoriality. In scientific teaching, in fact, experiments, per se, are not conceptually obvious and do not guarantee meaningfulness. As all epistemological reflession has pointed out, experiments are theory-laden. Therefore, to build vertical chemistry curriculum hypotheses based on experiments, an epistemologically and psychologically grounded analysis of scientific concepts is indispensable in order to identify, hypothetically, those concepts and experiments most suitable for various ages. An experiment-based approach might otherwise be a livelier variant of specialized disciplinary notionism.

In this contribution we will consider, with an example, the fundamental role of critical reflection on educational experimentation, an aspect much emphasized on the level of principles, but little analyzed and deepened in its indispensable specific functions. Of course, the previously mentioned multidisciplinary theoretical aspects are no less important and are the ones most developed. To these aspects we have dedicated a book [1] where the key parts are epistemological considerations, psychological and pedagogical considerations, those dedicated to a methodological and curricular proposal for the first cycle and finally those referring to a methodological and curricular proposal for the second cycle.

References:

[1] C. Fiorentini, Rinnovare l'insegnamento delle scienze: Aspetti storici , epistemologici, pedagogici e didattici, ,Rome, Aracne, 2018.

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MD-04

1988-2024, a 35-years journey across computational life and material sciences

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Over the past 35 years, we have witnessed the emergence and development of computational chemistry tools that have significantly influenced the way chemical research is conducted in academia and industry. In particular, with the advent of colour workstations and computer graphics, a new hybrid field of molecular modelling and computational chemistry called "computer-aided molecular design" has emerged.

In this article, I will review some of the key results of my research aimed at deepening our understanding of the physicochemical processes in proteins, hard materials, and protein-material interactions for the design of better drugs, materials, and devices. New challenges and opportunities will also be discussed.

MD-05

Nanomaterials for a Better Future

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How strange it is to completely ignore all the restrictions we experienced during the pandemic! It now feels as though those years never existed! However, if the situation has returned to normal, we owe it to the vaccines that were rapidly developed using highly innovative technologies. In fact, especially over the last few decades, science has accustomed us to the rapid resolution of even complex problems, such as the broad diffusion of COVID-19. Solving particularly difficult problems requires considerable efforts from the scientific community, employing multidisciplinary approaches and modern tools, the result of years of research and development.

However, problems are not always solved, and some are not always solvable by science. Think of wars, world hunger, human rights, and poverty. Yet, certain issues, particularly those concerning health and environment, can and must be addressed and solved by scientific research.

During this talk, we will discuss how Chemistry can play a fundamental role in our society. New classes of materials with tailored properties can be prepared and applied once we have the right vision.

Part of the work described in this talk is financially supported by the AXA Research Funds and the European Commission - Horizon Europe through the EIC Pathfinder OPEN 2022 project: PLANKT-ON / 101099192.

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MD-06

Luminescence-based detection of analytes of clinical and environmental relevance

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Light serves as a potent tool for various applications, including (i) generating bright contrast agents for *in vivo* imaging, (ii) achieving high analytical performance in vitro diagnostics, and (iii) facilitating real-time and spatial measurements of analytes of biological and environmental relevance. Luminescence-based techniques, encompassing photo-, chemi-, electrochemi-, and thermochemi-luminescence, offer high sensitivity and versatility to cater to diverse analytical needs.

This presentation highlights two applications demonstrating the versatility of luminescence-based techniques. Firstly, it addresses the imperative for developing an accurate, rapid, cost-effective, and portable platform for detecting infectious agents, emphasized by recent pandemics. In this case, the use of electrochemiluminescence as a signal transduction mechanism, coupled with effective signal amplification, can enable the detection of infectious pathogen genomes with analytical performance comparable to, or even surpassing, PCR methods.[1] Secondly, this presentation explores the design of derivatized natural polymers to detect micro- and nano-plastics, which pose a significant global challenge lacking adequate analytical solutions. In this case, fluorescence-based microscopies facilitated the visualization of small plastic particles and, in certain cases, enabled material speciation.[2]

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References:

[1] P. Nikolaou, E. L. Sciuto, A. Zanut, S. Petralia, G. Valenti, F. Paolucci, L. Prodi, S. Conoci, *Biosensors and Bioelectronics*, **2022,** 209, 114165.
[2] M. Cingolani, E. Rampazzo, N. Zaccheroni, D. Genovese, L. Prodi, *Environ. Sci.: Nano*, **2022**, 9, 582–588.

MD-07

Unlocking Large Biomolecules: Insights into Public Health and Industrial Activity Signatures

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Wastewater-based epidemiology (WBE) has emerged as a powerful approach for surveying the health and lifestyle of population. In this context, proteins have been proposed as potential biomarkers that complement the information provided by previous studies (small exogenous molecules, metabolites, and genomic material). Proteins can also offer a more comprehensive evaluation of wastewater treatments, typically assessed through parameters such as chemical and biochemical oxygen demand[1,2].

In this work, we studied the protein composition in the influent and effluent waters of 3 wastewater treatment plants (WWTPs) in Catalonia which serve communities of different population and industrial profile. The results indicate that excreta (urine and faeces) from humans, and blood and other residues from livestock were the two main protein sources[2]. Furthermore, our findings enable the proposal of specific bioindicators for wastewater-based environmental monitoring. A list of candidates with different application in environmental and health-related fields is selected and will be quantified. This includes human and animal population monitoring, particularly for rodent pest control (amylases) and livestock processing industry monitoring (albumins). Protein-related WBE enables to detect rodent pests in cities and can be a tool with potential for their population control. Rat feces, like human feces, contain proteins that are secreted in the pancreas so, detection of these enzymes in wastewater indicates the presence of live animals, and relative quantification to rodent amylase could allow us to monitor the increase or decrease of rodent feces in these samples. There is no standardized method to determine the numbers of rodents in a city or to estimate population density although some groups have tried to understand their population dynamics. Our work proposes detecting and quantifying rats according to rat feces located in sewage water using some appropriate protein biomarkers.

Additionally, we identified hundreds of proteins from different species including human, livestock and bacteria that allows us a better understanding of the habits and industrial activity of population server by the WWTPs. Our results have allowed us to select a list of protein biomarkers related to different human pathologies to be monitored.

Moreover, this study offers a complete set of complementary information that enhances the understanding of the processes occurring at water treatment plants at a protein level. Proteins are retained in the WWTP and only some recalcitrant molecules remains. This data will be invaluable for implementing new control methodologies in the WWTPs and investigating the impact of wastewater discharge in environmental buffers. In conclusion, sewage proteomics give us new tools for control rodent pest in cities, understand population characteristics and evaluate wastewater treatments

References:

[1] Kasprzyk-Hordern, B., F. Been, *et al.*, J Hazard Mater 2023, 450: 131009, 1-6.
[2] Carrascal M, Sánchez-Jiménez E, *et al.*, Environmental Science & Technology 2023, 57 (30), 10929-10939.

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MD-08

Fostering youngsters'interest in chemistry for sustainable society: Mission ~~im~~possible!

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Chemical culture is seen by youth with less and less interest, probably due to the way science is taught in schools, to the difficulties in the understanding of the real impact on the everyday life and finally, to the shortage of attractive career perspectives. In addition, there is the need to bring the themes proposed by the new European challenges into schools to train in the short term (7-10 years) human resources who have entrepreneurial skills, digital, relational and communication skills, respect for gender and diversity.
In this perspective to trigger the students' interest in chemistry, new materials and solutions for a sustainable society, several learning paths for pupils aged 10–18 years were developed in the framework of two projects, "**Change the Game: playing to be trained for a sustainable future**" (Progettidiricerca@CNR) and "**Raw Matters Ambassadors at Schools**" (RM@Schools - EIT), working at national and European level thanks to two networks involving 15 institutes and 11 cities in Italy, and 29 partners from 18 countries, respectively.[1,2] Different educational approaches are used to foster students' interest in chemistry, circular economy, and RM-related topics, but the core element of the approach is to engage youngsters i.e. by empowering them to communicate with peers and wider society.[3] Serious games and laboratory experiments based on the research works were developed and insert in educational pathways offered to Schools. Thus, students were led to deepening for example the chemistry importance in the development of innovative technologies and the green transition by playing i.e. the RawSeeker board game (Fig. 1) as well as the main strategies of the circular economy by playing EcoCEO-it's your business.[4]
These actions will be of benefit to make youngsters aware of the complexity and interrelation of science, economy with social and sustainability issues.

Figure 1: (from left) The RawSeekes and EcoCEO board games, and European Conference RM@Schools project, CNR Bologna

References:

[1] A. Torreggiani, A. Zanelli, A. Degli Esposti, E. Polo, P. Dambruoso, R. Lapinska-Viola, K. Forsberg, E. Benvenuti, in *Rare Metal Technology 2021* The Minerals, Metals & Materials Series; Springer, 2021; 277–287.
[2] http://rmschools.eu/ ; https://www.changegame.cnr.it/ ; https://ecoceo.eu
[3] M. Canino, A. Zanelli, M. Seri, A. Degli Esposti, A. Torreggiani *Frontiers in Education* 2021, *6*, 690294
[4] A.Torreggiani, A. Zanelli, et al. *11th International Conference of The Future of Education*, 2021, 118-123

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Nobel Lecture

NB-1

From Supramolecular Towards Adaptive Chemistry

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Molecular chemistry has developed a wide range of very powerful procedures for building ever more complicated molecules from atoms linked by covalent bonds.

Supramolecular chemistry aims at generating highly complex chemical systems from molecular components held together by non-covalent intermolecular forces, on the basis of the *molecular information* stored in the covalent framework of the components. A step beyond consists in the design of systems undergoing *self-organization*, i.e. systems capable of spontaneously generating well-defined functional architectures by self-assembly from their components.

Supramolecular chemistry is intrinsically a *dynamic chemistry* in view of the lability of the interactions connecting the molecular components of a supramolecular species and the resulting ability to exchange components. The same holds for molecular chemistry when the molecular entity contains covalent bonds that may form and break reversibly. These features allow for a continuous change in constitution by reorganization and exchange of building blocks and define a *Constitutional Dynamic Chemistry* (CDC) covering both the molecular and supramolecular levels.

CDC introduces a paradigm shift with respect to constitutionally static chemistry. It takes advantage of dynamic diversity to allow variation and selection and operates on dynamic constitutional diversity in response to either internal or external factors to achieve *adaptation*.

CDC generates networks of dynamically interconverting constituents, *constitutional dynamic networks*, that may respond to perturbations by physical stimuli or to chemical effectors. Of special interest is the case where the driving force is an *increase in order*.

The implementation of these concepts points to the emergence of *adaptive* and *evolutive chemistry,* towards *systems of increasing complexity.*

References:

- Lehn, J.-M., *Supramolecular Chemistry: Concepts and Perspectives*, VCH Weinheim, **1995**.
- Lehn, J.-M., *Dynamic combinatorial chemistry and virtual combinatorial libraries*, Chem. Eur. J., **1999**, 5, 2455.
- Lehn, J.-M., *Toward complex matter: Supramolecular chemistry and self-organization*, Proc. Natl. Acad. Sci. USA, **2002**, 99, 4763.
- Lehn, J.-M., *From supramolecular chemistry towards constitutional dynamic chemistry and adaptive chemistry*, Chem. Soc. Rev., **2007**, 36, 151.
- Lehn, J.-M., Chapter 1, in *Constitutional Dynamic Chemistry*, ed. M. Barboiu, *Topics Curr. Chem*, **2012**, *322*, 1-32.
- Lehn, J.-M., *Perspectives in Chemistry – Steps towards Complex Matter*, Angew. Chem. Int. Ed., **2013**, *52*, 2836-2850.
- Lehn, J.-M., Perspectives in Chemistry – *Aspects of Adaptive Chemistry and Materials,* Angew. Chem. Int. Ed., **2015**, *54*, 3276-3289.

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Plenary Lectures

PL-01

A brief philosophical history of the periodic table

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The lecture will begin with a brief history of the origins of the periodic table, beginning with the contributions of Lavoisier, Dalton, Döbereiner and others. I will proceed to the Karlsruhe conference and the ensuing independent discovery of the periodic table by as many as six individuals, culminating with Mendeleev's table just over 150 years ago. We will move on to the challenges that the periodic table faced, such as the existence of pair reversals and the discovery of the noble gases.

Next came several discoveries in physics, including X-rays, radioactivity and the electron, all of which had a profound effect on the understanding of the periodic table. Research in atomic structure beginning at the turn of the 20th century prompted some physicists such as J.J. Thomson and Niels Bohr to begin to seek a fundamental explanation for the periodic table in terms of electronic structure. The later developed quantum mechanics of Heisenberg, Schrödinger, Pauli and others led to a more rigorous explanation, although some open questions remain up to present times. For example, there is yet no fundamental explanation for the empirical rule that the occupation of atomic orbitals proceeds via the simple n + l rule.

In addition, relativistic effects are being increasingly considered in attempts to understand the heavier elements in particular. Finally, several other remaining open questions will be discussed, such as the membership of group 3 of the periodic table, alternative representations such as the 32-column format, the left-step periodic table and whether there may exist an 'optimal form' of the periodic table [1, 2]

References:

[1] E.R. Scerri, The Periodic Table, Its Story and Its Significance, Oxford University Press, New York, 2019[2]
[2] E.R. Scerri, Various forms of the periodic table including the left-step table, the regularization of atomic number triads and first member anomalies, *Chem Texts*, 8, 6 (2022). https://doi.org/10.1007/s40828-021-00157-8

PL-02

"They do it with mirrors"
Biogenic advanced functional materials engineered to fulfill optical functions

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Organisms construct optical 'devices' based on assemblies of crystals of organic compounds. The constituent molecules are mostly purines and pteridines. All the crystals have unusually high refractive indexes in the directions along which the light penetrates the crystal. The crystals form mirrors and light scattering layers that function to increase light sensitivity in the eyes of some organisms, or endow them with brilliant structural colors[1]. The architecture of the reflecting layers varies from multi-layered mirrors tiled with mosaics of guanine[2] or xanthine[3] crystals, to densely packed assemblies of multilayer core-shell spherulites composed of isoxanthopterin crystals[4], or to assemblies of block-shaped crystals of 7,8-dihydroxanthopterin[5]. In all these examples, the hierarchical organization is controlled from the crystal structure at the nanoscale to the complex 3D super-structure at the millimeter level. The molecule, the crystal structure, the crystal size, the crystal morphology and the super-structural arrangement, all together determine the optical properties of the material. We have thus a vast choice of molecular components, assembled following precise blueprints. What makes these components especially apt to fulfill optical functions in organisms, and how do organisms assemble them? Answers to these questions may allow us to synthesize materials with interesting optical properties[6].

[1] D Gur, B Palmer, S Weiner, L Addadi, Adv Funct Mater 2017, 1603514

[2] BA Palmer, GJ Taylor, … N Elad, D Oron, S Weiner, L Addadi, Science 2017, 358, 1172–1175

[3] O Friedman, A Böhm, … G Pass, S Weiner, L Addadi, J. Struct Biol 2022, DOI 10.1016/j.jsb.2022.107834

[4] BA Palmer, VJ Yallapragada, … S Weiner, L Addadi, D Oron, Nature Nanotechnology 2020 15 , 138–144

[5] G Zhang, A Hirsch, … L Kronik, L Leiserowitz, S Weiner and L Addadi, J Am Chem Soc 2019, 141, 50, 19736–19745

[6] L Alus, L Houben, … Dan Oron, Lia Addadi, Adv Mater 2024, manuscript under revision.

PL-03

Computational Discovery of Metal-Organic Frameworks for a Changing World

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Addressing the energy challenges that we face globally requires the coordinated efforts of scientists, engineers, and policy makers. Chemistry has the potential to drive quantum leaps in technology. With theory, computation, and machine intelligence we can accelerate the search for solutions to water scarcity, decarbonization, and clean energy. Metal-organic frameworks (MOFs) are versatile platforms for various applications including catalysis for complex reactions and water harvesting. I will first present our ongoing efforts to understand and design the water-filling mechanism for water-harvesting MOFs.[1]

I will then describe our combined computational and data-driven study of MOF-supported catalysts. Utilization of machine learning algorithms in conjunction with experimental data can not only predict superior catalytic materials, but also under which experimental conditions they are most optimal.[2]

[1] N. Hanikel, D. Kurandina, S. Chheda, Z. Zheng, Z. Rong, S. E. Neumann, J. Sauer, J. I. Siepmann, L. Gagliardi, and O. M. Yaghi, ACS Central Science., 2023, 9, 551-557.

[2] K. E. McCullough, D. S. King, S. Chheda, M. S. Ferrandon, T. A. Goetjen, Z. H. Syed, T. R. Graham, N. M. Washton, O. K. Farha, L. Gagliardi, and M. Delferro, ACS Central Science 2023, 9, 266-276.

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PL-04

Thermodynamic and kinetic approaches for drug discovery to target protein misfolding and aggregation

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Protein misfolding diseases, including Alzheimer's and Parkinson's diseases, are characterised by the aberrant aggregation of proteins. These conditions are still largely untreatable, despite having a major impact on our healthcare systems and societies. To address this problem, I will describe drug discovery strategies to target protein misfolding and aggregation. More specifically, I will compare thermodynamic approaches based on the stabilization of the native states of proteins with kinetic approaches based on the slowing down of the aggregation process. This comparison will be carried out in terms of the current knowledge on the process of protein misfolding and aggregation, the mechanisms of disease and the therapeutic targets.

PL-05

Medicinal Chemistry of Orphan G Protein-coupled Receptors

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Integral cell membrane proteins such as membrane receptors, in particular G protein-coupled receptors (GPCRs), represent the most important classes of drug targets. With more than 800 members GPCRs constitute the largest protein family in humans. However, only a small percentage of membrane proteins is targeted by current therapies. For about 100 (non-olfactory) GPCRs the endogenous agonist still remains unknown or has been postulated but could not be confirmed. These so-called *orphan receptors* belong to the most enigmatic members of the GPCR superfamily. In order to study their roles and functions, and to validate them as drug targets, selective agonists and antagonists are required as tool compounds. Many orphan GPCRs belong to the δ-branch of rhodopsin-like (class A) GPCRs, and are related to the purine/pyrimidine nucleotide-activated P2Y receptor family. Examples include the MAS-related G protein-coupled receptors (MRGPRs).[1] The subgroup of MRGPRX receptors comprises four subtypes, MRGPRX1-4, which appear to be involved in pain transmission, inflammation, immune responses, allergies, and cancer. However, these receptors are primate-specific, which makes pharmacological in vivo studies challenging.[1] Moreover, potent and selective tool compounds have been lacking to elucidate their potential as drug targets.

Originally motivated by the fact that some MRGPRs are activated by the nucleobase adenine,[2] and based on our proprietary compound library which is enriched in purine-related small molecules (https://www.pharma.uni-bonn.de/pharmazeutische-und-medizinische-chemie/en/muller-lab/compound-library?set_language=en), we embarked on identifying and subsequently optimizing tool compounds for the various MRGPRX subtypes. We discovered the first highly potent MRGPRX4 agonists.[3] Moreover, we discovered that the orphan chemokine CXCL14 activates MRGPRX2.[4] Moreover, we developed MRGPRX2 antagonists with sub-nanomolar potency, that were demonstrated to efficiently inhibit mast cell degranulation (unpublished results). MRGPRX receptors and related orphan GPCRs have great potential as future drug targets for the treatment of inflammation, immunity, and cancer.

References:

[1] G. Al Hamwi, Y.K. Riedel, S. Clemens, V. Namasivayam, D. Thimm, C.E. Müller, Pharmacol. Ther. 2022, 238, 108259.
[2] D. Thimm, A.C. Schiedel, J. Peti-Peterdi, B.K. Kishore, C.E. Müller, Acta Physiol. 2015, 213, 808-818.
[3] D. Marx, M.W. Alnouri, S. Clemens, R. Gedschold, Y. Riedel, G. Al Hamwi, T. Pillaiyar, J. Hockemeyer, V. Namasivayam, C.E. Müller, J. Med. Chem. 2023, 66, 15674-15698.
[4] G. Al Hamwi, V. Namasivayam, B. Büschbell, R. Gedschold, S. Golz, C.E. Müller, Commun. Biol. 2024, 7, 52.

PL-06

Artists' secrets revealed under synchrotron light

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Since their discovery in 1895, X-rays have been largely used to analyze historical artefacts. Different X-ray based techniques exist (tomography, fluorescence, diffraction…) which offer complementary information about artistic objects structure and composition. Some chemical analyses intend at determining *a posteriori* chemical and physical reactions at stake in the creation of objects (materials, processes…) while other target reactions which have modified the artworks later on, and the main factors responsible for its degradation. Over the last three decades, a new generation of X-ray based techniques have completed the toolbox of heritage scientists, those based on synchrotron light. Synchrotron facilities offer together a high beam intensity, the possibility to focus the beam to few tens of nanometers, an extended spectral range, and a high coherence. These properties are increasingly used to track the chemical composition of fragments of ancient and artistic materials at the sub-micrometric scale. This presentation will focus on analyses carried out at the European Synchrotron Radiation Facility on major Italian artworks, such as Leonardo da Vinci's *Mona Lisa* and the *Last Supper*[1].

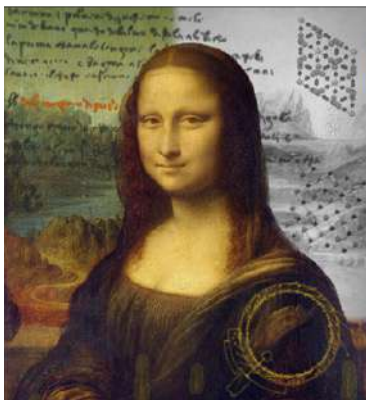

Figure 1: Identification of unusual lead compounds in *Mona Lisa*.

References:

[1] 1. V. Gonzalez, G. Wallez, E. Ravaud, M. Eveno, I. Fazlic, T. Fabris, A. Nevin, T. Calligaro, M. Menu, V. Delieuvin, M. Cotte, Journal of the American Chemical Society, 2023, 145, 23205–23213.

PL-07

Chemistry Innovation in Small Molecule Drug Discovery

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Small molecule therapeutics continue to form the backbone of therapies for all types of life-threatening diseases. The last decade has seen significant progress in extending the range of biological targets which can be addressed with small molecules.

This progress is based on an extension of drug modalities beyond the classical reversible inhibitors of enzymatic active sites or receptor ligand binding sites. Covalent inhibitors allow to design inhibitors for proteins which were considered undruggable just one decade ago. In addition, small molecule inducers of protein-protein interactions open completely new approaches for the modulation of activity of disease-causing proteins.

Synthetic chemistry innovations are at the core of many of these drug discovery breakthroughs. I will talk about the importance of synthetic chemistry in medicinal chemistry in order to shape the future of drug discovery.

Figure 1: The essence of medicinal chemistry

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PL-08

Elements of Future for Sustainable Energy Storage

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Rapid increase in global energy use and growing environmental concerns have prompted the development of clean, sustainable, alternative energy technologies. Renewable energy sources like solar and wind are a promising solution, but they are intermittent. Batteries are the most viable option to efficiently store and utilize electricity produced from them as well as for electrification of transportation sector. However, their widespread adoption requires optimization of cost, cycle life, safety, energy density, power density, and environmental impact, all of which are directly linked to severe materials challenges. Among them, cost, sustainability, and supply chain will be the single dominant hurdle, while maintaining fire safety, as the energy storage market is rapidly expanding.

The appetite for high energy density has driven the lithium-ion battery industry with positive electrodes (cathodes) containing expensive and scarcely available elements like cobalt and nickel;[1] cathode is the most expensive in lithium-ion batteries, comprising 50% of the materials cost. It is critical that the chemistry community embarks on a path toward the development of sustainable, supply-chain-free next-generation battery chemistries and materials. Earth-abundant elements like iron, manganese, sulfur, and sodium need to be the focus to be sustainable.[2] However, battery chemistries based on these elements are met with formidable scientific and technological challenges. A fundamental understanding of the intricacies involved in overcoming the challenges can enhance their widespread viability.

To illustrate a path forward towards the sustainable goal, this presentation will center on strategies and approaches for progressively eliminating expensive and scarcely available cobalt, followed by eliminating nickel, and ultimately any mined metal, including lithium. As an example, the progress on cobalt-free lithium-ion cells,[3] cobalt- and nickel-free lithium-ion cells, sodium-ion cells, lithium-sulfur cells, and sodium-sulfur cells[4] will be presented. The challenges of bulk and surface instability, the complexities of electrode-electrolyte interfaces, and the role of electrolytes on these will be discussed. The power of advanced characterization methodologies to tackle the challenges and develop an in-depth understanding will be presented.

References:

[1] A. Manthiram, Nature Communications 2020, 11, 1550: 1 – 9.
[2] A. Manthiram, Y.-Z. Fu, S.-H. Chung, C. Zu, Y.-S. Su, Chemical Reviews 2014, 114, 11751 – 11787.
[3] W. Li, S. Lee, A. Manthiram, Advanced Materials 2020, 32, 2002718: 1 – 6.
[4] J. He, A. Bhargav, L. Su, H. Charalambous, A. Manthiram, Nature Communications 2023, 14, 6568: 1 – 10.

PL-09

The Periodic Table's Women

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The Periodic Table, a single page, apparently simple, which revolutionized science, also has a human face. In fact, in each box of this document there is not only an element with its properties, but there are also the people's names who contributed to its birth and those who made it grow by adding new elements.

It is a story made up of prestigious names that are found in all the sacred texts of Chemistry. Those mentioned are basically male names, but many women also contributed, if not to the birth of the Periodic Table, then to filling new boxes. Surely Marie Curie, who was responsible for the discovery of radium and polonium, is known to everyone, but the list is long and includes scientists of great value, often forgotten. The names of these women can be found in the book "Women in their Element"[1] and some of them will be mentioned in the contribution.

[1] *Women in their Element: Selected Women's Contributions to the Periodic System*, edited by A. Lykknes and B. Van Tiggelen, World Scientific Publishing Co, 2019; https://doi.org/10.1142/11442

PL-10

Between Materials and Meanings: Research at the Interface of Chemistry and Art.

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In the Spring of 1882, the citizens of New York received an unprecedented – and to this day unique – invitation. In response to accusations in the media that some of the Ancient Cypriot objects in the collection of the Metropolitan Museum of Art were forgeries, the Museum decided to present two large marble sculptures in the Great Hall, outside of their cases and invited Members of the Public to "make the most careful examination of them". Apparently, the visitors were allowed to "cut, … scrape, …treat with chemicals, and examine microscopically" the statues. The verdict of the public was unanimous: authentic!

In the 1920s and '30s the Museum realized that crowdsourcing chemistry was perhaps not the best idea, and started a collaboration with Columbia University electrochemist Colin Fink, who conducted pioneering work on metal analysis, conservation treatments, and preventive conservation research. More important for todays' conversation, in the same decades a young Medieval art curator who had studied chemistry at Harvard, James Rorimer, began experimenting with ultraviolet light as a tool to highlight restoration, alterations, and in general, to "render the invisible visible".

Today, scientists are involved in every aspect of museum practice at the Met, from evaluation of potential acquisitions to art historical studies, from research in support of conservation treatment to indoor air quality monitoring, from development of new analytical techniques to large scale artists' materials and technique studies.

Raman and surface-enhanced Raman spectroscopy, X-ray fluorescence spectrometry and mapping, mineralogical and petrographic techniques, mass spectrometry, reflectance spectroscopy and reflectance spectroscopy imaging are commonly used in collaboration with art historians and conservators to investigate the complexity of works of art. These tools enable us to read works of art -just as historians read documents- and to explore the intersection of materials and meanings.

Chemistry allows us to tell stories about the art, its context, and the people who make it, highlighting cultural practices, economic and social relationships, technical developments, spiritual insights, or the imminent vulnerability of the objects themselves.

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KN-001

Rapid Evaporative Ionisation Mass Spectrometry for the Real-time Monitoring of Medical Interventions: Towards Single Cell Resolution Autonomous Robotic Surgery

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Hyperspectral imaging of biological cells and tissues has been in the forefront of biomedical research for the last decade. Nevertheless, these methods were developed for chemical histology-type applications, where histological sections of tissues are analysed for their molecular content. Typical examples include spatial transcriptomics, imaging mass cytometry or spatial metabolomics. While these tools brought a true revolution, their applicability to actual living systems is limited. In-vivo spatial spectroscopic approaches are impeded either by coarse resolution exemplified by magnetic resonance spectroscopy or their targeted nature, as in case of calcium imaging by two-photon microscopy. Mass spectrometry seems to be a strange methodological choice for in-vivo applications due to its highly invasive character, however its ultimate sensitivity and specificity still makes it a feasible contender to become the great unifier of the ex-vivo, in-vitro and in-vivo approaches. We have originally developed Rapid Evaporative Ionisation Mass Spectrometry for the real-time identification of dissected tissues in course of cancer surgery, employing a standard surgical diathermy knife as an ion source. Since then various REIMS-based setups were conceived to perform live cell analysis in the laboratory environment, analyse bacterial metabolism in-situ or image biological tissues at subcellular resolution. Combining the REIMS concept with picosecond resonant infrared laser ablation sources resulted in an ultimately versatile setup capable of mapping cellular metabolism in arbitrary environment and providing identical data type for biomedical research, clinical microbiology, histopathology, clinical chemistry and invasive/diagnostic medical interventions. The paper will discuss some of these applications including the data analysis aspects and describe our vision for the broader embedding of the technology into the 21st century healthcare systems.

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KN-002

Plasmonics and Cancer Diagnostics: Ultrasensitive Optical Biosensing of Circulating Tumor DNA in Blood-based Liquid Biopsies from Cancer Patients

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Standard clinical protocols for cancer diagnostics and tumor profiling primarily rely on tissue biopsy, involving the extraction of human cells via specialized needles or surgery. However, tissue biopsy poses challenges for the frequent monitoring of cancer patients due to its invasive nature and limitations in accounting for tumor cell heterogeneity. Liquid biopsy offers an alternative approach, sampling body fluids to assess cancer biomarker levels, notably in peripheral blood, plasma, and serum.

Detecting nucleic acid biomarkers for cancer diagnosis and monitoring through liquid biopsy presents challenges for conventional biosensing platforms. Many biosensors utilize enzymatic amplification to achieve necessary sensitivity, but this amplification step introduces constraints and drawbacks, such as artefacts from sample contamination and recombination between homologous regions of DNA.

To address these challenges, there is a growing emphasis on developing PCR-free protocols for DNA detection. These protocols often leverage signal amplification strategies involving enzymes or metallic nanostructures, such as gold nanoparticles, for highly sensitive DNA detection.[1,2]

One promising approach involves nanoparticle-enhanced surface plasmon resonance imaging (SPRI), which holds the potential for detecting non-amplified DNA circulating in cancer patients' blood. This technique, combined with innovative plasmonic sensor surface designs, including the use of a novel dual-functional low-fouling poly-L-lysine-based surface layer, offers exciting prospects for advancing cancer diagnosis through liquid biopsy.[3]

References:

[1] R. D'Agata, N. Bellassai, M. Allegretti, A. Rozzi, S. Korom, A. Manicardi, E. Melucci, E. Pescarmona, R. Corradini, P. Giacomini, G. Spoto, Biosensensors and Bioelectronics 2020, *170*, 112648.

[2] M. Calcagno, R. D'Agata, G. Breveglieri, M. Borgatti, N. Bellassai, R. Gambari, G. Spoto, Analytical Chemistry 2022, 94, 1118–1125.

[3] N. Bellassai, R. D'Agata, A. Marti, A. Rozzi, S. Volpi, M. Allegretti, R. Corradini, P. Giacomini, J. Huskens, G. Spoto, ACS Sensors 2021, *6*, 2307–2319.

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KN-003

When MALDI-MSI meets the clinical need: case experience in nephrology

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Renal diseases are progressively representing a rising burden for patients' quality of life and for the National Health System. The evolution of renal damage can potentially lead to end stage kidney disease (ESKD), whose only therapies are dialysis and transplantation. To prevent this progression, the prompt detection and therapy initiation is paramount, currently being achieved through the histological analysis of renal biopsies. Although proteomics has been introduced for detecting biomarkers in mini-invasive samples (e.g. blood/urines), the evaluation of structural modifications directly in situ within the diseased renal tissue is a stimulating and intriguing perspective, with enormous potentialities for routine clinical practice translation. Matrix-assisted laser desorption/ionisation mass spectrometry imaging (MALDI-MSI) is the natural solution to study proteomic changes of the renal parenchyma in different pathological states, as documented by the last 10 years activity of the Renal Pathology and Protoemics Units of UNIMIB, applying MALDI-MSI on both snap-frozen and archived formalin-fixed paraffin-embedded (FFPE) tissues. This already allowed the detection of molecules with pathogenetic roles, biomarkers of progression and response/resistance to therapy in different diseases, lastly helping in the diagnosis/detection/quantification and classification of renal amyloidosis, for which the proteomics is already unanimously considered the gold standard. Moreover, the recent introduction of instruments with higher lateral resolutions, down to the level of a single-cell, and the association of digital pathology tools to the in situ proteomics is unlocking the full potentialities of this technique, approaching the bedside day-by-day in this niche of pathology.

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KN-004

MRI-CEST contrast agents: in vivo sensors for metabolic Imaging

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Metabolic imaging is a branch of molecular imaging that aims at identifying alterations in metabolic pathways to gain early evidence or insight into a given pathological condition. In clinical and pre-clinical settings, numerous imaging techniques have been successfully used to detect aberrant metabolism-associated diseases with Positron Emission Tomography (PET) in a primary position for its impressive sensitivity. However, the drawbacks associated with PET imaging are i) the poor spatial resolution and ii) the use of radioactive tracers. MRS and MRSI (Magnetic Resonance Spectroscopy and Magnetic Resonance Spectroscopic Imaging) were early recognized as powerful tools to detect physiology not invasively and with high spatial resolution. MRS addresses the direct visualization and quantification of NMR signals belonging to different molecules of biological interest as it can detect in vivo endogenous molecules present down to millimolar concentration looking at either ^{1}H- or ^{23}Na- or ^{31}P-resonances. Moreover, with the advent of efficient hyperpolarization techniques, even metabolites enriched in ^{13}C can be observed and their metabolic fate can be directly assessed in real-time[1]. Interesting results have been reported recently by using deuterium-containing substrates. The main issue in most of the MRS/MRSI studies relies on the limited sensitivity only partially overcome by the increased availability of high-field scanners. In parallel, CEST-MRI has emerged as an efficient tool to image metabolic processes by enhancing the detectability of the NMR signals of endogenous molecules through their indirect effect on the much more intense signal of the bulk water following the selective irradiation of their mobile protons[2]. In this regard, CEST-MRI represents an intriguing approach for detecting tumor metabolites with higher sensitivity compared to MRS. Up to now, the in vivo detection of important metabolic substrates such as glucose, glutamate, choline, creatine, and lactate, as well as pH and enzymatic activity assessment, have been demonstrated to be feasible. Despite the promising potential of MRI-CEST contrast agents, challenges such as sensitivity, specificity, and standardization of imaging protocols persist. In this contribution a concise overview of the current landscape of MRI-CEST contrast agents as in vivo sensors for metabolic imaging will be provide focusing on potential and challenges to be addressed.

References:

[1] Von Morze et al. Magn Reson Med. 2021;85:1795–1804.
[2] F Kogan Hariharan , R. Reddy. Curr Radiol Rep. 2013 1(2):102-114.

KN-005

Translating spatial biology applications from early drug development to a clinical setting

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Spatial biology technologies have revolutionized our understanding of cellular processes and disease mechanisms in heterogenous tissues. In early drug development, having access to spatial-omics data consisting of transcriptomics, metabolomics and proteomics from a single tissue slice can offer invaluable insights into target identification, biomarker discovery and drug response prediction. Moreso, the integration of these data with gold standard histological methods provides a holistic understanding of disease state and drug action detected by advanced technologies such as mass spectrometry imaging (MSI), imaging mass cytometry (IMC) and spatial transcriptomics (ST). These technologies have been applied to analyse a range of tissue types to support early drug development from complex 3D in vitro models such as patient-derived organoids (PDOs) to pre-clinical animal tissues and patient-derived xenografts (PDXs). In addition to the depth of information retrieved from these samples, spatial data collected from patient biopsies has added a greater level of value in supporting therapeutic development and patient stratification. In this presentation, the applications of spatial biology technologies (including MSI, IMC & ST) established for early drug development will be discussed, alongside how the translation of these applications currently support the clinical setting to advance precision medicine and improve patient outcomes.

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KN-006

Point-Of-Care Ultra-Portable Single-Molecule Bioassays for One-Health

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Screening individuals, including humans, animals, and plants, who show no symptoms, using point-of-care-testing (POCT) technologies with high diagnostic accuracy, although still considered visionary, holds significant promise. Effective surveillance necessitates user-friendly, cost-efficient, highly portable, yet dependable, in-vitro-diagnostic devices that can be deployed wherever necessary.

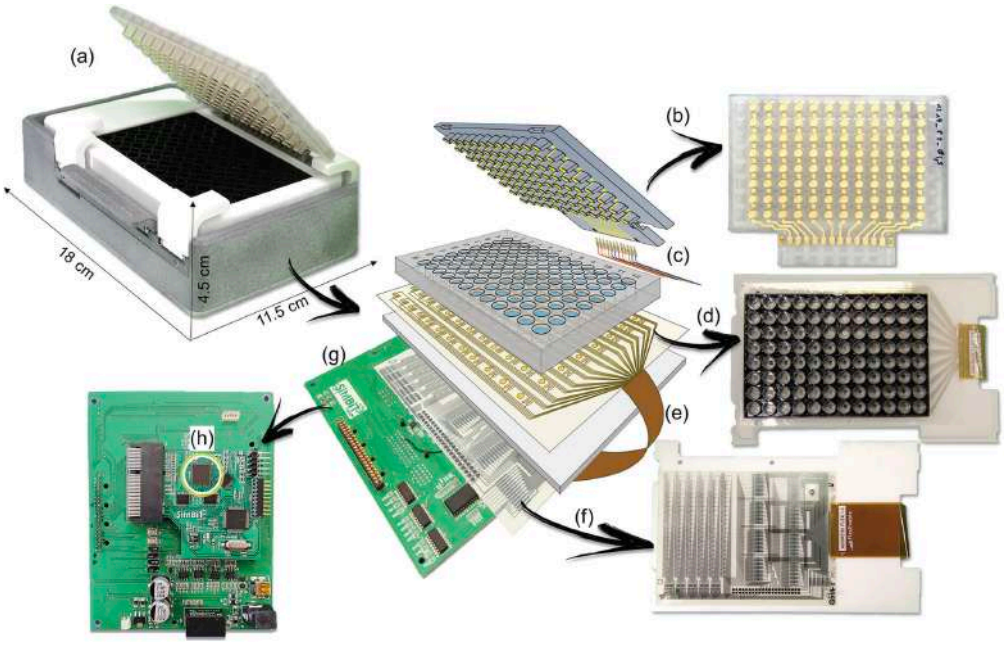

Figure 1: **a)** Picture of the small footprint bioelectronic platform developed in the framework of the SiMBiT project (https://www.simbit-h2020.eu). The disassembled system, shown on the right, comprises, from top to bottom, the following elements: **b)** a 3D-printed array of biofunctionalized sensing gates covering the ELISA plate, **c)** spring-loaded pins connectors, **d)** an array of the EGOFETs on poly(ethylene 2,6-naphthalate) (PEN)-foil glued on a bottomless ELISA-plate, **e)** flat cable connecting the bioelectronics array to the f) multiplexing electronics based on a unipolar OTFT-based technology (*FlexEnable Technology*), **g)** a printed circuit board (PCB), integrating h) a custom Si-IC chip (reproduced with permission from Ref. 1)

Presently, such devices are not available on the market. However, there are two promising technologies in development at readiness level 5: the Clustered-Regularly-Interspaced-Short-Palindromic-Repeats (CRISPR) lateral-flow-strip tests and the Single-Molecule-with-a-large-Transistor (SiMoT) bioelectronic palmar devices. The array version of the SiMoT platform, developed in the framework of the SiMBiT project

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KN-007

Integrative approach by multiscale imaging to monitoring neuron/glia neurochemical communication in healthy and diseased brain networks

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Although the discovery of novel neuroactive drugs could take advantage of the innovative high-throughput in vitro drug-screening technological development, few novel classes of neuroactive molecules have been discovered in the last few years. This limitation arises mainly because most of the in vitro screening assays fail to capture dynamic properties of neuron/glia neurochemical communication in the brain networks as well as their fast morphological, chemo-physical, and functional adaptation to external stimuli. Moreover, almost all of these studies employ cell homogenates either from tissue or cell culture thus information of spatial distribution is not preserved and contribution from different cell types, each of which could have a very distinct metabolic profile, is lost. To fully understand the role of neurochemical and cell function, it is crucial not only to identify but also to correlate cellular metabolites in the context of tissue anatomy and cell-type composition. In this communication, I will describe an integrative approach to screen small neuroactive molecules by combining advanced in vitro multiple assays at multi-scale levels exploiting the medium-throughput time-lapse sensing and imaging platform Incucyte© coupled with the multiscale morpho-functional imaging obtained by confocal, correlative light and electron microscopy (CLEM), and patch-clamp recording [1-3]. The characterization of neuronal responses to bioactive organic molecules, mostly (endo)cannabinoids and endocannabinoid-like gut microbiota-derived metabolites, will be described at a resolution ranging from nano- to micro-metric scale in different subcellular compartments, neuronal networks, and brain areas. Method that integrates the well-defined cellular classifications obtained by immunochemical staining from selected brain areas with chemical information found within mass spectra recorded by DESI-MS imaging, will also be discussed in ongoing research aimed at identifying new immunoregulatory molecules for pharmacological applications.

[1] N Forte, S Boccella, L Tunisi, AC Fernández-Rilo, R Imperatore, M De Risi, F Piscitelli, R Capasso, P De Girolamo, E De Leonibus, S Maione, V Di Marzo, **L Cristino**. Orexin-A and endocannabinoids are involved in obesity-associated alteration of hippocampal neurogenesis, plasticity, and episodic memory in mice. *Nature Communications* 2021; 12: 6137.

[2] AC Fernández-Rilo, N Forte, L Palomba, L Tunisi, F Piscitelli, R Imperatore, A Di Costanzo, V Di Marzo, **L Cristino**. Orexin induces the production of an endocannabinoid-derived lysophosphatidic acid eliciting hypothalamic synaptic loss in obesity. *Molecular Metabolism*. 2023;72:101713.

[3] N Forte, A Nicois, B Marfella, I Mavaro, L D'Angelo, F Piscitelli, A Scandurra, P De Girolamo, P Baldelli, F Benfenati, V Di Marzo, **L Cristino**. Early endocannabinoid-mediated depolarization-induced suppression of excitation delays the appearance of the epileptic phenotype in synapsin II knockout mice. *Cell Mol Life Sci*. 2024;81:37.

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KN-008

Recent advances in portable NMR sensor and its applications

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Nuclear Magnetic Resonance (NMR) is recognized as a powerful tool in many areas of research.

Chemistry is one of the areas where NMR is widely used as structure elucidation in organic chemistry, in pharmaceutical and natural-product sciences, in complex mixture analysis, in structural biology and in materials science.

Recent developments of new NMR methodologies as dynamic nuclear polarization (DNP), that can boost sensitivity in NMR experiments, or developments in probe technologies that allowed to rotate the sample faster spinning frequencies (100 kHz and above) to obtain "solution-like" in NMR spectra of solids, combined with the use of superconducting magnets and sizable electronics, have made NMR technique one of the most potent analytical methods. On the other hand high costs of maintenance made NMR spectrometers less commonly available in many laboratories.

With the advent of the 21st century miniaturization began to play an essential role in everyday life and also involved many spectroscopic techniques, including NMR [1-2], leading to dedicated sensors and portable devices with new applications in different research fields. Thanks to the reductions in size, maintenance needs and price tag, the miniaturized portable NMR sensor assemblies have extended their uses beyond conventional NMR laboratories to a broad range of "field" applications, including polymer products [3], food [4], biological tissue [5], and objects of cultural heritage [6]. A price to pay is the inhomogeneity of the magnetic field, which compromises the sensitivity of these devices. However, recent developments in unilateral magnets design offer larger sensitive volume, higher sensitivity and shorter dead times. By these devices it is possible to measure relevant parameters such as proton density, longitudinal (T_1), and transverse (T_2) relaxation times, and the self-diffusion coefficient, and to collect T_1-T_2 correlation maps.

Here recent advances on portable NMR sensors will be shown as well as the various applications in the different fields of research.

References:

[1] J. Perlo, F. Casanova, B. Blümich, J. Magn. Reson. 2005, 176 , 64–70.

[2] F. Casanova, J. Perlo, B. Blümich, NMR in Inhomogeneous Fields. In Single-Sided NMR; Springer-Verlag: Berlin, Germany, 2011; pp. 11–55.

[3] B. Blümich J. Perlo, F. Casanova, Progress in Nuclear Magnetic Resonance Spectroscopy 2008, 52, 197–269.

[4] C. Capitani, A.P, Sobolev, V. Di Tullio, L.Mannina, N. Proietti, Biol. Technol. Agric. 2017, 4:17

[5] F.J. Rühli,T. Böni, J. Perlo, F. Casanova, M.Baias, E. Egarter, B. Blümich J. Cult. Heritage 2007, 8, 257–263.

[6] V. Di Tullio, N. Proietti, M. Gobbino, C. Capitani, R. Olmi, S. Priori, C. Riminesi, E. Giani, Anal. Bioanal. Chem. 2010, 396, 1885–1896.

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KN-009

Micro and nanoplastics detection in air and water environments

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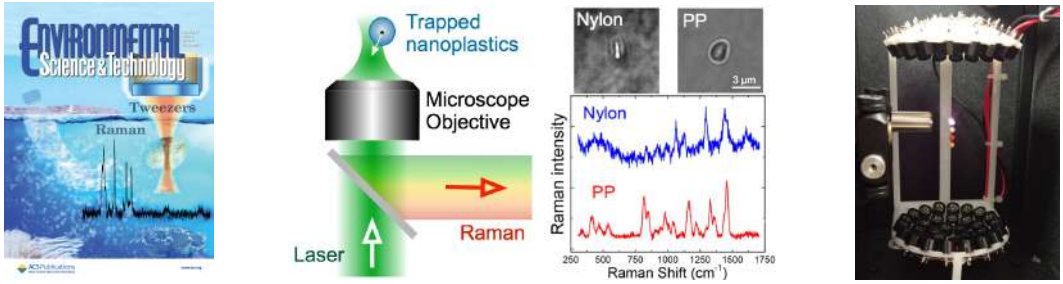
Microplastics (fragments < 5 mm, MPs) and nanoplastics (particles < 1 µm, NPs) have been found in air, oceans, rivers, and lakes. Recent studies showed their presence in human blood, placenta, stools and lungs, raising concerns for human health. MPs and NPs are generated either during production processes (e.g. 3D printing) or weathering, due to photo-oxidation and/or friction processes (e.g. car tyres wearing) leading to fragmentation at different scales. Detecting small MPs (< 20 µm) is a technical challenge, especially if they are dispersed in liquid. To fill this technological gap, our group has developed an original technique combining optical trapping with Raman spectroscopy (Optical Raman Tweezers, RT) enabling the chemical identification of individual MP and NPs in liquid environments. RT employ tightly focussed laser beams (Fig.1, a-b) to both optically trap and excite the Raman scattering of MPs and NPs (Fig. 1c), with a sensitivity down to tens of nanometres in size.[1,2] In this talk I will first review methodologies and gaps in the analysis of MNPs. Then I will illustrate the most recent advancements and future challenges regarding the development of portable RT setups interfaced with microfluidics for MPs and NPs analysis. Finally, a new method to analyse particles levitated in air in a contactless and container-less fashion, namely Raman Acoustic Tweezers (Raman-AT), is introduced. Here, by taking advantage of an array of ultrasound transducers coupled with a compact Raman spectrometer (Fig. 1d) we developed a portable setup capable enabling the chemical analysis of millimetric and sub-millimetric MPs, but also dispersions of NPs in µL volumes. These results were obtained within the projects NextGenEU PNRR-SAMOTHRACE (ECS00000022) and PRIN2022-PLASTACTS (202293AX2L).



(a) (b) (c) (d)

Figure 1: (a, b) Schematic of the Optical Raman Tweezers concept. (c) Images and spectra on optically trapped microplastics. (d) Acoustic Raman Tweezers setup for the analysis of levitated microplastics.

References:

[1] R. Gillibert et al., Environ. Sci. Technol. 2019, 53, 9003 – 9013.
[2] R. Gillibert et al., Environ. Sci. Nano 2022, 9, 145 – 161.

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KN-010

Smart Biosensors in food analysis: current applications and future trends

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The issue of food safety is a significant global concern, regardless of a nation's level of economic advancement. To safeguard consumers' well-being, it is imperative to prioritize food safety along the entire supply chain: "from farm to fork''. The implementation of strict quality control protocols and regulatory frameworks can effectively reduce risks and uphold exemplary standards in the food industry. The use of advanced analytical technologies that provide rapid and accurate results plays a key role in monitoring food safety and detecting any undesirable substances, including allergens, toxins, chemicals, or pathogens, that could potentially expose public health if consumed.

As a solution, sensors and biosensors have emerged as essential tools for quantitative detection and screening of various contaminants, ensuring immense potential in food safety and quality control. However, further progress still needs to be made to combine all the necessary features for on-site detection and real-time quantitative assessment.

In this presentation, the potential of integrating (bio)sensors with portable devices for rapid and on-site detection in a cost-effective manner will be discussed[1]. Moreover, the advancements in nanotechnology and new synthetic bioreceptors that can enhance sensitivity, selectivity, and speed of detection, making biosensors ideal for use in various food safety applications, will be presented[2].

Additionally, the future directions and potential applications of advanced electrochemical (bio)sensors will be explored.

References:

[1] G. Melinte, O. Hosu, G. Stefan, D. Bodgan, C. Cristea, G. Marrazza, Electrochimica Acta, 403, 139718, 2022
[2] J. Huang, F. Yang, L. Geng, X. Chen, G. Wang, J. Han, Y. Guo, X. Sun, G. Marrazza, Food Chemistry 2023, 429, 136857
[3] G. Selvolini, M. Lettieri, L. Tassoni, S. Gastaldello, M. Grillo, C. Maran, G. Marrazza, Talanta 2019, 203, 49-57

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KN-011

Two-dimensional virtual imaging as a tool for the identification of unknown molecules using comprehensive two-dimensional chromatography techniques

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Multidimensional separation methods have gained widespread appeal across various fields, offering distinct advantages over traditional single-dimensional approaches. Since their introduction, comprehensive two-dimensional chromatography methods have transitioned from niche tools to commercially available solutions, advancing alongside improvements in hardware (interfaces and modulators) and software (data collection, processing, and analysis).

By focusing on sample complexity and integrating mass spectrometry detection, comprehensive two-dimensional chromatography techniques emerge as exceptionally potent tools to thoroughly characterize both volatile and non-volatile sample constituents.

Beyond their increased dimensionality, the notable benefits of comprehensive two-dimensional chromatography methods include organized chromatograms, where chemical components of the sample are systematically arranged based on their properties and retention mechanisms.

This structured distribution facilitates rapid identification of sample components and the prediction of analyte structures by analyzing their characteristic positions within the two-dimensional space (Figure 1).

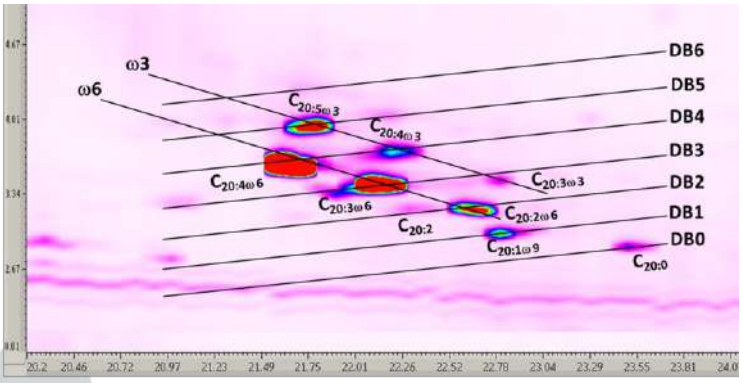

Figure 1: Comprehensive two-dimensional gas chromatography analysis of fatty acids.

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KN-012

Augmented Visualization and Sensing in Multidimensional Chromatography: We see what you smell

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Multidimensional chromatography systems, combining physico-chemical discrimination of individual components by orthogonal chromatography principles with the structure-elucidation potential of mass spectrometry, are the ultimate solutions for comprehensive investigations of complex samples in many application areas including the food quality and safety domains. However, the multidimensional data arrays generated by these platforms require non-conventional approaches to fully exploit the encrypted information potential and generate new knowledge on sample properties, going beyond current quality indexes.

In this context, Artificial intelligence (AI) offers tools and concepts to face the many challenges posed by food applications where the compositional complexity of samples (*e.g.*, primary metabolites, secondary/specialized metabolites, processing derivatives, exogenous compounds from microbial communities, presence of xenobiotics and contaminants, etc.) is connected to properties by specific yet unique chemical patterns.

The contribution aims to illustrate how the complex datasets derived from comprehensive two-dimensional gas chromatography (GC×GC) in the application area of food-omic can efficiently be explored AI tools. Thanks to the multidimensional nature of GC×GC data arrays, Computer Vision and Augmented Visualization open new opportunities for decision-making strategies targeted to food quality and sensory features. With these advanced yet peculiar AI tools chromatographic image distortions are efficiently compensated, thereby facilitating comparative visualization and related strategies. Moreover, by actively exploiting mass spectral signatures in the presence of co-elutions and misalignments, *unknown-knowns* can be specifically targeted, and by identifying key food odorants in the presence of interferents, aroma signatures can be predicted by an AI-smelling machine[1,2]. Practical examples showcase the challenges and potentials of the application of AI to GC×GC-MS data obtained in studies related to food volatilomics [3] and sensomics [4].

References:

[1] Nicolotti, L.; Mall, V.; Schieberle, P. *J. Agric. Food Chem.* **2019**, *67* (14), 4011–4022.
[2] Caratti, A.; Fina, A.; Trapani, F.; Bicchi, C.; Liberto, E.; Cordero, C.; Magagna, F. *Molecules* **2024**, *29* (3), 565.
[3] Caratti, A.; Squara, S.; Bicchi, C.; Tao, Q.; Geschwender, D.; Reichenbach, S. E.; Ferrero, F.; Borreani, G.; Cordero, C. *J. Chromatogr. A* **2023**, *1699*, 464010.
[4] Squara, S.; Caratti, A.; Fina, A.; Liberto, E.; Spigolon, N.; Genova, G.; Castello, G.; Cincera, I.; Bicchi, C.; Cordero, C. *J. Chromatogr. A* **2023**, *1700*, 464041.

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KN-013

Generation and modeling of plasmonic nanoparticles for sensing

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The ability of noble metal nanoparticles to couple with electromagnetic radiation in the near IR and visible regions stimulates research worldwide because of possible applications in several technological fields such as sensing, solar cells, spectroscopy and several biological and medical issues. It is also known that the geometrical features of the nanoparticles, their coupling and the nature of the metal, mostly define the optical properties in terms of scattering, absorption and extinction cross-sections. In this talk I will review some of the most challenging methods to obtain variously shaped metal nanoparticles in the colloidal form. Among them some conventional chemical methods[1], based on a classical nucleation and growth as well as new laser approaches[2] in the liquid phases which can give long-term stability despite the absence of stabilizing agents.

The plasmonic features of these particles are studied with the help of some simulation tools which are of great support to understand any optical properties and field distributions and help experimentation for specific application purposes.

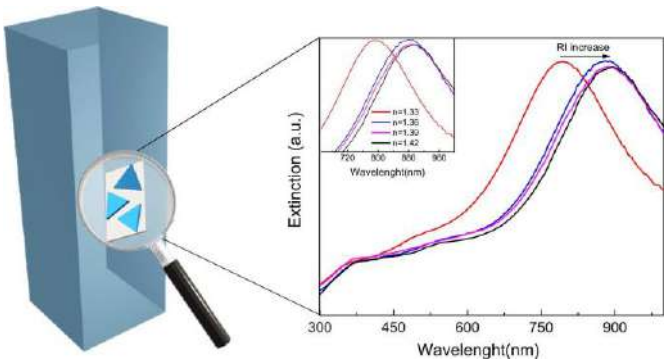

Figure 1: Generated metal nanoplates to pave disposable cuvettes for plasmon sensing devices.

Some strategies for the deposition of plasmonic layers onto solid substrates will be also presented in order either to transfer the plasmonic features on solid surfaces and obtain suitable sensing devices[3]. Applications of the obtained nanostructures for plasmon sensing and surface-enhanced phenomena are used as excellent examples showing the advantages of these tools.

References:

[1] V.Scardaci, M.Pulvirenti, M.Condorelli, G.Compagnini, J. Mater. Chem. C 2020, 8, 9734-9741
[2] E.Fazio, B.Gökce, A.De Giacomo, M.Meneghetti, G.Compagnini, et al. Nanomaterials 2020, 10, 2317
[3] M.Condorelli, L.Litti, M.Pulvirenti, V.Scardaci, M.Meneghetti, G.Compagnini, Appl. Surf. Sci. 2021, 566, 150701

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KN-014

Single-Cell and Imaging Mass Cytometry for Advanced Materials

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There is a critical unmet need to detect and image two-dimensional (2D) materials within single cells and tissues while surveying a high degree of information from single cells. Here, we propose a versatile multiplexed label-free single-cell detection strategy based on single-cell mass cytometry by time-of-flight (CyTOF) and ion-beam imaging by time-of-flight (MIBI-TOF).[1] This strategy, "Label-free sINgle-cell tracKing of 2D matErials by mass cytometry and MIBI-TOF Design" (LINKED), enables nanomaterial detection and simultaneous measurement of multiple cell and tissue features. As a proof of concept, we selected a set of 2D materials, transition metal carbides, nitrides, and carbonitrides (MXenes), to ensure mass detection within the cytometry range while avoiding overlap with more than 70 currently available tags, each able to survey multiple biological parameters. In addition, MXenes have received substantial attention for their promise as biomedical nanotools.[2-4]

First, we demonstrated their detection and quantification in 15 primary human immune cell subpopulations. Together with the detection, mass cytometry is used to capture several biological aspects of MXenes, such as their biocompatibility and cytokine production after their uptake. In vivo biodistribution experiments using a mixture of MXenes in mice confirmed the versatility of the detection strategy and revealed MXene accumulation in the liver, blood, spleen, lungs, and relative immune cell subtypes. Finally, we applied MIBI-TOF to detect MXenes in different organs revealing their spatial distribution. The label-free detection of 2D materials by mass cytometry at the single-cell level, on multiple cell subpopulations, and in multiple organs simultaneously, is expected to enable exciting new opportunities in biomedicine.

References:

[1] Fusco L. et al. Immune Profiling and Multiplexed Label-Free Detection of 2D MXenes by Mass Cytometry and High-Dimensional Imaging. Advanced Materials, 2022, 2205154.
[2] Vahidmohammadi A. et al. The world of two-dimensional carbides and nitrides (MXenes). Science, 2021, 372.
[3] Gogotsi, Y. & Anasori, B. The Rise of MXenes. ACS Nano, 2019, 13, 8491.
[4] Fusco L. et al. Graphene and other 2D materials: a multidisciplinary analysis to uncover the hidden potential as cancer theranostics. Theranostics, 2020, 10, 5435.

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KN-015

Advanced NMR monitoring of the transport properties in hydrogels and eutectogelst

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The investigation of entrapping small molecules within the voids of polymeric porous materials is not only a current research focus but also holds significant practical applications.

A paradigmatic case could involve trapping active pharmaceutical ingredients (APIs) within a polymeric scaffold, typically in the form of hydrogels, to obtain a drug delivery system.

The controlled release of APIs relies significantly on molecular diffusion within the porous structure of hydrogels, thus calling for a thorough understanding of the factors affecting the random displacement such as mesh size, drug dimensions, and intermolecular interactions (drug-polymer and drug-drug interactions).

The majority of hydrogels utilized thus far are derived from natural polymers or oligomers (such as cellulose, chitosan, pectin, and cyclodextrins), either chemically or physically cross-linked. More recently, a captivating category known as eutectogels has emerged, which are formed by physically cross-linking eutectic solvents with appropriate gelators, presenting a novel type of scaffold.

This keynote presentation highlights the strategies at the state-of-the-art based on NMR spectroscopy to attain detailed insights into the diffusion dynamics of small molecules within constrained environments like the pores of hydrogels and eutectogels. The high-resolution magic angle spinning (HR-MAS) NMR approach is described in combination with pulsed field gradient spin-echo (PGSE) sequences to investigate solute diffusion in confined networks. Experimental findings will be interpreted using refined mathematical models, enabling the generalization of motion types to non-Fickian diffusion.[1-3]

References:

[1] V. Vanoli, S. Delleani, M. Casalegno, F. Pizzetti, P. Makvandi, H. Haugen, A. Mele, F. Rossi, F. Castiglione, Carbohydrate Polymers 2023, 301, 120309 (1-11).
[2] G. de Araujo Lima e Souza, M. E. Di Pietro, A. Mele, RSC Sustainability 2024, 2, 288–319.
[3] G. de Araujo Lima e Souza, M. E. Di Pietro, V. Vanoli, W. Panzeri, F. Briatico-Vangosa F. Castiglione, A. Mele, Materials Today Chemistry 2023, *29*, 101402 (1-7).

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KN-016

Relevance of per- and polyfluoroalkyl substances (PFAS) contamination in Italy

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First environmental measurements of per- and polyfluoroalkyl substances (PFAS) contamination in Italy began in the first decade of the new millennium. Widespread environmental contamination by PFAS in human-inhabited areas is due to the extensive use of these substances in consumer products and subsequent discharge into water bodies through municipal wastewater treatment plants. However, in Italy it soon became evident that beside the baseline environmental contamination there are additional sources of contamination in the environment stemming from industrial production and usage of these compounds, and waste disposal.

This presentation will provide an overview of the PFAS distribution and sources in Italian ecosystems, covering both legacy and newly identified PFAS, along with examples of substitutions of regulated products that were banned or restricted.

Very high concentrations of PFASs have been documented in environmental matrices downstream of fluorochemical and fluoropolymer facilities, leading to both localized and widespread regional pollution. In one case, the manufacturing plant caused contamination of one of the largest aquifers in Europe, and the population have been exposing to contaminated drinking water for decades. However, some specific industrial districts involving mainly surface treatments, such as textile (including the production of technical textiles or upholstery fabrics) or tanneries also appear to be important sources of emissions of these compounds. No less important as a source of environmental contamination in Italy is the waste cycle precisely because of extreme chemical stability and environmental mobility of PFAS. Waste and sludge management has contributed to the PFAS contamination of Italian water bodies even far from the places of production and use.

Since the 2000s alongside the measurement of individual compounds, regulatory requirements have moved toward measuring total PFAS contamination. So, at the conclusion of the presentation, the advantages and disadvantages of nonspecific techniques for measuring total PFAS such as Total Organic fluorine by Combustion Ion Chromatography (TOF-CIC) or Total Oxidisable Precursor Assay (TOP Assay) will be presented and discussed. Of great help in bridging the knowledge of total PFAS that may be present in the environment is the implementation of chromatographic techniques coupled with high-resolution mass spectrometry, for which validation of dedicated workflows for suspect screening and non-targeted analysis particularly dedicated to PFAS identification are on going.

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KN-017

PFAS pollution in the aquifers of central Veneto Region: hydrogeological features and environmental implications

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Perfluorinated Alkyl Substances (PFAS) pollution of groundwater in Central Veneto represents a significant environmental emergency in northern Italy. It has become a public health concern due to the exposure of at least 300,000 people who ingested contaminated drinking water.

Over several decades, a continuous source of PFAS from a chemical plant steadily contaminated the aquifer. The plume migrated over 40 km, impacting productive geological horizons in both the unconfined shallow aquifer system and the deeper artesian wells, utilized for water supply.

Despite ongoing safety measures and source control efforts, the release of PFAS continues.

The hydrogeological setting of the Agno-Guà valley plays a crucial role in contaminant migration. The highly conductive alluvial formations facilitated the extensive movement of PFAS along the prevailing groundwater flow paths. Additionally, fluctuations in the water table, with periodic rises in the water level closer to the surface, contribute to the transport and diffusion dynamics of PFAS within the aquifer.

The substantial width and complex hydrochemical characteristics of the plume, coupled with the heterogeneity of the geological formations, render widespread environmental remediation measures (plume control) challenging and economically impractical.

This contamination has resulted in a significant loss of a valuable drinking water resource, irreversibly compromising one of the most important regional water supply districts.

The event has had severe consequences for the public water service infrastructure and management: extensive emergency measures, including new infrastructure, operational modifications, and increased energy consumption, have been necessitated to address the contamination.

In the keynote, the case study is presented from the aquifer view-point, focusing attention both on the scientific aspects that emerge from this large-scale "tracer test" and on the social and economic implications of the environmental issue.

KN-018

"The Remediation in the National System of Environmental Protection: state-of-the-art and perspectives"

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The National System for Environmental Protection (SNPA) is a network made up of ISPRA and the 21 Territorial Environmental Protection Agencies (ARPA/APPA) established by Regional Laws. SNPA represents an example of consolidated federal system, which combines the direct knowledge of the territory and its issues with the national policies for environmental protection, so as to become an institutional and technical-scientific reference point for the whole country. SNPA assures its technical support to the Ministry of Environment and Energy Security (MASE) on contaminated sites of national interest activities and, in order to promote the sustainable management of contaminated sites and to stimulate harmonisation in this respect, develops guidelines and technical documents for the characterization and remediation of contaminated sites.

To comply with specific law provisions and to have a complete and homogeneous framework at national level on the sites subject to remediation procedures ISPRA, within SNPA, has implemented MOSAICO, the national register on contaminated sites in Italy. MOSAICO contains data related to sites interested in more than 33.000 management procedures, whether in progress or concluded, and allows to analyse the progress in the management and the contamination status of ongoing procedures, the closure methods of the concluded ones and their time duration. In 2023, a public online consultation section of the MOSAICO georeferenced spatial data, including information on potentially contaminated and contaminated sites, was made available on a dedicated website.

Experiences gained in supporting MASE activity on contaminated sites of national interest combined with analysis of data recorded in MOSAICO help to evaluate timing of the remediation processes, that is crucial for environmental and health considerations, effectiveness, and cost-effectiveness and can help policymakers to design more efficient and sustainable environmental management strategies.

KN-019

Emerging technologies for Environmental remediation

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Effective strategies for environmental remediation need green, sustainable, efficient, and low-cost solutions for soil/sediment and water remediation, by integrating traditional remediation strategies with innovative technologies. Moreover, the remediation of a range of organic and inorganic pollutants of high concern, can be often achieved with producing useful end-products, including hydrogen and electricity.

A summary of the existing technologies is here presented, with focus on electrochemical technologies combined with other processes.

Some case studies are then discussed where biological, chemical, and electrochemical technologies are applied to remediation of soils and water at pilot scale.

In the first example, an integrated system for effective groundwater technologies was used to enhance the removal of dyes and potentially toxic metals, with bio-electrochemical systems for TPHs, pesticides, antibiotics, and PAHs removal.

The second case study shows the combination of biological and bio electrochemical technologies for soil remediation.

In both case studies, operation conditions for the scale-up were defined, based on experiments and mathematical modelling.

An example of wastewater treatment is also presented, with the integration of a membraneless electrolysis process into the clean water system of a biomass gasification process. The process combines electrochemical oxidation for the removal of organics and production of Hydrogen. The obtained gas is of low quality, but it can however be added to the syngas from the gasification reactor. Results showed it is possible to obtain a steady sate concentration of organics in the cleaning water maintaining a good purity of the hydrogen.

The experimental results were then used in a simulation of the integrated scrubbing and electrolysis system. The simulations were performed with the commercial software AspenPlus (AspenTech, Bedford, MA, USA). The simulations were used to assess the impact of the integration on energy and mass balances of the biomass gasification plant.

Acknowledgements

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KN-020

Critical chemical elements for the energy transition

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In 1990 an entire house typically contained about 20 chemical elements. Today there are more than 40 elements in a smartphone only. The use of some elements defined as "critical" is particularly relevant to renewable energy conversion and storage technologies that are critical to the decarbonization of modern civilization: photovoltaic panels, wind turbines, batteries, fuel cells, grid infrastructure, etc. The main material bottlenecks of the energy transition will be discussed, focusing primarily on sustainable mobility and renewable power generation and storage.

References:

[1] N. Armaroli, Fossil fuels exit: challenges, perspectives, bottlenecks, *The Oxford Handbook on the Greening of Economic Development*, Oxford University Press, 2024
[2] F. Monti, A. Barbieri, N. Armaroli *Substantia* 2019, 3(2), 75-89

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KN-021

The arrow of time in recycling materials from energy storage devices

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Growing demand for green and renewable energy in the EU, combined with the vulnerability of supply chains for key raw materials, is driving the need to recover the materials used in green transition application (e.g. batteries and photovoltaic panels, etc.). This presents an opportunity to reduce the risk of downstream pollution from disposing of or recycling these items.[1]

Developments in recycling technology have largely focused on short-life-cycle products, such as plastic waste from packaging, consumer electronics, and construction debris, while complex, resource-rich, long-life-cycle electronic products, energy-storage, and photovoltaic components have been somewhat overlooked due to their intrinsic property of containing multimaterial in a complex manner. High-value products contain valuable elements, which are intricately incorporated and often lost at end of life.[2]

In light of the arrow of time, taking into account the necessity to supply free energy to let possible a transition from disorder to order, available technologies and processes to transform wastes from energy storage devices in secondary raw materials are presented. The usual representation of the circular economy, which considers only the mass balance, is discussed, illustrating new paradigms needed for the recycling techniques.

The recycling facilities also need to innovate their technologies to effectively recover material from the evolving material design products. Existing challenges and opportunities for recycling energy resources to achieve long-term sustainability will be presented, underlying the intertwining between recycling materials from energy devices and sustainability.

References:

[1] www.eea.europa.eu/en/european-zero-pollution-dashboards/indicators/recycling-from-green-technology
[2] Veena Sahajwalla, Rumana Hossain, Rethinking circular economy for electronics, energy storage, and solar photovoltaics with long product life cycles, MRS BULLETIN, 48 (2023) 375-385

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KN-022

Moving Towards More Sustainable (Post-)Lithium Batteries

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Lithium-ion batteries are today the dominating electrochemical energy storage technology, powering portable electronic devices as well as (hybrid) electric vehicles, and finding application also for the stationary storage of renewables.[1] Since their first commercialization about 30 years ago, the energy density has more than tripled and the cost have decreased almost exponentially.[2,3] This great improvement originates from advances in engineering and materials development; with regard to the latter, this includes especially the transition to graphite and nickel-rich lithium transition metal oxides as active materials for the negative and positive electrode, respectively. Remarkably, despite earlier concerns that their maximum energy density might have been reached, there is still continuous progress thanks to new electrode and cell designs as well as the development of new and better electrode materials and advanced electrolyte systems, and there is still room for further improvement, especially with regard to sustainability, which is key towards a truly greener future. Meanwhile, alternative battery technologies such as sodium-ion batteries promise an intrinsically greater environmental friendliness, as they do not rely – or at least much less – on critical elements and compounds such as cobalt, nickel, copper and graphite.[4,5]

Herein, the current state of the art will be presented with a specific focus on the remaining challenges and approaches to overcome these in the coming years and to enhance the sustainability of next-generation lithium and sodium batteries, while highlighting that the diversification of battery chemistries by itself provides already a pathway towards a more responsible use of (critical) resources.

References:

[1] Armand, M.; Axmann, P.; Bresser, D.; Copley, M.; Edström, K.; Ekberg, C.; Guyomard, D.; Lestriez, B.; Novák, P.; Petranikova, M.; Porcher, W.; Trabesinger, S.; Wohlfahrt-Mehrens, M.; Zhang, H., *Journal of Power Sources* **2020**, *479*.
[2] Nykvist, B.; Nilsson, M. Rapidly Falling Costs of Battery Packs for Electric Vehicles. *Nature Clim. Change* **2015**, *5* (4), 329–332.
[3] Li, Q.; Yang, Y.; Yu, X.; Li, H., *Chinese Phys. Lett.* **2023**, *40* (4), 048201.
[4] Hasa, I.; Mariyappan, S.; Saurel, D.; Adelhelm, P.; Koposov, A. Y.; Masquelier, C.; Croguennec, L.; Casas-Cabanas, M., *Journal of Power Sources* **2021**, *482*, 228872.
[5] Yadav, P.; Patrike, A.; Wasnik, K.; Shelke, V.; Shelke, M., *Materials Today Sustainability* **2023**, *22*, 100385.

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KN-023

Sustainability key-challenges across the European battery value chain: an overview from the BATT4EU/Batteries Europe joint Task Force

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Addressing present and emerging battery systems, the new position paper of the *BATT4EU/Batteries Europe joint Sustainability Task Force* [1] aims to take a comprehensive look at the sustainability of batteries and the entire value chain, including the framing conditions. It also explores how this fast-growing sector can foster an innovative environment and develop a more sustainable battery ecosystem, considering the importance of recycling, second use, and the circular economy. Three key dimensions are in focus: economic, social, and environmental sustainability, especially from a life cycle perspective. Furthermore, the paper will reflect on EU regulations and activities such as the "Net-Zero Industry Act," the "Critical Raw Materials Act" (ACRM), and “Safe and Sustainable by Design” (SSbD) as framing conditions.

For present batteries, the new Batteries Directive (including the Battery Passport) with challenging minimum recycling rates and recycling content in batteries in the future are quite important. The ongoing discussion regarding PFAS and the usage of critical raw materials in the case of lithium batteries highlights the challenges and importance of recycling and a circular economy. Additionally, the low economic value of used materials in Post-Lithium batteries (such as Sodium-Batteries) creates foreseeable challenges that need to be addressed today. Therefore, activities regarding "design for recycling" and first attempts towards direct recycling are promising options to overcome these challenges.

References:

[1] Sustainability Task Force – Position Paper- 2024. https://batterieseurope.eu/results/position-papers-on-cross-cutting-topics-2024/position-papers-on-cross-cutting-topics-2/

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KN-024

Recent Advances in Electrocatalysts for Low Temperature Fuel Cells and Electrolyzers

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Hydrogen has been identified as an essential part of the solution for enabling energy system decarbonization. Water electrolyzers and H_2-fed fuel cells are crucial to achieving H_2 production from renewable sources and using H_2 as a feedstock to generate electricity.

Polymer Electrolyte Membrane Fuel Cells (PEMFCs) and Polymer Electrolyte Membrane Water Electrolyzers (PEMWEs) technologies have reached a level of maturity but still depend heavily on critical raw materials (CRM) in their crucial components. Those devices share the oxygen electrode, substantially affecting their performance and durability due to the intrinsically slow kinetics for oxygen evolution/reduction and poor durability under harsh operating environments. Although CRM-based electrodes are catalytically active toward oxygen electrocatalysis, their use in fuel cells and water electrolyzers is not sustainable. Therefore, the rational design of advanced electrocatalysts for oxygen electrocatalysis is critical for advancing the development of PEMFCs and PEMWEs [1,2].

This work overviews recent advancements in developing transition metal (TM)--based electrocatalysts for applications in PEMFCs and PEMWE electrodes. We present the main strategies and synthetic approaches for tailoring the properties of TM-based electrocatalysts to enhance their activity and durability toward oxygen reduction reaction (ORR) and oxygen evolution reaction (OER).

Emphasis will be given to designing TM-based (TM=Fe, Co, Ni) electrocatalysts derived from metal-organic-frameworks (MOFs) and porous organic polymers (POPs) as self- or soft-template to modulate the materials' micro/meso/macro porosity and enhance metal functionalization. The versatility of the synthetic approaches allows for the development of bifunctional ORR/OER electrocatalysts. Applications in H_2-fed anion exchange membrane fuel cells (AEMFCs), microbial fuel cells (MFC), alkaline direct methanol fuel cells (ADMFCs), and anion exchange membrane water electrolyzers (AEMWEs) will be discussed [3-4].

Based on the achieved results, TM-based electrodes result to be suitable for developing electrodes for low-temperature fuel cells and electrolyzers.

References:

[1] Zeng K. et al., Advanced Functional Materials, 2020, 30, 2000503
[2] Y. He, G. Wu, Acc. Mater. Res. 2022, 3, 224−23
[3] W. Freitas et al., Chem. Eng. J. 465 (2023) 142987.
[4] B. Ricciardi, et al., Carbon 219 (2024) 118781.

KN-025

Membranes for Energy

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Energy is one of the key resources determining the overall socioeconomic development: a robust energy supply must be secured for a sustainable growth and an improved living standard. Global energy consumption is increasing at an exponential rate: it is estimated that global energy consumption will rise by 48% between 2012 and 2040 [1]. In this context, the development of alternative energy resources able to alleviate the skyrocketing demand for clean energy and related environmental issues are urgently required [2].
Water has always been crucial to combustion and hydroelectric processes, but it could become the source of power in membrane-based systems that capture energy from water or produce hydrogen as energy vector. In this contest, two innovative based membrane operations will be presented and discussed: *a)* Reverse Electrodialysis (RED) using Salinity gradient energy or Salinity Gradient Power (SGP), also referred to as 'Blue Energy' for sustainable power generation [3], *b)* Membrane-based water electrolysis applied to produce high-purity and sustainable hydrogen for green energy production. In both cases, the conducting membranes are the heart of the investigated processes. Several factors, as the operating parameters, the membrane materials, which influence the performance of the membrane process will be discussed and future prospects will be also highlighted.

References:

[1] Energy US. Information administration, international energy outlook. U.S Department of Energy 2016.
[2] Elimelech M, Phillip WA. The future of seawater desalination: energy, technology, and the environment. Science 333 (2011) 712–717.
[3] R. A. Tufa, S. Pawlowski, J. Veerman, K. Bouzek,E. Fontananova, G. di Profio, S. Velizarov, J. G. Crespo, K. Nijmeijer, E. Curcio, Progress and prospects in reverse electrodialysis for salinity gradient energy conversion and storage, Applied Energy 225 (2018) 290-331
[4] E. Esposito, A. Minotti, E. Fontananova, M. Longo, J. C. Jansen, A. Figoli, Green H2 Production by Water Electrolysis Using Cation Exchange Membrane: Insights on Activation and Ohmic Polarization Phenomena, membranes, 12 (1) 2022 15

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KN-026

Applications of NMR techniques in the design and development of Polymer Electrolyte Membranes for energy production and storage

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Polymer electrolyte membranes (PEMs) hold a critical role in shaping the performance of various energy production and storage technologies, including fuel cells and batteries [1]. Ongoing research efforts focus on enhancing the ion conductivity, durability, and reliability of PEMs through meticulous control over their composition, morphology, and nanostructure. The overarching goal is to overcome key challenges such as efficiency and cost-effectiveness, thereby facilitating widespread commercial adoption across various energy applications [2]. Nevertheless, the pursuit of efficient PEMs demands a deeper understanding of their structure-property relationships. In this context, Nuclear Magnetic Resonance (NMR) techniques have clearly emerged as invaluable tools for elucidating the molecular dynamics, morphology, features of ion solvation, structure of transport channels, and transport phenomena within PEMs [3].

The presentation delves into the myriad applications of NMR spectroscopy in the characterization of PEMs, accentuating its pivotal role in assessing polymer chain mobility, ion conduction mechanisms, water uptake behavior, and interface interactions within the membrane matrix. Notably, NMR techniques, especially pulsed field gradient NMR, offer a distinct competitive advantage since enables the selective measurement of the mobilities and self-diffusion coefficients for all ions and molecules involved in charge transfer, for example, solvents (^{1}H and ^{13}C NMR), protons and hydroxides (^{1}H NMR), lithium cations (^{7}Li NMR), and counterions (^{19}F NMR). Through a comprehensive overview of recent advancements, challenges, and future perspectives, the presentation underscores the indispensable contributions of NMR techniques in paving the way for targeted enhancements and advancements in the design and development of PEMs for enhanced energy conversion and storage applications.

References:

[1] A. Kausar, Journal of Macromolecular Science, Part A, 2017, 54, 640-653.
[2] P. Hosseinabadi, K. Hooshyari, M. Javanbakht, M. Enhessari, New Journal of Chemistry, 2019, 43, 16232–16245.
[3] S. Abbrent, S. Greenbaum, Polymer Electrolytes: Fundamentals and Applications, 2010, 278-313.

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KN-027

Sustainable and Circular Materials Chemistry

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In addition to the well-known Green Chemistry principles that have revolutionized optimizing and sustaining linear processes, Circular Chemistry[1] moves beyond value extension and aims at making chemical processes and production cycles circular by using waste (or ideally products) as resource.

In this lecture, I will highlight the importance of using waste as resource as well as stress the need to develop Circular Technologies, which use chemistry as enabling tool, to target the conservation of critical raw materials (element scarcity) as well as contribute to solving pressing waste problems.[2,3] Such an endeavour will combine molecular design and synthesis with the environmental fate and impact of current products targeting safe by design (no persistent, bio-accumulative, and toxic compounds; green chemistry) and design for re-use, recovery and recycling (circular chemistry).

I will apply this vision to the key biogenic elements CHNOPS and hydrogen in particular, since H_2 has becoming one of the key energy carriers for the future to deal with the challenge of climate change and achieve the goals of the Paris Agreement. Hydrogen can also can help to compensate for the intermittency of renewable energy resources, while it can be sustainably produced from e.g. solar and wind power through the electrolysis of water. Large-scale usage of H_2, however, will necessitate its storage at massive scales, which will also allow the safe transport of large volumes of hydrogen from cheap production sites to demand centres elsewhere in the world. Multiple H_2 storage options exist, among which through the production and use of $NaBH_4$, associated with the regeneration of the carrier $NaBO_2$. I will highlight our recent advances in the development $NaBH_4$ as circular H_2 storage option and energy vector. In particular the focus is on the electrochemical recycling of the carrier to achieve the circular use of $NaBH_4$. Also a comparison will be made between H_2 usage from $NaBH_4$ and the direct usage of $NaBH_4$ in fuel cells to generate and use electricity, as well as other popular hydrogen storage materials like methanol, ammonia and LOHC.

References:

[1] T. Keijer, V. Bakker, J.C. Slootweg, Nature Chem. 2019, 11, 190–195.
[2] J. C. Slootweg, Curr. Opin. Green Sust. Chem. 2020, 23, 61–66.
[3] H. Flerlage, J. C. Slootweg, Nat. Rev. Chem. 2023, 7, 593–594.

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KN-028

Discovery of entrectinib: an amazing journey from target biology to innovative therapy

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Treatment of lung cancer dramatically changed during the last 20 years due to the identification of genomic alterations resulting in the expression of activated proteins that set the basis for precision medicine approach. In particular, the identification of recurring ROS1 and ALK chromosomal rearrangements in discrete subsets of lung cancer patients emerged as valuable opportunity for the development of highly potent and selective drugs for the treatment of patients harbouring such alterations.

At the time the screening of NMS proprietary kinase targeted library was conducted and led to identify the initial promising hits, the liabilities of the first-generation ALK/ROS1 inhibitor crizotinib in clinical settings were already emerging demonstrating that, despite the good clinical efficacy, relapse due to the acquisition of secondary mutations was common. In addition, the poor brain penetration of crizotinib resulted in lack of efficacy in patients with brain metastases at baseline and evidence of progression in the brain in patients relapsing after initial response. These emerging clinical observations guided the medicinal chemistry efforts in NMS with the aim to identify a second-generation ALK/ROS1 inhibitor able to overcome such liabilities. The focused lead optimization approach led to the identification of entrectinib, a highly potent ALK/ROS1 inhibitor, able to inhibit several acquired resistance mutations and, importantly, able to efficiently cross the blood-brain barrier and achieve efficacious exposure in the brain.

Although these features of entrectinib already opened the possibility for its development and approval as best-in-class drug, the most extraordinary opportunity arose from the discovery that entrectinib, designed to be a ROS1/ALK inhibitor, was also highly potent in inhibiting NTRK, a closely related kinase. However, no evidence of a potential major role of NTRK as target in tumours had been published at that time. The full exploitation of this activity become possible due to the serendipitous detection of a NTRK rearrangement in a colorectal cancer (CRC) cell line that prompted to search for this genomic alteration in patients. The successful identification of NTRK rearrangements in a subset of CRC patients spurred the exploration of other tumour types resulting in the identification of activated forms of NTRK in several different histologies.

Based on preclinical evidence, the clinical development of the drug was conducted in target-selected patients, including ROS1- and ALK-positive lung cancer and NTRK-positive tumours across 19 different tumour types. The excellent clinical efficacy associated with the good safety profile resulted in breakthrough therapy and priority medicine designation granted by FDA and EMA, respectively, and, ultimately, to an accelerated approval for treatment of ROS1-positive lung cancer and agnostic approval for NTRK-positive tumours. The partial response achieved in the first NTRK-positive CRC patient treated with entrectinib represented the first compelling clinical validation of NTRK as a target in this tumour type and paved the way for the treatment of all subsequent patients.

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KN-029

Targeted radionuclide therapy: the influence of linker modification on cell selectivity

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In this work, we present a crosstalk between medicinal chemistry, pharmaceutical technology, and biology to address the challenge of overcoming therapeutic and delivery limitations of existing radiopharmaceuticals. Cholecystokinin type 2 receptor (CCK2-R) represents an ideal target for cancer therapy since it is overexpressed in several tumors and it is associated with poor prognosis. Based on preliminary studies from our group[1], Nastorazepide (Z-360), a selective CCK2-R antagonist, has been selected as CCK2-R ligand for targeted therapy[2]; however, Z-360 high hydrophobicity may represent a limit to cell-selectivity and optimal in vivo biodistribution.[1,2] Here, Z-360 was linked to spacers bearing a mono, a di or a tri-saccharide (x) to sulforhodamine B leading to new derivatives of increasing hydrophilicity (IP-002x-Rho). Through 2D and 3D in vitro studies we evaluated the influence of spacer features on compounds association with and selectivity for CCK2-R overexpressing cells (A431-CCK2-R$^+$) *vs* CCK2-R low expressing cells (A431 WT). 2D in vitro studies highlighted a progressively increase of IP-002x-Rho association with A431-CCK2-R$^+$ cells according to the linker hydrophilicity. Trafficking studies on A431-CCK2-R$^+$ cells incubated with IP-002x-Rho suggested the co-existence of receptor-mediated endocytosis and simple diffusion. On the contrary, a high and selective uptake of the most hydrophilic derivative by A431-CCK2-R$^+$ cells only was observed on 3D scaffolds embedded with cells, underlying the importance of 3D models in in vitro preliminary evaluation. Once selected the best performing molecule, sulforhodamine B has been replaced with a set of chelators and investigated for targeted radiotherapy.

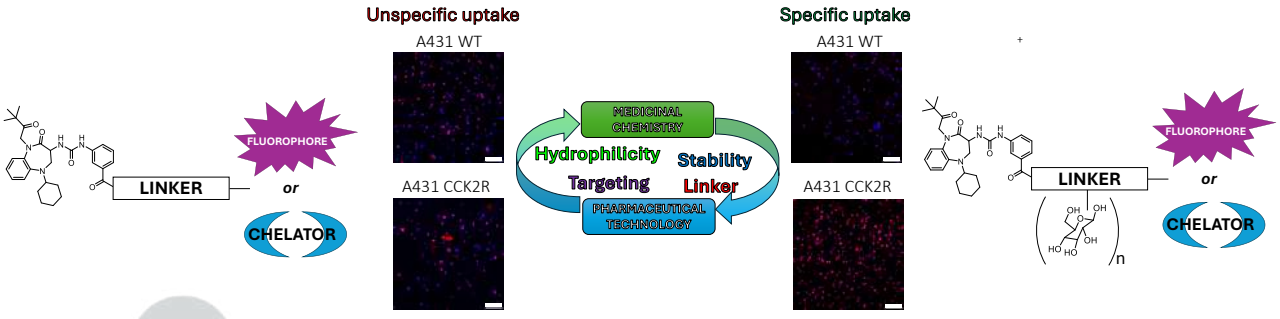

Figure 1: Schematic representation of Z-360 derivatives and specificity for CCK2R$^+$-expressing cells.

References:

[1] Verona, M.; Rubagotti, S.; Croci, S.; Sarpaki, S.; Borgna, F.; Tosato, M.; Vettorato, E.; Marzaro, G.; Mastrotto, F.; Asti, 2021, Molecules, 26, 918.

[2] Novak D, Tomašič T, Krošelj M, Javornik U, Plavec J, Anderluh M, Kolenc Peitl P, 2021, ChemMedChem, 16: 155.

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KN-030

Non-canonical nucleic acids arrangements for targeted therapies

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Upon the discovery of the DNA double helix, our understanding of the multifaceted structures and functions of nucleic acids has steadily advanced, fostering an ever-increasing interest in these biomolecules within medicinal chemistry. This correlates with the abundance of chemotherapeutics known to target nucleic acids which, despite a frequent lack of selectivity, remain widely used in the clinic. In parallel, we are finally recording a constant increase in the number of approved nucleic-acids-based therapeutics. Besides two aptamers and emerging mRNAs, the majority share a common molecular mode of action based on the pairing of two nucleic acid strands[1]. The good prediction of the energetic associated to the RNA-RNA, DNA-DNA or RNA-DNA double helices formation from the sequence composition remarkably speed-up the design of short oligonucleotides selective for the selected target and made it potentially adaptable to treat many diseases as well as specific variants or mutations that may emerge. This encouraging scenario still faces several limitations, largely related to the stability and distribution of oligonucleotides. An additional frequently underestimate issue is related to the structural features of the target and the drug. For example, RNA chains easily accommodate folded domains where the pairing of a complementary strand is hindered. This structural issue is further complicated by the potential occurrence of so-called “non-canonical nucleic acids arrangements” which depend on both primary sequence and environmental conditions. Unfortunately, the predictive capability for these arrangements remains unsatisfactory[2].

However, we can look at this polymorphism from an alternative perspective and transform it into a novel opportunity for targeted therapies. Indeed, the divergent three-dimensional features of nucleic acids structures, suggest differences in cellular component recognition. Moreover, their formation can be time and space controlled directly by the cellular environment, overall indicating their involvement in specific cellular functions. Last but not least, they occur at a small subset of nucleic acid sites. These evidences envisage their exploitation as sites for targeted therapeutic interventions[3]. Here, we will present how different experimental approaches can provide a comprehensive understanding of the functions of these structural elements at the molecular level, and how this knowledge can be used to develop variegate of strategies to ultimately modulate a single cellular pathway.

References:

[1] M. Egli,M. Manoharan, Nucleic Acid Res, 2023, 51, 2529 - 2573.
[2] M. Ghezzo, M. Trajkovski, J. Plavec, C. Sissi, Angew Chem Int Ed Engl, 2023, 62, e202309327.
[3] S. Ceschi, M. Berselli, M. Cozzaglio, M. Giantin, S. Toppo, B. Spolaore, C. Sissi, Nucleic Acid Res, 2022, 50, 1370 – 1381.

KN-031

Exploring a new dimension in DNA for the future of precision medicine

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In the ever-evolving landscape of biomedical research, G-quadruplex (G4) nucleic acid structures have emerged as fascinating therapeutic targets for precision medicine and molecular diagnostics. These noncanonical arrangements of DNA or RNA play crucial roles in gene expression regulation and are implicated in the pathogenesis of various diseases, including cancer[1]. Integrative analyses of mutations found in patient-derived tumor cells, combined with assessments of differentially G4-enriched genomic regions, have linked G4s to cell-type specific transcriptional control, tumor heterogeneity, and genome instability[2]. G4-interacting ligands show potential for therapeutic modulation of G4 biology. However, precise targeting of specific G4 structures is essential for clinical translation. Developing ligands with enhanced affinity and specificity is essential to realize the full therapeutic potential of G4-targeting strategies[3,4]. Moreover, G4-ligand interactions offer diagnostic potential, enabling the development of biosensors and imaging tools for early disease detection and personalized treatments, with potential to improve patient outcomes. The latest advances in this research field will be discussed, along with strategies for enhancing the specificity and effectiveness of G4-targeting ligands.

References:

[1] F. Romano, et al., Expert Opin. Ther. Pat. 2023, 33, 745 – 773.
[2] R. Hänsel-Hertsch, et al., Nat. Genet. 2020, 52, 878 – 883.
[3] J. Amato, et al., J. Med. Chem. 2020, 63, 3090 – 3103.
[4] S. Marzano, et al., J. Med. Chem. 2022, 65, 12055–12067.

KN-032

Well known polysaccharides (hyaluronic acid, alginate) we know rather little about

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Polysaccharides have a well deserved position in drug delivery (mostly as excipients), in biomaterials (as components of artificial extracellular matrices) and in medical devices (viscosupplementation, dermal fillers); facing this wealth of medical/pharmaceutical applications, it would seem natural that both their physico-chemical behaviour and biological interactions have been long understood, down to a very detailed level.

This is, however, not often the case.

This talk provides two examples:

- The nature of the counterion can dramatically and somehow unexpectedly alter both solution properties and gelation processes of alginate. Here we focus on magnesium, which is the only double-charged cation that does not induce alginate gelation; on the contrary, Mg intramolecularly cross-links polysaccharide chains, reducing their viscosity in solution and changing both kinetics and morphology of the exchange with calcium ions[1]. The latter makes Ca alginate obtained from Mg alginate significantly different from that produced from the Na salt; this provides a very convenient means to fine tune e.g. mechanical properties and therefore enhance the potential of personalization of a delivery vehicle.
- The interactions with cell surfaces, and the mechanism of binding (recognition) and internalization are what we invoke in cell targeting, which is a cornerstone concept in personalized medicine. CD44 is the main receptor for hyaluronic acid, and the tumour cell-targeting properties of this polysaccharide are typically ascribed to their interactions. In cell targeting through receptors such as CD44 we have a basic question: are the receptors those that a) recognize and bind an extracellular object (capture), b) bring it inside the cell through endocytosis (internalization), or c) both? Starting a few years ago[2], with time we have accumulated sufficient evidence that CD44 is essentially a selective internalizer (point b). One or more yet to-be-identified receptors would take case of the initial, and possibly less selective capture of hyaluronic acid. This begs the question whether we may still refer to phenomena of non-selective binding/selective internalization as “cell targeting”, due to the inherent presence of off-target effects (non-selective recognition).

References:

[1] G. Della Rosa, N.E. Gostynska, J.W. Ephraim, S. Sganga, G. Panuccio, G. Palazzolo, N. Tirelli, Carbohydrate Polymers 2024, 331, 121871.

[2] J.M. Rios de la Rosa, P. Pingrajai, M. Pelliccia, A. Spadea, E. Lallana, A. Gennari, I.J. Stratford, W. Rocchia, A. Tirella, N. Tirelli, Advanced Healthcare Materials, 2019, 8 1901182.

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Innovation in Precision Medicines: Antibody-Drug Conjugates

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Antibody–drug conjugates (ADCs) are a successful technology for targeted delivery of cancer therapeutics. Based on the covalently coupling of a drug to a tumour-specific monoclonal antibody, ADCs have demonstrated effectiveness against various cancers with 13 ADCs in clinical use and more than 100 in clinical investigation. An ADC targets a specific tumour antigen, typically a cell surface receptor, and specifically deliver potent drugs (EC50 < 0.01-0.1 nM) to tumor cells. After binding to the antigen, the ADC-antigen complex is internalized into the cancer cell, and addressed to lysosomes where the drug is released through an enzymatic, hydrolytic, or reducing step. Several factors can dramatically affect the success of ADCs, like the rate of endocytosis and lysosomal trafficking or the level of neonatal Fc receptor (FcRn)-mediated cell surface recycling. Other factors influencing the activity include the payload potency and mechanism of action and the type of antibody-payload linkage that determines the mechanism and rate of drug release or the payload itself.

Tubulin binders are the most common payloads in currently approved ADCs but, despite their clinical success, they suffer from some liabilities in terms of sensitivity to multidrug resistance system with reduced activity in chemoresistant tumors and showed some safety concerns, being hematological toxicity and peripheral neuropathy among the most common ones. The recently introduced Topoisomerase I inhibitor dexuxtecan, characterized by a cleavable linker and with a strong bystander effect, interestingly showed activity in context where previously tested ADCs failed. This renewed the interest in novel payloads with diversified mechanism of action to face emerging resistance and to explore new combinations. Nerviano Medical Sciences is developing a platform of cytotoxic and targeted payload linkers, based on its proprietary chemical collection of more than 100.000 compounds and selects tumor antigens, for possible synergism with the payload mechanism of action, to maximize selectivity and further increase the therapeutic window of generated ADCs.

Regarding ADC linkers, these are divided in two categories: cleavable or non-cleavable. The most used releasable linker is the cathepsin-sensitive dipeptide Val-Cit coupled with the self-immolative spacer p-aminobezyl carbamate. In the case of non-cleavable linkers, the drug is released only after the lysosomal proteolysis of the antibody. Recently, Pasut's group reported on the use of a hydrophilic, non-cleavable, PEGylated linker for the preparation of ADCs with high drug loadings, showing increased physical stability and decreased plasma clearance in mice compared to Kadcyla. The linker had been designed with a "pendant" shape having two monodisperse PEG12 arms appended to the linker. Such linkers have been further improved by the insertion of cleavable peptides (Phe-Gly or Val-Ala-Gly), thus allowing the release of the drug.

In conclusion, it is important to highlight the relevance of the drug-linker optimization, specific insights can help the design and development of new antibody-drug linkers.

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KN-034

Navigating Extracellular Vesicles heterogeneity by Membrane Sensing Peptides

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Extracellular vesicles (EVs), crucial mediators of cell-to-cell communication, hold significant diagnostic potential due to their ability to concentrate protein biomarkers in bodily fluids. However, challenges in isolating EVs from complex biological specimens hinder their widespread use. The preferred strategy involves direct analysis, integrating isolation and analysis solutions, with immunoaffinity methods currently dominating. Yet, the heterogeneous nature of EVs poses challenges, as proposed markers may not be as universally present as thought, raising concerns about biomarker screening reliability. This issue extends to EV-mimics and analogues, where conventional methods may lack applicability. Addressing these challenges, we report on Membrane Sensing Peptides (MSP) as pan-vesicular affinity ligands for both EVs and their non-canonical analogues, streamlining capture and phenotyping through Single Molecule Array (SiMoA). MSP ligands enable direct analysis of circulating EVs, eliminating the need for prior isolation. Demonstrating clinical translation, MSP technology detects an EV-associated epitope signature in serum and plasma, distinguishing myocardial infarction from stable angina. Additionally, MSP allows analysis of tetraspanin-lacking Red Blood Cell-derived EVs, overcoming limitations associated with traditional antibody-based methods. Overall, our work underlines the value of MSP as complementary tools to antibodies, advancing EV analysis for clinical diagnostics and beyond and marking the first-ever peptide-based application in SiMoA technology

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KN-035

Fluorinated nanoparticles as bioimaging tools and delivery agents

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This work addresses the current need for novel sensitive, robust, and selective diagnostic tools for non-invasive *in vivo* imaging, which are able to improve the medical practice through earlier diagnosis of disease, implementation of targeted therapies, and localization of diseased tissues. Our approach is based on the development of sustainable fluorinated probes enabling ^{19}F-MRI, as a complementary tool, to be coupled with other diagnostic imaging techniques such as ^{1}H-MRI, Raman and fluorescence imaging, in order to overcome their present shortcomings. This talk reports about a unique fluorinated imaging agent (PERFECTA) bearing 36 equivalent ^{19}F atoms and therefore showing a single, intense ^{19}F-NMR signal. Biocompatible nanoparticles loaded with PERFECTA demonstrated excellent cellular compatibility and spectral properties (relaxation times and sensitivity) adequate for in vivo ^{19}F-MRI use [1-2]. In this presentation PERFECTA ability to work as multiscale and multimodal probe will be shown [3]. Moreover, effects of fluorination on self-assembly of PERFECTA amphiphilic derivatives will be also presented as well as their biological interactions and response also in the perspective to use them in precision medicine.

References

[1] I. Tirotta, A. Mastropietro, C. Cordiglieri, L. Gazzera, F. Baggi, G. Baselli, M.G. Bruzzone, I. Zucca, G. Terraneo, F. Baldelli Bombelli, P. Metrangolo, G. Resnati J. Am. Chem. Soc. 2014, 136,24, 8524-27.

[2] B. L. Bona, O. Koshkina, C. Chirizzi, V. Dichiarante, P. Metrangolo, F. Baldelli Bombelli Acc. Mater. Res. 2023, 4, 1, 71–85.

[3] C. Chirizzi, C. Morasso, A. Caldarone, M. Tommasini, F. Corsi, L. Chaabane, R. Vanna, F. Baldelli Bombelli F., P. Metrangolo J. Am. Chem. Soc. 2021, 143, 31, 12253–12260.

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KN-036

Printed electrochemical strips to early diagnose diseases, to evaluate vectors' encapsulation, and to monitor therapeutic efficacy: user-friendly diagnostics for personalized treatments

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The use of portable diagnostics is always more occurrent in the clinical field, and in particular the application of screen-printed electrochemical strips is capable to provide benefits to all the steps, from prevention to therapy. Focusing in the field of cancer, screen-printed electrodes have been successfully applied towards the determination of various molecules, relevant for managing cancer. In this presentation, the use of portable electrochemical devices will be highlighted in 1) detecting miRNA and exosomes as markers for early diagnosis, 2) evaluating the efficacy of encapsulation of drug in lipid nanovectors to be used for treatment and 3) evaluating the therapeutic efficacy in various type of cancers by monitoring the changes in reactive oxygen species level.

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KN-037

Making the invisible visible: contrast agents for diagnostic imaging

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Bracco Imaging, a private-capital Italian company, is a worldwide leader in the production and marketing of contrast agents for *in vivo* diagnostic imaging. The use of a contrast agent in combination with the suitable diagnostic technique allows the visualization of the inside of a human body leading to a fast and accurate diagnosis.

In this presentation the main diagnostic imaging techniques,[1] such as CT,[2] MRI,[3] Ultrasound, Nuclear Medicine and Optical Imaging (Figure 1), and the corresponding contrast agents employed will be disclosed and discussed.

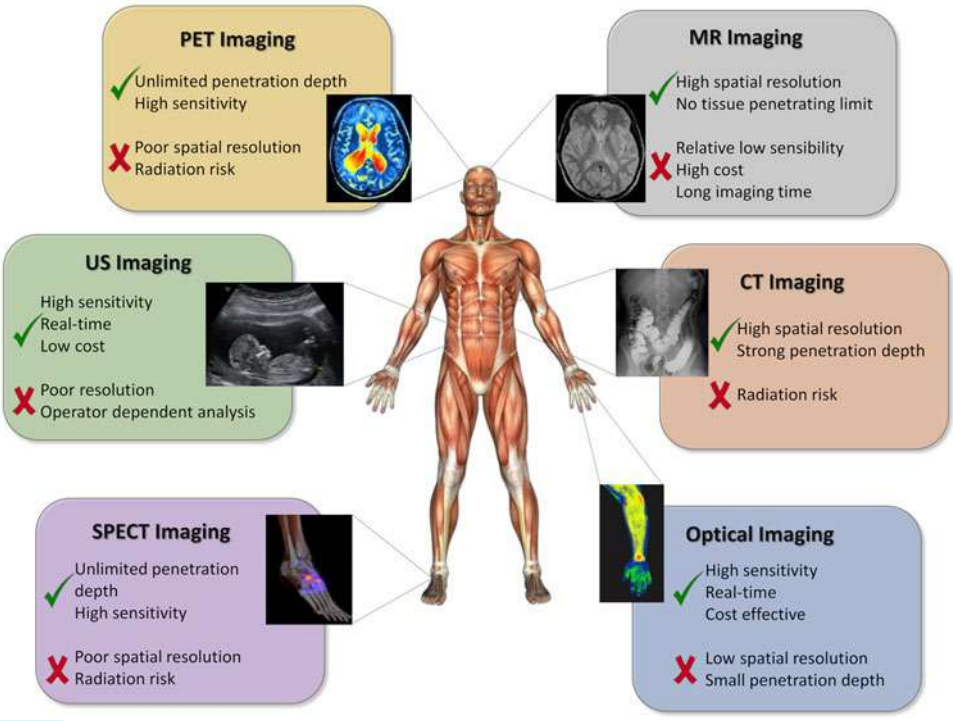

Figure 1: Principal diagnostic imaging techniques.

References:

[1] M. L. James, S. S. Gambhir, Physiol. Rev. 2012, 92, 897-965.
[2] H. Lusic, M. W. Grinstaff, Chem. Rev. 2013, 113, 1641-1666.
[3] J. Wahsner, E. M. Gale, A. Rodríguez-Rodríguez, P. Caravan, Chem. Rev. 2019, 119, 957-1057.

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KN-038

Targeted MRI contrast agents for precision medicine

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Non-invasive diagnostic imaging plays a key role in advancing precision medicine, particularly in scenarios where achieving a minimum drug concentration threshold is critical for therapeutic efficacy. Boron Neutron Capture Therapy (BNCT) is a pre-targeting technique that involves the injection of a non-radioactive, non-toxic chemical containing ^{10}B, which is only triggered by neutron irradiation after accumulation at the tumour site. The main advantage of this approach is that by administering ^{10}B and producing alpha radiation selectively in diseased cells, it can kill the pathological cells while sparing the surrounding healthy tissue.[1] However, the expected efficacy has been compromised by the non-specific and non-sufficient biodistribution and rapid metabolism of clinically used BNCT agents. By incorporating a magnetic resonance imaging (MRI) probe into the NCT agent, it is possible to assess the amount of ^{10}B nuclei that have reached the tumour region, thus offering the possibility of personalised therapy thanks to direct observation of biodistribution. In addition, the non-radioactive isotope ^{157}Gd can also react with neutrons to produce high LET Auger electrons, further enhancing the therapeutic power. Therefore, our research is focused on the development of theranostic agents based on closo-carboranes, with high boron content and in vivo stability, acting as a platform linked to a suitable biological vector and an MRI agent. These agents were administered alone or formulated into nanoparticles capable of improving pharmacokinetics and achieving an appropriate tumour-to-blood ratio.[2] To avoid tumour cell relapse and increase the efficacy of the boron agents, a synergistic strategy was also adopted by coupling the enzymatic inhibition of carbonic anhydrase IX to BNCT. (Figure 1) More recently, our group has envisaged the use of BNCT as a powerful and innovative technique for the treatment of Alzheimer's disease as a means of disaggregating β-amyloid plaques.

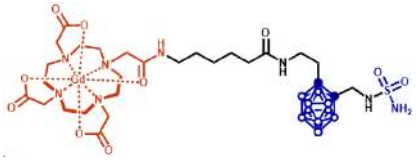

Figure 1: Theranostic agent Gd-CA-SF

References:
[1] WH Jin, C. Seldon, M Butkus, W Sauerwein, HB Giap. Int J Part Ther. 2022;9:71-82
[2] Sforzi J, et al Sci Rep. 2023;13:620

KN-039

The Superintendence of the Sea.
Research, protection, enjoyment, and enhancement of underwater cultural heritage in Sicily

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The “first” Superintendence of the Sea in Italy was established in Sicily in 2004, thanks to the driving force of Sebastiano Tusa [1]. In the framework of the Department of Cultural Heritage and Sicilian Identity, the main tasks are the protection, enjoyment, and enhancement of underwater cultural heritage. Its activities, based on a multidisciplinary approach that combines historical-archaeological aspects with ethno-anthropological and naturalistic ones, have placed it in a position of European prominence since its inception.

The Superintendence of the Sea, equipped with a highly specialized team (composed of archaeologists, art historians, underwater technicians, restorers, architects, biologists, and chemists), has carried out numerous research projects, excavations, and conservation activities on the seabeds throughout Sicily and its smaller islands over the past twenty years. Many missions have also been conducted abroad (Japan, Kenya, Tunisia, Estonia, Denmark, Libya, Turkey), often in collaboration with prestigious universities. Close collaboration has also been established with law enforcement agencies (Carabinieri and Guardia di Finanza), the Armed Forces (Navy, Harbor Masters, and Air Force), and the Italian and foreign academic world. Numerous scientific publications, conferences, thematic meetings, and awareness-raising activities with schools have been organized. Among the most important achievements, it is worth mentioning the reconstruction of the location and dynamics of the "Battle of the Aegates" in 241 B.C., where 27 rams, numerous helmets, weapons, and onboard equipment were recovered from the traces of the clash between the Roman and Carthaginian fleets. The submerged cultural itineraries, currently 26 realized by the Superintendence, represent a real network of distributed museums that offer the opportunity to visit archaeological sites still in their original location. The current itineraries, already accessible through authorized local diving centers, will soon be even more inclusive, thanks to their adaptation for blind and disabled visitors.

For this year, the Superintendence already has plans to complete the restoration and musealization of the Imperial-era wreck named "Marausa II," which was completely recovered in a complex operation never before realized; the excavation and recovery of the Archaic Greek wreck named "Gela II"; instrumental investigations in deep waters on 11 underwater sites (about 700 square kilometers) with the help of AUVs equipped with Side Scan Sonar; and the new research campaign on the site of the Battle of the Aegates.

Finally, while work has already begun that will lead in a couple of years to the opening of the "Museum of the Sea and Navigation of Sicily" in the historic and monumental building of the Arsenal of Palermo, the restoration and adaptation works of the operational headquarters (former Roosevelt Institute, Addaura) are nearing completion, which will provide a center of excellence for the study and research in underwater archaeology.

[1] https://www2.regione.sicilia.it/beniculturali/archeologiasottomarina/

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KN-040

Underwater Cultural Heritage: knowledge and conservation

Part 1: Physico-chemical approaches for underwater archaeological metals

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The investigation of archeological metals recovered in underwater sometimes is a challenge for a chemist because of the reactions involved in the developing of their corrosion and the lack of information about the environmental conditions. Here, some examples of investigation is reported: the Montefortino-type helmets [1] and the metals fragments (nails and lead sheathings) from the Punic Ship [2], the roman and punic rostrum from the Egadi battles, the orichalcum ingots of Gela [3] and a series of metal objects belonging to the ship's cargo, so-called. For each case-study, an appropriate approach was developed to answer to the archaeological questions, and help to reconstruct the history of the objects. The approaches will be presented to describe possible available information and at the same time clearly show the strong impact of the chemical-physical investigations to unveil a kind of degradation processes developed in the underwater archaeological metals.

[1] F. Armetta, et al. Scientific Reports 11, **(2021)**, 23022. https://doi.org/10.1038/s41598-021-02425-6
[2] F. Armetta, et al. Molecules 28(4) **(2023)** 1968. https://doi.org/10.3390/molecules28041968
[3] E. Caponetti, et al. Microchemical Journal 135 **(2017)** 163–170

Part 2: Underwater Cultural Heritage, balancing conservation, exploitation and sustainability

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Underwater cultural heritage (UCH) represents a significant part of human history submerged beneath oceans, seas, rivers, and lakes. Conservation efforts for UCH aim to protect, preserve, and manage submerged cultural sites for present and future generations. Conservation involves various activities, including site documentation, excavation, artifact preservation, and site monitoring. Conservation strategies must prioritize the protection of UCH from natural deterioration, looting, and damage caused by human activities such as fishing, maritime traffic, and industrial development. Additionally, international frameworks such as the UNESCO Convention on the Protection of the Underwater Cultural Heritage (2001) provide guidelines for the preservation and management of UCH at the global level. Since then, several goals have been achieved in the framework of the protection of UCH, particularly concerning the examination of stone materials, degradation processes, and novel methodologies for in-situ consolidation and protection. This contribution centers on scrutinizing the primary findings derived from numerous investigations conducted thus far, offering supplementary guidelines for practitioners in the UCH domain, including restorers, archaeologists, conservation scientists, geologists, among others. These guidelines serve as a pivotal factor in augmenting understanding, management, protection, and promotion of underwater sites. Several case studies, such as Baiae in Naples, demonstrate the diverse approaches to managing UCH and the importance of balancing conservation, exploitation, and sustainability.

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KN-041

The preservation of historical violins between restoration, function and enhancement

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The violin as well as all bowed string instruments require special attention from a conservative point of view, being composed mainly by wood and organic materials.

The focus on microclimatic control is based on the interaction of wood with the environmental thermo-hygrometric parameters and with all aspects related to the biological degradation processes, including the xylophagous attack. It is also important to highlight that the case of musical instruments as a class of historical artifacts often involves their use and therefore the fact that they can be played can represent a potential negative effect on their state of preservation.

The new control procedures developed at the Violin Museum in Cremona, based on maintenance and conservation procedures, also through preventive diagnostic campaigns, is an interesting case of control and evaluation of their conservation status.

Figure 1: Giuseppe Guarneri del gesù, violin, 1734

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KN-042

Invasive and non-invasive diagnostic techniques for the study of violin historical materials

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Scientific and technical studies of ancient musical instruments have seen an important development in recent years with a particular attention to string instruments and especially violin. The study of this extraordinary historical artifact that was born in the first half of 1500 involves some different scientific perspectives that must dialogue with each other and that deal with interdisciplinary and connected issues.

Thus, the study of violins has been in the last ten years an important aim for several scientific and diagnostic researches.

The studies have been performed by new non-invasive analytical protocols that have allowed to shed light on some construction techniques and on different classes of materials historically used by important luthiers such as Stradivari or Guarneri.

The main spectroscopic and imaging techniques, as well as facilities such as synchrotron light, have allowed to characterize the original varnishes, grounds and wood treatments. In addition, micro-invasive analyses[1] performed on cross-section have deepened the studies on the different layers and thickness of the different treatments.

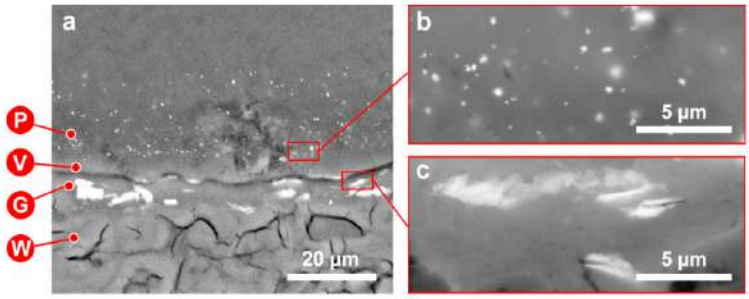

Figure 1: BSE-SEM images of cross section from violin

References:
[1] Poggialini, F., Fiocco, G., Campanella, B., Legnaioli, S., Palleschi, V., Iwanicka, M., Targowski, P., Sylwestrzak, M., Invernizzi, C., Rovetta, T., Albano, M., Malagodi, M., Stratigraphic analysis of historical wooden samples from ancient bowed string instruments by laser induced breakdown spectroscopy (2020) Journal of Cultural Heritage, 44, pp. 275-284.

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KN-043

The role of science between research, protection, and fruition of cultural heritage: a 20-year experience at the CCR "La Venaria Reale"

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Museum galleries and heritage sites worldwide house countless artifacts of enormous historical, artistic, and monetary value, many of which have come down to us from the distant past and each of which requires tailored care in order to be passed on to future generations. Increasingly, over the years, the protection and enjoyment of cultural heritage objects has based its identity on the contributions made by conservation science, a technically complex field at the intersection of chemistry, physics, biology, geology, materials science, and engineering. The scientific investigation of artifacts of archaeological, historical, and artistic significance often constitutes a multifaceted endeavor, combining multiple aspects such as dating of the works, analysis of their material composition, degradation studies, and environmental monitoring. The development of cutting-edge technologies and, more broadly, fundamental research provide conservation scientists with essential tools to meet the needs typically encountered in this field: among them, the need to preserve the physical integrity of particularly delicate artifacts, which cannot be moved outside of museum galleries, storages, or conservation studios, by carrying out investigations in situ and in a non-invasive manner; the availability of highly specialized analytical techniques that are able to deliver an increasingly more detailed characterization of materials of different nature; and the development of innovative instrumentation enabling the continuous monitoring of the works' state of preservation as well as ongoing conservation treatments. Through relevant case studies tackled over the years at the CCR "La Venaria Reale", this talk aims to illustrate the crucial role of science and the challenges currently faced in the field of conservation and cultural heritage research.

KN-044

Cutting-edge investigation methods in the field of non-invasive and micro-invasive analytical approaches for diagnostics applied to heritage studies and conservation

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Part I, Bruno Brunetti: MOLAB laboratory: from single point analysis to hyperspectral imaging

Non-invasive identification of chemical composition of a polymateric work of art is one of the specific tasks of diagnostics applied to heritage studies and conservation. In this field, characterized by investigations carried out in situ, with no sampling and even no contact with the examined object, single point analytical measurements have led during the last decades to the achievement of powerful results in studies of paintings, sculptures, manuscripts, ceramics, etc.. However, a more complete answer to the questions posed by heritage professionals, today comes from the identification of materials coupled with information on their semi-quantitative spatial distribution on a macroscopic scale (surfaces of thousands cm2).

In recent years, some efforts of heritage science have been addressed to the development and applications of hyperspectral analytical imaging/mapping techniques, which led to significant results thanks to the exploitation of innovative instruments and methodologies. Along this line of development, the MOLAB laboratory, born in the early 2000s with the first projects for the establishment of the E-RIHS infrastructure (E-RIHS-http://www.e-rihs.eu/), has recently strengthened its own analytical potential, open to the access of Italian and European researchers, with the introduction of systems for hyperspectral imaging/mapping, thus ensuring an effective alignment of its services to the most advanced analytical methodologies required by the sector. Recent applications of traditional and established imaging techniques will be described, along with innovative methodologies that, based on multimodal/integrated approaches, probe different chemical properties and unexplored spectral ranges.

Part II, Maria Perla Colombini: Shedding light on the organic materials in artistic and archaeological objects by chromatography-mass spectrometry

A detailed understanding of the organic chemical composition of archaeological objects and paintings is crucial for identifying not only the original materials but also for enabling the detection of materials added during restorations or those induced by time and pollution. Additionally, it aids in comprehending the function of archaeological objects. Chemical characterization integrated with historical and archaeological data, has significantly advanced our understanding of past painting techniques and technologies.

Chemical analysis of organic materials poses challenges for chemists due to their complex compositions, susceptibility to degradation processes from aging, environmental factors, and human activities (e.g., heating processes applied to plant resins). Moreover, these materials are often present in very low quantities compared to inorganic materials.

Currently, techniques based on chromatography and mass spectrometry, including SIFT-MS (selected ion flow tube mass spectrometry), EGA-MS (evolved gas analysis mass spectrometry), Py-GC-MS (pyrolysis gas chromatography-mass spectrometry), GC-MS, and HPLC-MS, play a crucial role in analytical procedures for artistic and archaeological objects. The lecture focuses on current analytical procedures based on chromatography-mass spectrometry techniques that allow the characterization of macromolecules in archaeological objects and paintings, demonstrating their utility in integrating historical and archaeological information. Case studies will be discussed to illustrate the practical application of these techniques in providing valuable insights into the composition and preservation of cultural heritage.

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KN-045

Methodologies and experiences in comparison in the field of paper restoration

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The *Opificio delle Pietre Dure* (OPD) is an autonomous institution within the Ministry of Culture in Italy. Its mission concerns in all aspects fine art conservation, including treatment, research, education and training. OPD is divided into distinct departments of conservation categorized according to the various materials and techniques used in the creation of works of art. The Paper and Parchment Department Conservation deals whit the conservation and restoration of traditional media, including drawings, prints, preparatory cartoons, and a wide range of paper-based decorative objects, as well as the restoration materials and their possible interaction. Research finalized to diagnostics and knowledge of works of art materials and their deterioration is a key activity of OPD. The application of modern nanotechnologies and materials has been intensively investigated in the last decade in cooperation with distinguished partners as CSGI & University of Florence, whose contribution was fundamental for the development of specific intervention protocols carried out at OPD. Among others, many efforts have been addressed to consolidation of graphic media and supports (e.g. modern papers), treatment of photographic materials, removal of stains and aged pressure sensitive tapes (PSTs).
This contribution will report on some illustrative examples which include drawings, printings, and manuscripts.

References:

[1] M. Trabace, A. Mirabile, L. Montalbano, R. Giorgi, N. Bonelli, M. D. Pianorsi, P. Ferrari, P. Baglioni OPD Restauro, 2017, 29, 259-266.
[2] M. Becattini, C. Merelli, L. Montalbano, OPD Restauro, 2024, 35, in press.

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KN-046

Nanostructured materials for the conservation of graphic documents

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Graphic documents constitute one of the pillars of our cultural identity and legacy. Unfortunately, they often suffer severe degradation pathways due to both endogenous and exogenous factors, which favoured chemical alteration and a consequent loss of mechanical properties. Sometimes the effects of such processes are also strongly amplified by wrong past interventions. The conservation of these valuable objects is very challenging, requiring a continuous development of innovative solutions, which must meet several constraints: eco-sustainability of the treatment, chemical compatibility of materials, long-term stability, cheapness.

Nanoscience is nowadays providing innovative and effective technological solutions in a wide range of applicative fields. Among others, nanomaterials have hugely enriched the palette available to conservators to rescue and protect works of art. The aim of the present contribution is to provide an up-to-date overview of the main achievements of CSGI, which pioneered the use of nanostructured materials in this field, on the use of advanced colloidal systems tailored to the conservation of graphic documents.

Consolidation of graphic media and removal of undesired detrimental materials represent two of the most serious concerns of conservators. Highly retentive organogels loaded with green solvents are very promising and efficient tools to achieve controlled and complete removal of aged pressure sensitive tapes (PSTs), largely used in the past to repair torn or weakened pages. The main effects of natural aging of PSTs are their colour variations, stains formation, and loss of adhesion. For that, a complete removal of them is usually necessary, but the commonly used procedures are sometimes ineffective. Weakly bound dyes or inks, typically found in graphic art, represent another complicated conservation challenge. Unfortunately, the commonly used practices rely on the use of synthetic or natural adhesives, which are not fully satisfactory, because they may alter the optical properties of surfaces. Nanostructured starch-based systems have been recently obtained and investigated. A bottom-up approach was followed to obtain a gluten-removed *Jin Shofu* wheat starch that was gelatinized and then precipitated in a non-solvent to obtain a stable dispersion to be used by nebulization.

Successful interventions recently performed on valuable objects using these novel solutions will be described.

References:

[1] D. Chelazzi, R. Giorgi, P. Baglioni, Angewandte Chemie - International Edition, 2018, 57, 7296-7303.
[2] P. Ferrari, D. Chelazzi, N. Bonelli, A. Mirabile, R. Giorgi, P. Baglioni, Journal of Cultural heritage, 2018, 34, 227-236.
[3] A. Mirabile, D. Chelazzi, P. Ferrari, C. Montis, D. Berti, N. Bonelli, R. Giorgi, P. Baglioni, Heritage Science, 2020, 8, 42-48.
[4] A. Casini, D. Chelazzi, R. Giorgi, ACS Applied Materials and Interfaces, 2021, 13, 37924-37936.

KN-047

A Nobel Prize to shape our future. An example of technology transfer

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Many stereoregular polymers exist in nature, for example cellulose and rubber. Giulio Natta broke the monopoly of nature for the synthesis of stereoregular polymers with a high degree of order, as it was stated on the occasion of the awarding of the Nobel prize to Prof. Ziegler and Prof. Natta. Isotactic polypropylene is the most famous stereoregular polymer and is also the most widely used polymer today. But professor Natta and coworkers prepared more than one hundred new polymers and, among them, a large number of polymers with different stereoregularity. "The results are of extraordinary interest; perhaps one should call them revolutionary in significance" said Paul Flory. Giulio Natta was named as the "father of stereospecific polymerization".

This revolutionary adventure was characterized by interdisciplinarity and by a tight cooperation between University and Industry, i.e. between Politecnico di Milano and Montecatini, which provided sufficient funding to set up an advanced training school and to form an important research group at Politecnico. Many young researchers belonging to Montecatini worked in the labs of Politecnico, interactions were deep and continuous, also on a daily basis, in the academic and industrial sites. The time to market of isotactic polypropylene was of only three years.

The scientific rigour and the originality of Giulio Natta's research throughout his career were often directed at solving industrial problems. The Nobel Prize for the discovery of stereospecific polymerization is the brightest example of how goals for industrial development and collaboration with forward-looking companies can benefit basic research.

The legacy of Giulio Natta is fundamental to shape our future, inspiring the eco-design of sustainable polymers.

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KN-048

Sustainability evaluation to support technological transfer: a case study.

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Benefits associated with the development of new green markets due to the diffusion of new suitable technologies may be substantial. For example, Meyer [1] evaluated that resource efficiency improvements may allow to obtain 17–24% of raw material savings with a cost savings of more than €600 million in Europe. However, in general, despite continuing dramatic increases in published research about new proposed sustainable technologies, there has been poor exploitation in an industrial context of such results.

The discrepancy between scientific and applicative results may be attributed to several reasons, such as the absence of a suitable legislative framework, the lack of transferability of the research results, and/or the high cost of the stabilized (or synthesized) secondary raw materials. Another reason why new technologies are not widely used in industry may be also attributed to the lack of knowledge about their real convenience. This presentation aims to present a tool (ESCAPE) designed to evaluate the sustainability of new emerging technologies, in terms of involved energies and emissions, in comparison, to a reference one [2]. This approach is expressly designed to support laboratory studies that often need preliminary evaluations, allowing the comparison with already available natural and/or commercial materials/technologies. The use of this tool is extremely promising in increasing the resilience of industries. The presentation will demonstrate the potentialities of using the ESCAPE index in materials design synthesis strategies (Fig. 1), with the possibility to account for the difference in countries' energy mix (that derives from the local mix of fossil and non-fossil fuels). This approach can support the rapid and flexible change of strategies, supporting technological transfer.

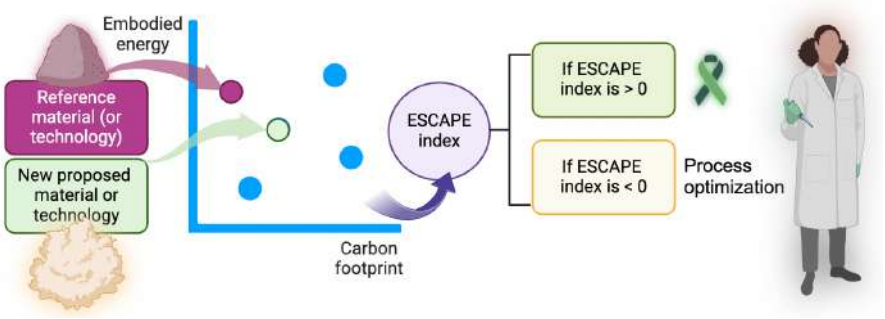

Figure 1: The ESCAPE index evaluation. The figure was realised with Biorender

References:

[1] B. Meyer, Publications Office of the European Union - Macroeconomic modelling of sustainable development and the links between the economy and the environment, 1-89.

[2] S. Ducoli, A. Zacco, B. Valentim, B., Y. Guozhu, E. Mousa, E. Bontempi, Sustainable Materials and Technologies, 38, Article number e00709

This study was carried out within the MICS (Made in Italy – Circular and Sustainable) Extended Partnership and received funding from Next-GenerationEU (Italian PNRR – M4 C2, Invest 1.3 – D.D. 1551.11-10-2022, PE00000004).

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KN-049

WembraneX: the next generation of membranes for water treatment

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WembraneX s.r.l. is an Italian start-up founded in September 2023 with the ambition to make a significant contribution to the United Nations Sustainable Development Goal 6: Ensure Access to Clean Water and Sanitation for all by 2030. The Company aims, as its first target, to step-change the performance of municipal wastewater treatment facilities by significantly reducing membrane fouling, which is their largest operating cost challenge. It also aims as a second target to address complex industrial separation processes in Food and Beverage, Textiles, Pharmaceuticals and Chemicals. The operating performance improvements are achieved thanks to a proprietary coating technology developed by WembraneX and applicable on commercially available substrates. The unique coating technology was originally developed by the researchers of the Institute on Membrane Technology (CNR-ITM) in collaboration with the University of Calabria (UNICAL) and the Karlsruhe University of Applied Sciences (HSKA, Germany) within the framework of a EU project (BIONEXGEN, GA n.246039) and later redefined to create a new class of membranes with superior anti-fouling characteristics. The technology was further validated in a second EU project (VICINAQUA, GA n. 689427,) where the newly developed membranes were applied in wastewater treatment processes in the Lake Victoria region (Kenya). In 2021, the technology was selected and funded by Progress Tech Transfer s.r.l. (MITO technology), within the call for Proof of Concept (PoC) with the aim of further validate the coating process on a larger scale. The novel coating has already shown excellent benefits at the lab-scale which are described in papers published in several international journals[1,2,3]. The coating technology is protected by a patent (WO 2015/044335) exclusively licensed to WembraneX[4].

References:

[1] F. Galiano, A. Figoli, S. A. Deowan, D. Johnson, S. A. Altinkaya, L. Veltri, G. De Luca, R. Mancuso, N. Hilal, B. Gabriele, J. Hoinkis, Journal of Membrane Science 482 (2015) 103–114

[2] F. Galiano, I. Friha, S. A. Deowan, J. Hoinkis, Y. Xiaoyun, D. Johnson, R. Mancuso, N. Hilal, B. Gabriele, S. Sayadi, A. Figoli, Journal of Colloid and Interface Science 515 (2018) 208–222

[3] S. A. Deowan, F. Galiano, J. Hoinkis, A. Figoli, D. Johnson, N. Hilal, S. A. Altinkaya, B. Gabriele, E. Drioli, Journal of Membrane Science 510 (2016) 524-532

[4] A. Figoli, J. Hoinkis, B. Gabriele, G. De Luca, F. Galiano, S. A. Deowan, WO 2015/044335 A2. Granted in EU on 08.04.2020 (EP 3049178 B1

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KN-050

PolyCrystalLine – When a good scientific idea is met with passion and competence a company is born.

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A journey between dreams, hopes and a great desire to get involved. PolyCrystalLine represents a good example of how a scientific idea becomes an opportunity and the opportunity becomes a company when it is supported by a lot of passion, competences, tenacity and finally perseverance. PolyCrystalLine represents a message for next generation of scientist and/or graduates in general on how an academic spin-off can become a company if behind there is a good idea and know-how.

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KN-051

Technology Innovation to enable Polymer Circularity: *MoReTec,* from inception to industrialization

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The chemical industry is going through a transformation towards a sustainable and circular approach. Society, consumers and regulations are driving an increased demand for sustainable solutions and low carbon footprint materials.

To realize this transformation post-industrial and post-consumer plastic waste will be the new feedstocks of the polymer value chain. Realizing true circularity and contributing to addressing climate change by displacing fossil-based raw materials and ultimately ending the plastic waste problem.

Technology development will play a fundamental role in this transformation and Innovation will be instrumental to advance the circularity of plastics through complementary pathways: mechanical recycling, advanced recycling and the use of renewable-based feedstocks.

The development of advanced recycling technologies is complementary to mechanical recycling as it addresses hard-to-recycle post-consumer mixed plastic waste that today end up in incineration and landfills and serve applications requiring high purity such as food packaging and healthcare.

Due to this urgent need, LyondellBasell has accelerated the development of its advanced recycling technology, called *MoReTec*. Starting from break-through research at LYB labs in 2018, a pilot plant was built to test the process technology and develop the scale-up design. The engineering for a commercial scale plant progressed and the investment was approved in 2023: the industrial unit is scheduled to be started up in early 2026.

LyondellBasell's *MoReTec* technology is based on an innovative process, uses proprietary catalysts, it is suitable for large scale plants, it is characterized by low carbon footprint and produces feedstocks that can be utilized in the existing olefins crackers.

KN-052

Corporate Open Innovation- Barilla case

Claudia Berti- Global Open Innovation & IPR

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Open Innovation (OI) is a concept invented in 2003 by Henry Chesbourg, an organizational theorist that is based on the central idea that companies cannot afford to rely entirely on their own research for innovation. It encourages collaboration, even with competitors, to enhance efficiency and discover new solutions. The diversity of perspectives in this model fosters innovation.

In the context of the food industry, open innovation is particularly important due to the constant changes in demand and supply, and the escalating competition. The industry has shifted its focus towards customer satisfaction, producing goods that align with customer demands. This requires innovative solutions and technologies, which can be facilitated through open innovation.

However, the application of open innovation can be hindered by multiple barriers, especially cultural factors and to maximize success and reduce frictions it is crucial to establish a clear governance and specific initiatives to broaden access to participants and expertise, enhance quality of innovation outputs and product impact on business.

Source- Internal Barilla

Barilla has started its open innovation journey in 2011, when a dedicated role has been formalized. At that time the main goal was to ensure flowless connections with academia and research centers. Since then the

KN-053

Technology transfer for sustainable industrial development

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Technology transfer can play a key role in boosting companies growth in dynamic and competitive business landscape. The overall process mainly consists of knowledge, technologies and intellectual property sharing from between companies, research laboratories, academic institutions for the purpose of combining together different assets to create value through the development of innovative products, services, or solutions.

Since its establishment, SAES has been continuously engaged in radical research activities to develop new materials and technologies supporting a long-term perspective that continuously puts the company on the edge of innovation. In particular, many efforts have been devoted during last fifteen years to develop new technology platforms able to create new materials [1-4], ranging from functional additives to composite formulations, where sustainability and flexibility are the innovation drivers. In this context, SAES has been adopting different forms of technology transfer including i) inbound technology acquisition from academic Spin-offs to further develop an innovative technology based on nanostructured materials; ii) Joint-venture approach to establish a new entity to develop a new technology for display applications; iii) collaborative R&D involving research centres to work together on the development of a new membrane based process to create a new class of chemical materials; iv) high-tech hub for advanced materials Start-ups to sustain the development of new technologies helping bridge the gap between R&D and industrial applications.

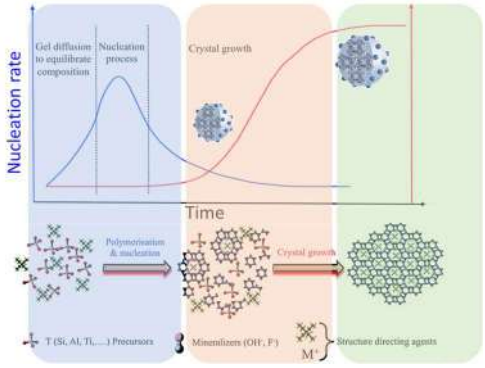

Figure 1: Zeolites technology platform developed through a technology transfer approach

SAES experiences in applying technology transfer approaches will be presented and discussed in terms of materials platform and process characteristics from lab scale to industrial feasibility.

References:

[1] WO2016125050 Active package. A. Colombo, M. Riva, P. Vacca.
[2] WO2022101496 Antiviral composition comprising modified zeolites. M. Riva, K. Fidecka, P. Vacca
[3] WO2020012396 Aqueous ethylene-vinyl alcohol copolymer dispersion. S. Santoro, M. Mudu, P. Vacca
[4] WO2024023341 Dye-exchanged zeolite marker. P. Vacca, S. Zilio, A. Nuzzo, K. Fidecka, A. De Simone

KN-054

Pharma Innovation & Business in Italy: Nurturing potentials in an underestimated environment thorough EXTEND, a unique structured partnership between Accademia, VC and Pharma

Antonio Felici, PhD

Vice President, Academic Partnership
Evotec S.E.

The pharmaceutical landscape in Italy is undergoing a transformative phase, driven by a convergence of factors such as technological advancements, global health challenges, and changing therapeutic modalities. Amidst this dynamic environment, the concept of innovation has taken center stage. In this context, the collaboration between academia, venture capital (VC), and pharmaceutical companies becomes pivotal.

EXTEND, a translational bridge joint venture, was founded collaboratively by CDP Venture Capital, Evotec and Angelini Ventures in 2022. This unique initiative aims to accelerate the development and commercialization of promising assets originated within Italy's academia and emerges as a catalyst for nurturing untapped potentials within Italy's pharmaceutical ecosystem.

Academic institutions play a crucial role in fostering innovation. By bridging the gap between research and practical application, they provide a fertile ground for novel ideas. EXTEND leverages the expertise of Italian universities and research centers, encouraging collaborative projects that address unmet medical needs.

Venture capital firms bring financial backing and strategic guidance. Their involvement in EXTEND ensures that promising innovations receive the necessary resources to flourish. By connecting accademia and early-stage ventures with established players, VC firms facilitate knowledge exchange and accelerate product development.

Established pharmaceutical companies often face challenges in adapting swiftly to disruptive changes. EXTEND offers a structured platform for these industry giants to collaborate with academia and startups. By sharing insights, resources, and risk, pharma companies can explore novel business models, streamline R&D processes, and enhance market access.

Italy's pharmaceutical ecosystem has immense potential, yet it remains underestimated on the global stage. EXTEND recognizes this discrepancy and aims to unlock latent opportunities. By fostering cross-sector partnerships, it seeks to elevate Italy's position as a hub for innovation, clinical trials, and commercialization.

In conclusion, EXTEND represents a paradigm shift, a departure from siloed approaches toward a holistic ecosystem that thrives on collaboration. As Italy's pharma landscape evolves, this structured partnership holds the promise of unlocking breakthroughs, benefiting patients, investors, and society at large.

References:

McKinsey & Company. "Emerging from Disruption: The Future of Pharma Operations Strategy."
McKinsey & Company. "The Next Horizon of Innovation for Pharma."

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KN-055

Drama Science, Diversity, and Inclusion

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Carolyn Bertozzi, who was awarded the 2022 Nobel Prize in Chemistry for the development of bioorthogonal chemistry, is among the 25 female Nobel laureates in STEM subjects; almost 600 men shared this honour. Carolyn Bertozzi is an extraordinary "role model" for the inclusion of women in STEM subjects. She is also an advocate for diversity as an open lesbian in academia and science.

This contribution reports on a drama science tribute to her research focus on sugars. The theatre piece was designed and prepared during the first curricular course of Outreach in an Italian secondary school (ITT "G. e M. Montani" Fermo) and will be performed on the 5th Nov 2024 in Turin by chemistry students. It follows that it is also an innovative educational experiment. Since 2012 extra-curricular projects have been combining the formal learning of chemistry with informal, exciting and stimulating on-stage spectacular experiences because acting in science festivals, videomaking, photo essays, and experiment mastering increase students' understanding[1]: a positive emotional energy in outreach events[3 4 5 6] stimulates a greater propensity to propose explanations[2].

We will show (live with two students / reels) the spectacular chemistry of sugars whose didactic importance is beyond any dispute. In particular, the well-known oxime/hydrazone formation from aldehydes and ketones, commonly practiced by students, will be shown to be a ligation strategy that fulfils the requirements of bioorthogonality, discussed by Carolyn Bertozzi in the Nobel Prize lecture "The Bioorthogonal Chemistry Journey, from Laboratory to Life" delivered in 2022 at the Stockholm University.

The performance aims at inspiring young girls to be #"STEMerarious" and engage with chemistry, which is a crucial tool for civil commitment.

References:

[1] M. Ødegaard, Stud. Sci. Educ. 2003, 39, 75–102.
[2] G. Marx, C. Gilon, Front. Aging Neurosci. 2014, 6, 76685.
[3] M. D. Pluth, S.W. Boettcher, G. V. Nazin, A. L. Greenaway, M. D. Hartle, J. Chem. Educ. 2015, 92, 625–630.
[4] J. M. Pratt, E. J. Yezierski, J. Chem. Educ. 2018, 95, 7–16.
[5] J. M. Pratt, E. J. Yezierski, J. Chem. Educ. 2019, 96, 414–422.
[6] H. W. Kerby, B. K. Dekorver, J. Cantor, M. J. Weiland, C. L. Babiarz, J. Chem. Educ. 2016, 93, 613–618.

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KN-060

Contribution of catalysis and process optimization to improve sustainability in thermoset materials

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Composite thermoset materials play a key role in green transition as they are widely used in the production of renewable energy and in the electrification, production, and transport of hydrogen. There are also many other essential applications in transportation, building and construction, and infrastructure. Therefore, decreasing the carbon footprint of thermoset polymers and composite materials is key in achieving better sustainability and targeting the Green Deal objectives.

Among thermoset polymers, unsaturated polyester resins (UPR) are the most important polymers used in the production of fibre-reinforced articles. Two very important raw materials (building blocks) for UPRs are maleic (MA) and phthalic (PA) anhydrides, industrially produced by catalysed gas phase oxidation reactions of n-butane (MA) and o-xylene (PA).

Even if the industrial processes to produce MA and PA are well consolidated and have been used worldwide for decades, continuous and incremental improvements in catalyst performances are sought to improve process yields and contemporaneously decrease CO_2 emissions, thus decreasing the carbon footprint of the entire production chain of composite materials (Figure 1). In parallel, breakthrough research activities are focused on using renewable raw materials and developing lower energy consumption processes to further improve the sustainability of these monomers.

In developing new solutions, the availability and cost of renewable raw materials, as well as investment costs needed to implement new sustainable processes, must be carefully considered, as they could be barriers to the achievement of sustainability targets.

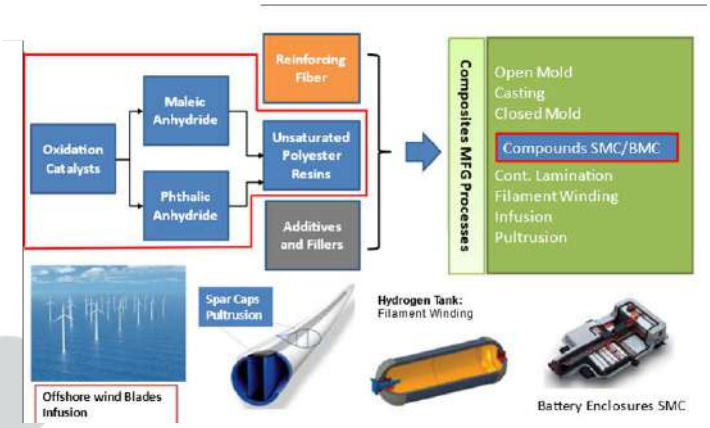

Figure 1: Impact of catalysis in the production chain of thermoset polymers and composite materials.

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KN-061

CO_2: from a Waste to a Resource in the Energy Sector

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The progressive accumulation of greenhouse gases of anthropogenic origin, in particular CO_2, in the atmosphere is one of the main problems that mankind must face today and in the near future. In fact, to contrast climate change it is necessary to contain the increase in the average earth temperature within 1.5°C compared to the pre-industrial era, as defined in the COP21 in Paris in 2015. This means eliminating GHG emissions well before the end of this century, preferably by 2050[1]. The *Net Zero Emissions* is a very challenging target, especially when considering that the main source of CO_2 is the energy sector which, in 2022, was responsible for the emissions of 36.8 $Gtonn_{CO2}$, 1% above the pre-COVID level[2].

To achieve this target, it is necessary to implement actions that lead to the progressive reduction of the use of fossil sources: increasing energy efficiency, development of renewable energy sources, electrification of transport and buildings are among the most frequently requested actions, but these require a radical time-consuming and expensive adaptation of the infrastructures. For this reason, the scenarios attribute an important role to Carbon Capture Utilization and Storage (CCUS), i.e. to the ways that envisage limiting CO_2 emissions through its capture, e.g. from flue gas, and permanent sequestration in suitable geological formations (CCS) or its use for the production of goods or services with market value (CCU). In this regard, the reuse of CO_2 as a carbon source is attracting more and more attention and extensive R&D activities are now focusing on its conversion into building materials, polymers and chemicals, sustainable synthetic fuels (e-fuels), the latter having a direct impact on the energy sector. In particular, e-fuel are intended to play a role in the transport sector, in particular, for the so-called *hard-to-abate* segments, aviation and marine for which electrification and the use of H_2 are difficult, at least in the medium-long term. e-fuels have very similar characteristics to the corresponding fossil fuels, and this makes them compatible both with the existing transport, distribution, and storage infrastructures, and with the current engines.

e-fuels, whether gaseous (methane) or liquid (methanol, dimethylether, gasoline, diesel, jet fuel) are produced by direct or indirect reduction of CO_2 captured either from concentrated sources (e.g., flue gas), from the air (Direct Air Capture, DAC) or of biogenic origin (e.g., from biogas). For the CO_2 reduction to fuel, green H_2 from electrolysis of water and renewable electrical energy are also required.

Here, the catalytic production processes of the main e-fuels will be briefly examined together with the limiting factors that may hamper their diffusion and the environmental benefits associated with their use.

References:

[1] International Energy Agency, *Net Zero Roadmap. A Global Pathway to Keep 1.5°C Goal in Reach*, Sept. 2023
[2] International Energy Agency, *CO_2 Emissions in 2022*, March 2023.

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KN-062

Ziegler Natta Catalysts & Polypropylene : 70 years of continuous advancement

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Since the discovery in 1953 in Mulheim by Prof. Karl Ziegler of the polymerization of ethylene catalyzed by transition metals and then the following year by Prof. Giulio Natta (11 march 1954),who demonstrated that the same catalyst could produce isotactic polypropylene, the development of Ziegler Natta catalysts evolved rapidly.

Together with technologies development focused on more efficient processes and driven by market products requirements, the development of catalytic systems used for the industrial production of polypropylene since the discovery of Giulio Natta passed through important milestones from first generation catalysts ($TiCl_3$ based) to more advanced catalytic systems based on $MgCl_2$ combined with different classes of internal donors as Phthalates (IV generation catalyst) and more recently also Diethers and Succinates (V generation catalyst).

These new donors classes contributed significantly to polymerization processes improvements and to introduction into markets of innovative polymeric compounds; and the journey is not over…

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KN-063

Finding Common Ground: A Modest Proposal for Effective Chemistry Communication Beyond Chemophilia and Chemophobia

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In modern technological societies, followers of chemtrail conspiracy theories and science enthusiasts coexist, for the most part, peacefully. On one side, an irrational and disproportionate fear or apprehension surrounding chemistry applications in everyday life is a constant presence in society. This at times escalates to the highest levels where political decisions are made, thereby exacerbating misconceptions about chemistry and its implications[1]. Chemophobia stems from a variety of events, some of which trace back to domestic[2] or international[3] industrial disasters rather than inherent aspects of chemistry. These incidents provoked a collapse of trust towards a fundamental science like chemistry within segments of the population. Conversely, many of us have witnessed the enthusiastic engagement of students, educators, and the general public in outreach events such as the European Researchers' Night. These events showcase the breadth of science and its tangible effects on people's everyday lives in engaging and inspiring ways[4], contributing to the gradual rebuilding of trust that has faded over recent decades. Yet, these events or how media are engaged with representation of science can generate bombastic and unwarranted optimism among the public or stakeholders, who may believe that a solution is imminent or that a problem has been effectively resolved[5].

The communication approach frequently contributes to polarization in discussions, creating the perception of two major opposing factions. However, within the spectrum spanning from followers of chemtrail conspiracy theories to fervent science enthusiasts, lies a significant portion of the public encompassing a broad spectrum of individuals. It is within this demographic that our interaction is most crucial. Our aim is to emphasize to our audience that chemistry represents the science of progress, acknowledging both its achievements and the inherent risks and failures like any in all human endeavors. We advocate for an intellectually honest approach that steers clear of pushing people from chemophilia to chemophobia.

[1] Donato Boscia, Maria Saponari, *Xylella fastidiosa: un batterio venuto da lontano*. **Sapere 87**(4), 2021
[2] F. Cosi, A. Repossi, S. Antonellini, *Il caso Seveso. Era un caldo sabato di luglio*. Becco Giallo, 2016.
[3] V. R. Dhara & R. Dhara *The Union Carbide Disaster in Bhopal: A Review of Health Effects*, Archives of Environmental Health: An International Journal, 57:5, 391-404, 2002; Alan Taylor, *Bhopal: The World's Worst Industrial Disaster, 30 Years Later*. **The Atlantic.** https://www.theatlantic.com/photo/2014/12/bhopal-the-worlds-worst-industrial-disaster-30-years-later/100864/ .
[4] **European Researchers' Night**. https://marie-sklodowska-curie-actions.ec.europa.eu/calls/european-researchers-night-and-researchers-at-schools-2024-2025 .
[5] A. L'Astorina. La comunicazione della scienza nel mondo dell'incertezza **Sapere 88**(5), 2022

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KN-064

Metaversity, a place where Education, Communication, and Outreach are innovative

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We are witnessing a new revolution in computing thanks to the virtual technologies of the Metaverse. The idea of developing virtual or augmented reality systems for use in scientific and educational fields is not new as it was born a few years after the introduction of the first computers but was also inaccessible until a few years ago due to the high cost of the technology. The immense power of PCs and all communication systems, including the latest smartphones, combined with recent advances in information technology and the ability to operate in a virtual environment, has made the metaverse widely accessible even on mobile devices. And so, we are witnessing a rapid development of virtual reality (VR) and augmented reality (AR), opening up scenarios and new potential in all sectors. The novelty of virtual reality can engage and motivate students more than current teaching approaches and can therefore have a high motivational impact on learning. Like all new technologies, this approach is also extremely useful in the training field, where it is already enjoying enormous success, especially in the academic field. For this reason, the term "Metaversity" was coined, i.e. an academic world where the transmission of knowledge passes from the teacher to the student using innovative methodologies for learning conveyed by digital platforms. In this communication, various scientific-educational approaches will be presented based on both augmented reality and virtual reality, with the aid of smartphones, pads, and dedicated viewers, to experience the virtual world of Metaversity.

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KN-065

The Virtual Laboratory Framework: Blending Computation, Representation and Visualization from Quantum Chemistry, through Machine-Learning, to Virtual Reality

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The field of Computational Chemistry demands care not only for the modeling of chemical systems but also for intricate technical aspects; from creating complex inputs files, through submitting computations, to interpreting numerical results. Amidst this complexity, the chemical insight into phenomena becomes obscured[1]. Notably, this challenge extends beyond researchers; it impacts the access to such computational tools in science education and teaching. In this context, the Virtual Laboratory[2,3] emerges as a transformative framework. It seamlessly combines the three critical steps of a computational workflow: computation, representation, and visualization. The goal is to create a user-friendly experience for both researchers and the general audience, allowing even non-experts to easily perform simple computational chemistry tasks. From the computational point of view, recent advancements in quantum software and processors, including novel ARM architectures[4], have ushered in a new era of computational power. Moreover, the boom in cloud computing and web-technologies[5] facilitates complex quantum simulations, transcending the limitations of traditional workstations. From the representation point of view, the explosive growth of Machine Learning empowers data extraction from raw inputs. This means automating the extraction of critical information, guiding scientists (and even non-experts) toward essential patterns in data that might otherwise remain elusive. From the visualization point of view, the market has witnessed an unprecedented surge in GPU capabilities, enabling intricate molecular representations. Beyond smartphones, new platforms like Meta Quest and Apple Vision Pro have democratized access to augmented and virtual reality. These immersive environments redefine how we perceive and interact with scientific data. The following contribution explores how Web technologies allow the use of Molecular Perception[6] and ML algorithms in Immersive Virtual Reality contexts, both for research and education. The case studies considered are an Interactive Molecular Editor and two computational tools (The BPCS1[7] and the Templating Synthon Approach[8]).

References:

[1] U. Raucci et al., Annual Review of Physical Chemistry 2023, 74, 313 – 336.
[2] A. Salvadori et al., Journal of Computational Chemistry 2018, 39, 2607 – 2617.
[3] M. Martino et al., Journal of Computational Chemistry 2020, 41, 1310 – 1323.
[4] D. Yokoyama et al., The Journal of Supercomputing 2019, 75, 7003 – 7036.
[5] W. Polik et al., Wiley Interdisciplinary Reviews: Computational Molecular Science 2022, 12, e1554.
[6] F. Lazzari et al., Journal of Chemical Information and Modeling 2020, 60, 2668 – 2672.
[7] V. Barone et al., The Journal of Physical Chemistry A 2023, 49, 10517 – 10527.
[8] F. Lazzari et al., The Journal of Physical Chemistry A 2024, 128, 1385 – 1395.

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KN-066

Chemistry and Complexity Science allied together for a better future

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In the last forty years, humanity has changed radically. The world population has grown over 8 billion in number. Humans are highly interconnected due to the fast means of transport and the World Wide Web. Individuals and societies, their thoughts and cultures are highly intertwined, as the national politics and economies are. In a nutshell, humanity has become a vast network. A problem in a community or a sector regards directly or indirectly everyone on Earth. Any local accident or issue can have global repercussions. Therefore, we are called to face global challenges. It is compelling to prepare new generations to tackle the global challenges of this new century. A paradigm shift in education is required. It is urgent to propose interdisciplinary courses[1]. In these courses, Complexity Science plays a relevant role.[2] Complexity Science is an "in-fieri" scientific theory that describes Complex Systems' features involved in global challenges[3-5]. Students learning Complexity Science discover that systems as diverse as ecosystems, the macroeconomy, cells, chemical reactions, climate, and societies have many common points. Furthermore, they learn that science faces substantial limitations in predicting the behaviours of complex systems. Students understand the reasons for these limitations and become acquainted with strategies to tackle them.

This contribution demonstrates that chemistry students should learn Complexity Science to achieve an interdisciplinary perspective on Complex Systems and systems thinking and promote sustainability. Such an approach favours the development of the "one-world chemistry" concept[6], according to which chemistry plays a pivotal role in the health of human beings, animals, and the environment.

References:

[1] E. Morin, The seven-knowledge necessary to the education of the future. 2001, New Vision, Bueno Aires.
[2] P. L. Gentili, J Chem Educ 2019, 96, 2704–2709.
[3] P.L. Gentili, Untangling complex systems: a grand challenge for science. 2018, CRC Press, Boca Raton.
[4] P.L. Gentili, Rend. Fis. Acc. Lincei 2021, 32, 117–134.
[5] P. L. Gentili, Int. Journ. Unconventional Computing 2023, 18, 291-304.
[6] P.G. Mahaffy, S.A. Matlin, J.M. Whalen, T.A. Holme, J. Chem. Edu. 2019, 96, 2730-2741.

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KN-067

Communicating Science. A creative and ethical challenge

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The secret of good communication lies in the ability to ignite a spark capable of stimulating the listener's curiosity. Researchers, however, usually tend to speak to colleagues or students, and rarely have a chance to develop the communication skills necessary to talk to and engage a lay public. This talk will provide participants with a simple toolbox of creative and reasoning tools that are essential in order to improve their ability to express themselves in an ethical and easily understandable way.

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KN-068

Stranger Molecules: chemistry becomes art

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Chemistry's beauty lies in our ability to handle and assemble atoms and molecules, which can take on strange and twisted shapes: since in every molecule there always is a shape-property relationship, as chemists we are obsessed with three-dimensional structures of our creations. Each of us wants to put atoms in the right position to obtain the desired properties. This is an utilitarian mindset, typical of applied research and of technological transfer. There is also an opposite, funnier and stimulating approach: a chemist can think of a design, recreate it at molecular level by joining various atoms together and afterwards investigate the properties of the substance. Chemistry thus becomes a form of art that embraces beauty without worrying about possible applications[1]. We have chosen 3 molecules with a strange structure, inspired by mathematics and engineering: Infinitene[2], Cubane[3], Nano-Cars[4]. We will tell their stories to show how there is no uselessness in scientific research and that even molecules created for fun are a fundamental piece in construction of the jigsaw of knowledge.

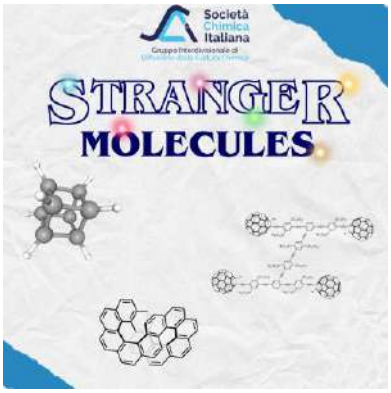

Figure 1: Cubane, Infinitene and Nano-Cars are the main characters of the lecture.

References:

[1] O. Bettucci, R. Lucentini, *La nanobellezza: la chimica che diventa arte* Sapere **89**(2), 2023
[2] M. Krzeszewski, H. Ito, K. Itami*, J. Am. Chem. Soc. 2022, 144, 2, 862–871
[3] B.A. Chalmers et al, Angew. Chem. Int. Ed. 2016, 55, 3580
[4] Y. Shirai, A. J. Osgood, Y. Zhao, K. F. Kelly, J. M. Tour Nano Lett. 2005, 5, 11, 2330–2334

KN-069

"It's not just a matter of Science!" Tips and clues from the acting world to improve your communication skills

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Our first aim as scientists is definitely to carry out meticulous and challenging research, as much as possible. Anyway, even the best research work could not spark interest in the audience of conferences, meetings, and public speeches if the communication is not incisive. Today, communication is everything: while, in the last century, scientists could peacefully work in their labs without any contact with the outside world, today society rightly requires us to be more transparent, social, and engaging. Moreover, the dissemination activity of a scientist is often a matter of judgment by boards and committees for the evaluation of possible work candidates and the funding of projects. For these reasons, delivering a presentation cannot be limited to a mere assembly of slides and graphs, accompanied by an incoherent speech.

During this talk, we will explore the logical process behind the preparation of a presentation and learn how to answer these simple questions:

1. What is the message? Which story would I like to tell?
2. Who is my audience?
3. Which communication skills should I implement in my talk to deliver the message effectively?

Finally, we will dive into some techniques borrowed from the acting world that can help us make our communication engaging and increase awareness and control of our body and voice.

KN-070

Chemistry, a good choice

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There is a very special link between School and Chemistry that must commit the two worlds to a continuous dialogue and common activities.

People are the hearth of the chemical companies; this involves continuous relationships with the education providers in order to have – quantitatively and qualitatively – well-trained young people who are aware of job opportunities.

These activities have always been important in medium-large companies and, in recent years, they have also spread to smaller companies with an increasingly high level of interaction with the territory, and in particular with technical high schools, but there is still a lot of work to do.

For this reason, Federchimica, for over 15 years, has been actively collaborating with the National Plan for Scientific Degrees, with the Italian Chemical Society and, more recently, also with ConChimica, the conference of Coordinators of Degree Courses in Chemistry with the aim of helping young people in orientation and in the implementation of their skills.

Federchimica's activities have four different targets: Primary School, Lower Secondary School, Upper Secondary School, University.

KN-071

But is chemistry just bad? A journey into the marvelous world of cinema, from Breaking Bad to Railway Men

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The 20th century is today certainly considered the most important period for the scientific and technological development of the planet, a development that has significantly influenced our lives: it has enriched us with energy, food and new materials, it has made us feel better but also produced major environmental disasters and climate change. Even cinema, born as a scientific invention, has often used science in its stories, even unconsciously, traveling from the science fiction of 2001: A Space Odyssey to Erin Brockovich's chromium pollution, description of pollution, from the search for a cure for 'Lorenzo's oil with Madame Curie's radioactivity (Fig. 1).

Unfortunately, chemistry is often represented as bad and negative; it would seem only useful to produce drugs or generate environmental disasters, it can be used to manufacture nuclear weapons or to poison people. Chemistry professors are often portrayed as crazy or as inventors of impossible things. It is certainly time to change this opinion and present it differently not only to the general TV audience but also on the big screens, showing how chemistry is instead a science that manages to provide us with solutions, to make us feel better, to make us progress.

Fig. 1. Madame Curie Movie (1943) - Greer Garson, Walter Pidgeon, Henry Travers

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Unveiling the Dual Genius of Aleksandr Porfir'evič Borodin: Between Chemistry and Music

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Aleksandr Porfir'evič Borodin (Алекса́ндр Порфи́рьевич Бороди́н, 1833-1887) serves as a remarkable example of interdisciplinary mastery, making seminal contributions to both sciences and music. As a well-known Russian composer and chemist, Borodin's life and work epitomize the synthesis of scientific rigor with artistic expression. The presentation will cover Borodin's dual legacy, illuminating his contributions to organic chemistry and classical music, ultimately enriching his work in both domains[1,2].

In the realm of chemistry, Borodin was a respected scientist, primarily focusing on aldehydes. He became a prominent researcher in the mid-19th century and made notable contributions to the field through his work on the Aldol reaction. His method became crucial for forming carbon-carbon bonds in organic synthesis. Borodin's research provided foundational knowledge that spurred to further developments in organic synthesis and facilitated the advancement of various chemical industries[1,2].

Nowadays, Borodin is better known for his work as a composer. He achieved considerable acclaim as a member of the Russian composer's group named *Moguchaya kuchka*, led by M.A. Balakirev, also known as the *Mighty Handful* or *The Five*[3]. His extensive research on national identity went beyond arranging folklore and liturgical songs and also extended to other aspects of musical language such as harmony, rhythm and texture, as well as drama and genre.

Among his most celebrated works, the opera *Prince Igor* stands out, particularly known for its *Polovtsian Dances,* which vividly embody Borodin's knack for crafting evocative melodies and harmonies. Moreover, his symphonic works, including *Symphony No. 2 in B minor*, reveal his adeptness at large-scale orchestral composition, infused with lush harmonic language and rhythmic vitality[4]. Some other examples of his relevant works are the symphonic poem *In the Steppes of Central Asia* and the *Petite Suite* for piano.

A special focus will be made on Borodin's piano production. A related video-performance by Alessia Benedetti featuring *2 Polovtsian Dances* from *Prince Igor* by Alexander Borodin (F. Blumenfield) will be shown.

References:

[1] F.H. Getman, J. Chem. Educ. 1931, 8, 1762–1781.
[2] H.M. Leicester, J. Chem. Educ. 1940, 17, 303–306.
[3] E. Garden, Music and Letters 1969, L, 153–157.
[4] E. Levašëv, A. Alberti, Il Saggiatore musicale 1998, 5, 69–92.

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KN-073

Bottom-up machine-learning for chemical modeling

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Machine-learning techniques are often used in cheminformatics to perform "end-to-end" predictions, making black-box estimates of a property of interest using only a coarse description of the corresponding inputs. In contrast, atomic-scale modeling of matter is most useful when it allows to gather a mechanistic insight into the microscopic processes that underlie the behavior of molecules and materials.

In this talk I will provide an overview of the progress that has been made combining these two philosophies, using data-driven techniques to build surrogate models of the quantum mechanical behavior of atoms, enabling "bottom-up" simulations that reveal the behavior of matter in realistic conditions with uncompromising accuracy [1-2]. I will present several examples demonstrating how the combination of machine-learning and atomistic simulations can offer useful insights on the behavior of complex systems, from molecules [3] to condensed-matter systems [4], and from high-entropy alloy catalysts [5] to matter in astrophysical conditions [6]. I will discuss the challenges and a few solutions to develop an integrated modeling framework in which physics-driven and data-driven steps are combined to improve the accuracy, the computational efficiency and the transferability of predictions, from interatomic potentials to electronic-structure properties.

References:

[1] F. Musil, A. Grisafi, A. P. Bartók, C. Ortner, G. Csányi, and M. Ceriotti, "Physics-Inspired Structural Representations for Molecules and Materials," Chem. Rev. 121(16), 9759–9815 (2021).

[2] M. Ceriotti, "Beyond potentials: Integrated machine learning models for materials," MRS Bulletin 47(10), 1045–1053 (2022).

[3] J. Nigam, M. J. Willatt, and M. Ceriotti, "Equivariant representations for molecular Hamiltonians and N -center atomic-scale properties," J. Chem. Phys. 156(1), 014115 (2022).

[4] L. Gigli, M. Veit, M. Kotiuga, G. Pizzi, N. Marzari, and M. Ceriotti, "Thermodynamics and dielectric response of BaTiO3 by data-driven modeling," npj Comput Mater 8(1), 209 (2022).

[5] N. Lopanitsyna, G. Fraux, M. A. Springer, S. De, and M. Ceriotti, "Modeling high-entropy transition metal alloys with alchemical compression," Phys. Rev. Materials 7(4), 045802 (2023).

[6] C. Ben Mahmoud, F. Grasselli, and M. Ceriotti, "Predicting hot-electron free energies from ground-state data," Phys. Rev. B 106(12), L121116 (2022).

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KN-074

Enhancing Atomistic Simulations of Oxide Glasses through the Power of Machine Learning

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Multicomponent oxide glasses, omnipresent in daily life and high-tech applications, conceal intricate structure-property relationships that challenge traditional experimental investigations. Computational simulations, notably Molecular Dynamics (MD), have emerged as powerful tools for deciphering glass structures. Yet, the trade-off between accuracy and computational efficiency remains a hurdle. Quantum mechanics, specifically Density Functional Theory (DFT), offers pinpoint precision but is computationally prohibitive for larger systems.

This keynote explores a transformative approach, leveraging Machine Learning (ML) to revolutionize atomistic simulations of oxide glasses. The talk unveils recent advancements in our research group, demonstrating how ML techniques optimize empirical force-field parameters,[1] develop direct ML potentials,[2] and predict NMR shielding with DFT accuracy.[3] By training ML models on precise DFT data for smaller systems, we transcend computational constraints, enabling accurate simulations of larger, more complex oxide glass structures.

Join this journey through the fusion of quantum mechanics and ML, unlocking the potential to decode the enigmatic world of multicomponent oxide glasses and propel materials science into a new era of discovery.

References:

[1] M. Bertani et al. J. Am. Ceram. Soc. 2022, 105, 7254-7271.
[2] M. Bertani et al. J. Chem. Theory Comput. 2024 20, 1358-1370.
[3] M. Bertani et al. ChemPhysChem. Submitted

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KN-075

From molecular modeling to data science: shaping computer-aided drug design for new therapeutic strategies

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Computer-aided drug design (CADD) has emerged as a powerful tool in therapeutic development. CADD methodologies assist the drug discovery pipeline across various stages, significantly reducing both time and costs. With the rapid progress in high-performance computational resources and the introduction of novel *in silico* approaches, the efficiency of CADD has notably improved. Recent advancements in CADD are enriched with different sets of computational methods encompassing physics-based modeling and emerging artificial intelligence and machine learning (AI/ML) technologies[1]. In this presentation I will illustrate how atomic-level simulations have contributed to identification of new drug candidates against diseases with high socio-economic impact, such as cancer, immune system disorders and senescent cell-related pathologies. Combining ligand-based and structure-based virtual screening we discovered new NEK6 kinase inhibitors useful for the treatment of solid tumours[2]. Protein-protein interaction modeling led to the identification of selective inhibitors of the TCR/antigen−MHC complex for the treatment of rheumatoid arthritis[3]. Pharmacophore modeling revealed novel HSP90 inhibitors with senolytic activity[4]. I will also show that ML/AI-powered screens can narrow the chemical space and find applications in drug repositioning for COVID-19[5] and in structural characterization of therapeutic targets[6].

References:

[1] A.V. Sadybekov, V. Katritch, Nature 2023, 616, 673–685.
[2] M. De Donato, B. Righino, F. Filippetti, A. Battaglia, M. Petrillo, D. Pirolli, G. Scambia, M.C. De Rosa, D. Gallo, Sci Rep 2018, 8, 16047. Patent WO2019193494A1.
[3] F. Ria, D. Pirolli, G. Di Sante, B. Righino, E. Gremese, J. Gervasoni, C. Nicolò, B. Giardina, G. Ferraccioli, M.C. De Rosa, ACS Med Chem Lett 2019, 10, 644-649. Patent WO2013144931A2.
[4] C. Gaetano, S. Atlante, M.C. De Rosa, D. Pirolli, A. Farsetti, M. Malavolta. Patent WO2023135532A1 and WO2023135533A1.
[5] D. Pirolli, B. Righino, C. Camponeschi, F. Ria, G. Di Sante, M.C. De Rosa, Sci Rep 2023,13, 1494.
[6] C. Camponeschi, B. Righino, D. Pirolli, A. Semeraro, F. Ria, M.C. De Rosa, Biomolecules 2023, 13,1047.

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KN-076

Unravelling the molecular aspects of catalysts under operando conditions combining simulations and machine learning

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Catalysis represents one of the most powerful technologies of our time but it is often not completely understood at the molecular level. Molecular simulations offer a potent means to explore these processes. However, simulating catalytic events presents its own set of obstacles: first of all the slow activation kinetics of these processes, subsequently an accurate description of the chemical bond-breaking and formation necessitates the use of computationally expensive ab initio potentials. Furthermore, the structural complexity of catalytic systems under operando conditions can complicate simulation analysis. To address these challenges, a synergistic approach combining enhanced sampling techniques and modern machine learning methodologies emerges as particularly promising. Enhanced sampling with machine learning approximates reaction coordinates for precise catalytic event characterization. Machine learning extends simulation times at costs akin to classical force fields. Tailored data science methods clarify complex simulation results, enhancing catalytic understanding.

Here, we focus on the development and application of such integrated approaches to investigate catalysis within confined environments involving water. Traditionally, such systems present computational challenges, as static ab initio calculations fail to capture the dynamic and statistical properties inherent to operando conditions. Our results center on two seemingly disparate systems— the conversion of aqueous biomass organic compounds within industrial zeolites, and the synthesis of fine organic compounds within hexameric calixarene capsules—revealing underlying similarities and shedding light on their respective catalytic mechanisms. The results demonstrate how leveraging these simulation technologies facilitates a deeper understanding of experimental evidence and promotes the design of materials through computational approaches.

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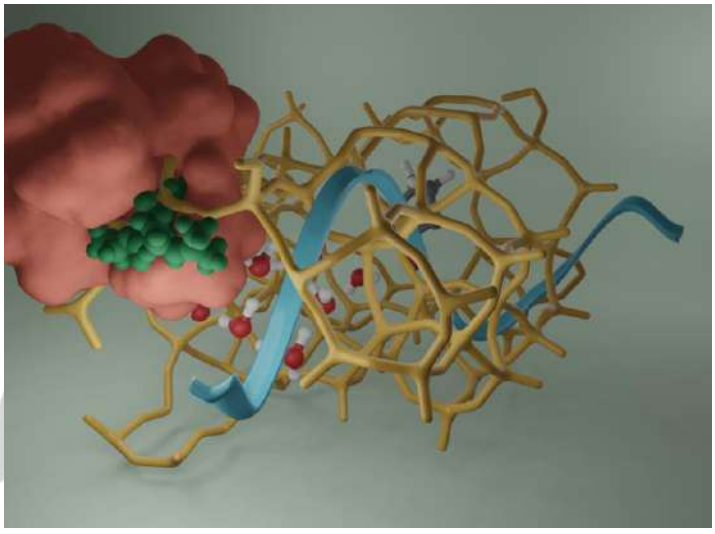

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KN-077

The Hidden Dynamics of Metals: A Deep Dive Fueled by ML

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In this contribution, we explore the dynamic nature of metal nanoparticles (NPs) and surfaces through an advanced analysis integrating machine learning (ML) with molecular dynamics simulations, shedding light on the complexities of atomic movements that dictate material properties.

Motivated by the need to understand how atomic dynamics influence the behavior of metals in applications ranging from catalysis, to nanoelectronics and biomedicine, our approach utilizes advanced descriptors, including the Smooth Overlap of Atomic Positions (SOAP), its temporal variant TimeSOAP (τSOAP),[1] and the Local Environments and Neighbors Shuffling (LENS) framework.[2] These methodologies, applied to high-dimensional data from molecular dynamics simulations, enable the precise characterization of atomic environments, identifying dynamic domains and shedding light on the "statistical identities" of metals.

Our findings reveal the inherent dynamics of atoms within gold nanoparticles[3,4] and copper surfaces,[5] challenging traditional perceptions of metals as rigid, unchanging materials. By leveraging ML, we discern the complex interplay of atomic environments, crucial for understanding metal NPs and surfaces' behaviors and even responses to stress-strain scenarios, such as dislocation and fracture. By integrating experimental techniques, such as annular dark-field scanning transmission electron microscopy (ADF-STEM) with advanced computational methods, we overcome the limitations of traditional experimental and simulation methods to provide a novel lens through which the atomic-scale dynamics of metals can be examined.[4]

Ultimately, this exploration into the dynamic atomic landscape of metals not only challenges conventional understanding but also underscores its critical importance for technological applications and material science innovation. Our findings illuminate the fundamental role of atomic dynamics in defining the properties of metals, paving the way for future material science innovations.

References:

[1] C. Caruso, A. Cardellini, M. Crippa, D. Rapetti, G. M. Pavan, J. Chem. Phys. 2023, 158, 214302
[2] M. Crippa, A. Cardellini, C. Caruso, G. M. Pavan, Proc. Natl. Acad. Sci. USA 2023, 120, e2300565120
[3] D. Rapetti, M. Delle Piane, M. Cioni, D. Polino, R. Ferrando, G. M. Pavan, Commun. Chem. 2023, 6, 143
[4] M. Cioni, M. Delle Piane, D. Polino, D. Rapetti, M. Crippa, E. Arslan Irmak, S. Van Aert, S. Bals, G. M. Pavan, Adv. Science, DOI: https://doi.org/10.1002/advs.202307261
[5] M. Cioni, D. Polino, D. Rapetti, L. Pesce, M. Delle Piane, G. M. Pavan, J. Chem Phys. 2023, 158, 124701

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KN-078

Quantum crystallography and quantum computing

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Quantum crystallography[1,2] is a discipline that combines experimental information from measurements on crystals (mainly X-ray diffraction) and quantum theory. The two fields have been tightly connected since the very beginning because X-ray scattering has been often considered as the best experimental tool to visualize the distribution of electrons in atoms and molecules. On the other side, the theoretically calculated wavefunctions enable an accurate prediction of atomic and molecular scattering factors to use in modelling of crystal structures and their corresponding electron densities.

In quantum crystallography, the most typical modelling technique is that of the X-ray restrained wavefunction calculation, which enables one to calculate a wavefunction of a system restrained to the measured X-ray diffraction intensities.[3] Similarly, refinements of first order density matrices elements is possible by combining elastic (Bragg) scattering/diffraction with inelastic (Compton) scattering.[4]

The disruptive advent of quantum computing may stimulate significant progresses in this field, especially because of the possibility to determine correlated wavefunctions with the quantum information techniques. The density matrices approach could also benefit from quantum computing. The implications of quantum computing for crystallography may be many others and will be discussed during this perspective lecture.

References:

[1] P. Macchi, Quantum crystallography: expectations vs. reality, Springer, 2022.
[2] P. Macchi, Cryst. Rev., 2020, 26, 209-268.
[3] D. Jayatilaka, Phys Rev Lett. 1998, 80, 798–801.
[4] B. De Bruyne, J. M. Gillet, Acta Cryst. 2020, A76, 1–6.

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KN-079

Role of computational methods in the era of precision medicine

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Computational drug discovery has become an increasingly important tool in the search for new drugs to treat a wide range of diseases. One of the critical challenges in this field is simulating the complex behavior of biomolecules at the atomic level, which can be computationally very expensive and time-consuming. The thermodynamics and kinetics of drug-target binding play a crucial role in understanding and optimizing the interactions between drugs and their target molecules. To address this challenge, molecular dynamics (MD) and related approaches combined with machine learning and artificial intelligence play a crucial role in accelerating the exploration of the conformational space of molecules. These methods also enable researchers to compute the free energy differences between different states of a molecule and estimate thermodynamic and kinetics properties such as binding free energies and residence time. This talk overviews various enhanced sampling methods combined with machine learning in computational drug discovery, as well as their advantages and limitations. The talk focuses on using these methods for free energy and kinetics estimations, reporting on the significant limitations toward accurate estimations for large datasets of compounds. The talk then describes recent applications in drug discovery and discusses the challenges and limitations of these methodologies when applied to biological systems of increasing complexity. In conclusion, the talk illustrates how MD, enhanced sampling methods, and machine learning can improve the efficiency and effectiveness of computational drug discovery and accelerate the development of new therapeutics to treat significant unmet medical needs in the era of precision medicine.

References:

[1] C. Abate, S. Decherchi, A. Cavalli, WIREs: Comp. Mol. Sci. 2023, 13, e1651.
[2] S. Decherchi, A. Cavalli, Chem. Rev. 2020, 120, 12788-12833.
[3] M. Bertazzo, D. Gobbo, S. Decherchi, A. Cavalli, J. Chem. Theory Comput. 2021, 17, 5287-5300.
[4] D. Gobbo, V. Piretti, R.M.C. Di Martino, S.K. Tripathi, B. Giabbai, P. Storici, N. Demitri, S. Girotto, S. Decherchi, A. Cavalli, J. Chem. Theory. Comput. 2019, 13, 4646-4659.
[5] L. Mollica, I. Theret, M. Antoine, F. Perron-Sierra, Y. Charton, J.M. Fourquez, M. Wierzbicki, J.A. Boutin, G. Ferry, S. Decherchi, G. Bottegoni, P. Ducrot, A. Cavalli, J. Med. Chem. 2016, 59, 7167-76.
[6] D. Gobbo, P. Ballone, S. Decherchi, A. Cavalli, J. Chem. Theory Comput. 2020, 16, 4126-4140.

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KN-080

Chemometrics in clinical chemistry: examples of open-source applications for method validation and evaluation of real cases

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In clinical chemistry, the fusion of chemometrics with open-source software is pivotal for ensuring robust and replicable analytical outcomes, particularly in method validation and real-case evaluations. Here, we showcase three compelling instances that underscore the efficacy of open-source applications across diverse clinical and analytical contexts.

(i) We investigated breast cancer detection, where sex hormones in urine are examined as potential biomarkers for early detection. Using supervised data analysis strategies, we conducted a comprehensive study of 250 postmenopausal women, including healthy women and women with breast cancer. Data from the quantified 20 sex hormones were evaluated by a benchmark of machine learning (ML) algorithms, including logistic regression (LR), naive bayes (NB), partial least squares – discriminant analysis (PLS-DA), k-nearest neighbors (kNN), classification and regression trees (CART), support vector machine (SVM), and random forest (RF). Our results demonstrate the superiority of RF in identifying robust biomarkers that achieve a remarkable diagnostic accuracy (i.e., 98% with 5 selected biomarkers).

(ii) Methods Validation App - MVA, an open-source web application crafted in Python, aims to stand as a pinnacle of analytical method validation. It orchestrates an automated workflow tailored for method validation, requiring the preparation of 9 calibration curves derived from triple repetitions across 3 distinct days. Featuring automated and ML tools for assessing the linear dynamic range, limits of detection and quantification (LOD and LOQ), as well as inter-day and intra-day precision and accuracy, sensitivity, specificity, carry-over, matrix effect and uncertainty. MVA ensures meticulous scrutiny of calibration models through *ad hoc* significance tests and streamlines the validation process while upholding the highest standards of precision and reliability.

(iii) SpectrApp is an open-source technology in the field of multivariate data analysis. Designed within the dynamic ecosystem of R Shiny, SpectrApp is meticulously designed for fine-tuning and validating chemometric and ML models. Leveraging its open-source framework, it empowers users to inspect and preprocess the collected data through several techniques and plots, then build exploratory (PCA, cluster analysis, t-SNE, UMAP), class modeling (SIMCA), discrimination (kNN, NB, PLS-DA, SVM), and regression (MLR, PCR, PLS-R) models. The use of user-friendly and open-source interfaces accelerates the analysis and validation process, allowing even non-programming experts to focus on result interpretation.

References:

[1] E.Alladio *et al,* Journal of Pharmaceutical and Biomedical Analysis 2024, 116113.
[2] https://www.spectrapp.unito.it/app/spectrapp
[3] https://methodsvalidation.streamlit.app/

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KN-081

Food toxicology and food bioactives assessment through in silico methods - is AI the new era of testing?

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The use of computational methods in the field of food science traces its origin back to the late 1970s (e.g. ref. [1]). Since then, food science has broadly benefited from using computer-driven approaches either as integrated methods of analysis or stand-alone analytical frameworks to empower the throughput of analysis and to cope with system dimensions otherwise unmanageable. Germane to the chemical safety and bioactivity assessment of food components, computational methods enabled to investigate the multitude of compounds of food origin quantifying their activity and underpinning mechanisms either as single substances or as a part of complex mixtures. In this respect, the integrated use of in silico methods brought a significant breakthrough expanding at a multidimensional level the space under analysis enabling the combined assessment of food components, rather than estimating the outcome as a sum of single contributions. In a more recent time, a consensus was reached on the importance of the "here and now" chemical context to determine the toxicity and bioactivity of food compounds considering that certain toxicants may vary the potency when combined with certain bioactives, and vice versa. Computational methods were gathered in the so defined New Approach Methodologies (NAMs) and made possible the continuum and unbiased analysis of food components avoiding the prejudicial categorization into toxic and beneficial compounds. This was an important step toward the real needs of current chemical risk assessment. In a few years, the progress in terms of hardware and software, along with the growing availability of high-quality data of all kinds, made possible the development of advanced algorithms giving birth to artificial intelligence (AI). Nowadays, AI systems are capable to accomplish tasks which traditionally required human intelligence, including those related to the assessment of chemicals of food origin and associated regulatory science. With respect to the analysis of food components, AI is renegotiating what's ordinary in the chemical risk assessment and either enables to scale at a human level the interpretation of immense vastitudes of data or expands the horizon of analysis. This upcoming scenario may substantially improve the assessment of risk and the consequent decision making in the matter of food safety [2]. This presentation aims at providing a critical sight on the most important improvements potentially brought by AI analysing also the crucial flaws that should be aware of for a proficient use and subsequent improvement of this technologies in the near future.

References:

[1] K. Hayakawa. J Assoc Off Anal Chem. 1977, 60, 1243-1247.
[2] N. Kleinstreuer, T. Hartung. Arch Toxicol. 2024, 98, 735-754.

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KN-082

DEEP LEARNING TO DESIGN NOVEL AND SELECTIVE NKCC1 INHIBITOR CHEMOTYPES FOR THE TREATMENT OF BRAIN DISORDERS WITH DEFECTIVE NKCC1/KCC2 RATIO

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Several clinical and pre-clinical studies have demonstrated that the intracellular Cl^- homeostasis is impaired, and Cl^- transporter cellular expression is dysregulated, in several brain disorders including neurodevelopmental disorders such as Autism Spectrum Disorders (ASD) and Down Syndrome (DS). Interestingly, inhibition of the Cl^- importer NKCC1 by the FDA-approved diuretic bumetanide reverts cognitive deficits in DS mouse models as well as core symptoms (social and repetitive behaviors) in ASD mouse models. However, bumetanide has a strong diuretic effect due to the inhibition of the kidney Cl^- transporter NKCC2, which prevents bumetanide from becoming a sustainable therapy for brain disorders. This evidence opened the way to the development of selective NKCC1 inhibitors as a viable therapeutic strategy for brain disorders characterized by impaired Cl^- homeostasis. In this context, we discovered a novel class of 4-amino-3-sulfamoylbenzoic acids[1,2] that resulted in the development of a drug candidate named IAMA-6, currently in a Phase 1 clinical trial (NCT06300398). On these bases, we have recently discovered novel follow-up compounds with good potency and different chemicophysical properties compared to the current drug candidate IAMA-6. We have employed deep learning-guided enhanced sampling simulations to elucidate the functional cycle of NKCC1 and identify key amino acids responsible for driving ion transport[3]. Subsequently, free energy perturbation calculations were utilized to facilitate the design of new chemical scaffolds. In this way, we experimentally identified new promising hits in a Cl^--influx assay in HEK cells transfected with NKCC1. Iterative medicinal chemistry efforts, guided by computational methods, allowed us to build a robust SAR model and improve the *in vitro* potency, efficacy, and drug-like properties of the initial hits. The chemical expansion of one of the classes of these chemotypes led to compounds with an inhibitory activity *in vitro* comparable to IAMA-6, and a favorable pharmacokinetics (PK) profile *in vivo*. These results further enrich our portfolio of novel and selective NKCC1 drug-like inhibitors, underscoring the efficacy of our computer-aided drug discovery pipeline in advancing new possible treatments for ASD, DS and many other pathologies characterized by defective Cl^- homeostasis.

References:

[1] Borgogno M, Savardi A, Manigrasso J, Turci A, Portioli C, Ottonello G, Bertozzi SM, Armirotti A, Contestabile A, Cancedda L, De Vivo M. J Med Chem. 2021 Jul 22;64(14):10203-10229
[2] Savardi A, Patricelli Malizia A, De Vivo M, Cancedda L, Borgogno M. ACS Pharmacol Transl Sci. 2023 Jan 4;6(1):1-11.
[3] Ruiz Munevar M J, Rizzi V, Portioli C, Vidossich P, Cao E, Parrinello M, Cancedda L, & De Vivo M. J. Am. Chem. Soc. 2023 Dec 26;146(1):552–566.

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KN-083

Sustainability in the chemical industry: a 100-year history

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Since the 1980s, the chemical industry has promoted improvements in chemical processes, aimed at obtaining technologies that are more environmentally friendly, as well as economically advantageous. The strategies adopted were different, also starting from the awareness of the damages caused during the period of great post-war economic development; from the modification of the synthetic route, often made possible by the discovery of innovative catalysts, to the use of less dangerous reagents, to the replacement of molecules harmful to health, to process modifications aimed at achieving energy savings. By retracing the history of the chemical industry, both at a national level and in a more international context, and going even further back in time, it is possible to find chemical processes that, even if unconsciously, anticipated the rules of Green and Sustainable Chemistry and Engineering. For example, multi-stage chemo- catalytic processes for the valorization of platform molecules from renewable raw materials; technologies that public research and research in the chemical industry today try to replicate, by virtue of the significant improvements potentially achievable in terms of sustainability. Some examples will therefore be illustrated, to demonstrate on the one hand the considerable progress made in this area by the chemical industry, and on the other how the latter has long since indicated the path to achieving important results in the field of the bioeconomy and clean processes.

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KN-084

The role of catalysis and novel technologies for the definition of modern green chemistry

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Our research group has been contributing to the shaping and development of what is named today green chemistry.

Starting from the Pollution Prevention Act[1] the attention of chemists has been dedicated to the "millions of tons of pollution" and the related cost of "tens of billions of dollars per year".

Accordingly, our approach to modern green chemistry is focused on the general idea that green/efficient processes are those designed to minimize the waste by the rational combination of different technologies and the use of specific metrics needed to quantify the advance in terms of sustainability.

Our research program is mainly committed to the definition of efficient and sustainable synthetic tools by combining the development of several crucial areas of investigation: i) use of safer reaction media, ii) preparation and use of nanostructured heterogeneous and reusable catalytic systems; iii) definition of continuous-flow reactors allowing a minimal waste production and high productivity; iv) applications of metrics and LCA to assess the overall sustainability of the results.[1]

Among the different projects, we are currently dedicated attention to the valorisation of waste for the preparation of recoverable catalytic systems and electrodes to define efficient protocols based on the use of continuous-flow reactors and electrochemistry.

In this contribution it will be presented an overview of our vision and ongoing research in the field.

References:

[1] Some recent examples L. Vaccaro et al: *Chem. Sci.* **2024**, *15*, 3831-3871; *Green Chem,* **2024***, 26,* 4871-4879; *Green Chem*, **2024**, in press, DOI: 10.1039/D4GC00830H; *Green Chem*, **2024**, in press DOI:10.1039/D4GC00699B, hot article and invited front cover; *Green Chem*, **2024**, in press, DOI: 10.1039/D4GC00930D; *ACS Sus Chem. Eng.* **2024**, in press, doi.org/10.1021/acssuschemeng.4c02486.

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KN-085

The intertwined fate of biomass and plastics in the green revolution: from fundamentals to chemical technologies for the circular economy

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Green chemistry, as a transformative research field, has made significant strides in developing high-value products through sustainable practices. This field distinctively utilizes renewable resources, such as various lignocellulosic biomasses, and repurposes waste materials, including plastics.[1,2]

The innovative approach of green chemistry lies in identifying underlying similarities between seemingly distinct materials. Indeed, biomass and plastics, although different in origin, share notable structural similarities, especially in their polymer makeup and bond types. Consequently, in recent years, biomass and plastics have developed conversion pathways that have begun to intersect, thereby influencing each other.[3]

This contribution presents a 'unified view' to examine the chemical principles underlying the conversion processes of both biomass and plastics. In areas where biomass valorization has significantly advanced, abundant prospects exist for upcycling waste plastics using analogous methods, and vice versa. Specifically, the chemical mechanisms underlying the cleavage of C-C and C-O bonds in lignocellulosic biomass, and C-C bonds in polyolefins, will be presented. The knowledge gained from lignocellulose conversion, particularly in the cleavage of C_{arom}-C and ether bonds, can be applied to the upcycling of plastics, notably in the production of aromatic compounds. Moreover, even with the inert Caliph-C bond in polyolefins, innovative strategies, such as reductive-assisted depolymerization, have emerged, offering new pathways for biomass transformation. Within these areas of research, the gap between theory and practice will be presented highlighting scientific challenges that have been adequately addressed, and those that are underexplored or yet to be tackled.

Understanding the fundamental chemistry behind these transformations will be crucial in advancing conversion technologies that will align with national and European goals for ecological transitions and the green revolution. Therefore, the ultimate goal of this contribution is to illustrate how fundamental chemical knowledge can drive technological innovations and contribute to a sustainable future.

References:

[1] A. J. Martín, C. Mondelli, S. D. Jaydev, J. Pérez-Ramírez, Chem 2021, 7, 1487–1533.
[2] K. Lee, Y. Jing, Y. Wang, N. Yan, Nature Reviews Chemistry 2022, 6, 635–652.
[3] P. Gallezot, ChemSusChem 2008, 1, 734–737.

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KN-086

From research lab to industry embracing circular economy and green chemistry: the real-life case of *ISusChem Srl*

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The intensive consumption of raw materials and the resulting environmental impact highlight the urgency to move from a linear to a circular economy. Within this change, the choice of feedstocks is a key point, and biomass exploitation needs to be preferred. Among raw materials, waste and non-food vegetable oils are valuable replacements for aliphatic fossil feedstocks, and are prone to chemical modifications through the reactivity of carboxyl groups and double-bond moieties. Nevertheless, the used process needs to be sustainable and coherent with the green chemistry principles. Starting from the background experience on vegetable oils transformations, Metor+ and Nicle research groups at the University of Naples Federico II first came across unexpected solubility properties of some fatty acid esters suitable to prepare offset printing varnishes,[1] and then developed a fatty acid esterification based on a fully recyclable Zn(II) catalyst.[2] Trying to put out the acquired know-how from university labs into the real industrial world, in 2018 the innovative startup ISusChem Srl was founded. To date, ISusChem Srl is an university spin-off at the University of Naples Federico II, and thanks to the Italian public founding Smart & Start, in 2022 a pilot plant was settled in Marcianise (CA), which started producing esters by September 2023. In this talk, the real case of the start-up ISusChem Srl will be illustrated, from ideas to actions, from obstacles to facilitations, and all the steps that we had to face and still face to keep our ideas real.

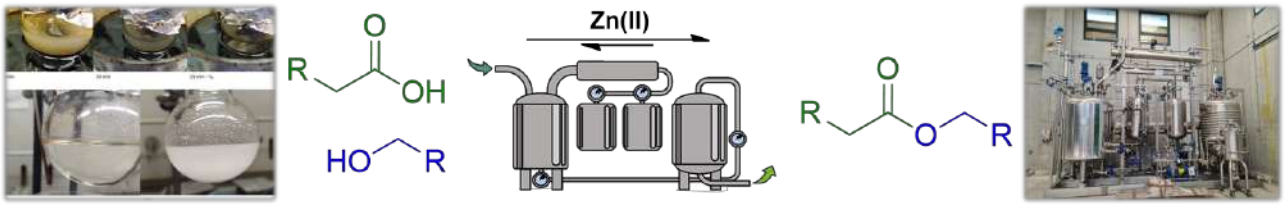

Figure 1: from lab to plant ISusChem esterification process.

References:

[1] V. Benessere, M. E. Cucciolito, A. De Santis, M. Di Serio, R. Esposito, M. Melchiorre, F. Nugnes, L. Paduano, F. Ruffo, J Am Oil Chem Soc 2019, 96, 443 – 451.

[2] a) M. Melchiorre, M. E. Cucciolito, M. Di Serio, F. Ruffo, O. Tarallo, M. Trifuoggi, R. Esposito, ACS Sus Chem Eng 2021, 9, 6001 – 6011; b) V. Benessere, M. E. Cucciolito, , M. Di Serio, R. Esposito, M. Melchiorre, F. Ruffo, 2021, EP4093841B1, European Patent Office.

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KN-087

Developing complementary technologies and skills for the green transition: from the fundamentals of ecocompatible solvents in liquid chromatography to process intensification in (bio-pharmaceutical) industry

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Reversed-phase liquid chromatography (RPLC) stands as the predominant analytical technique in the (bio)pharmaceutical industry. It finds extensive application not only for analytical tasks like quality assessment of bulk drugs and formulations but also for preparative purposes in industrial settings, facilitating the extraction of highly pure target (bio)pharmaceutical compounds. Acetonitrile emerges as the most commonly utilized organic modifier in RPLC owing to its chemico-physical attributes, including strong elution power, UV transparency, excellent water miscibility, and low viscosity. Nonetheless, it is important to note that acetonitrile carries a slight toxicity risk upon acute exposure through ingestion, skin contact, or inhalation, and can potentially be metabolized by the body into cyanide.

In the past year, there has been a growing focus on the adoption of environmentally friendly analytical methods in the pharmaceutical sector. This shift aims to minimize the environmental footprint typically linked to manufacturing processes and safeguard the well-being of personnel. Particularly in preparative settings, the extensive use of solvents results in significant waste generation that requires proper disposal. Embracing greener analytical approaches not only addresses these concerns but also promotes sustainability within the industry.

There exist three fundamental strategies to enhance the environmental sustainability of (bio)processes that will be discussed in this presentation:

1. Process Greening. One approach involves process greening, which entails the substitution of conventional chemicals with more environmentally friendly alternatives. This shift towards greener chemicals aims to reduce the ecological impact of industrial activities.

2. Process Intensification. Another method is process intensification, which involves transitioning from traditional discontinuous batch operations to more efficient continuous processes. This change not only enhances productivity but also minimizes resource consumption and waste generation.

3. Process Modeling for Data-Driven Decisions. Furthermore, implementing process modeling techniques allows for the replacement of trial-and-error methods with data-driven decision-making. By leveraging advanced modeling tools, organizations can optimize processes, improve efficiency, and reduce environmental impact through informed and strategic choices.

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KN-089

Circular Economy and material efficiency in Europe: policy failures and strategic autonomy

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The presentation addresses the evolving strategic framework for the Circular Economy and material efficiency in Europe. Stable trends of international real prices of materials and energy, together with abundant reserves of industrial natural resources, do not provide market incentives for significant increases of material efficiency and innovation. As a consequence, environmental and energy policies took the leading role in driving material efficiency and circularity. In the EU, even before the European Green Deal (EGD), the framework of policies and legislations addressing materials, waste and recycling was already very dense, and the EGD further pushes the transition to a new paradigm for materials through the Circular Economy Action Plan [1]. However, in different key sectors, like plastics, the prevailing policy approach has been insufficient to trigger the development of secondary materials markets that can close the circle. Furthermore, high incentives to renewable energy pushed to a competition between the energy and the material use of bioresources. The insufficiency of policy outcomes brings towards shifting the policy attention to the demand side of secondary raw materials markets and towards a more intensive use of policy approaches like Extended Producer Responsibility that demonstrated to be effective in closing the circles of materials [2]. A parallel need of more intensive research and innovation efforts emerges. European strategies to face the new risks of the international system are bringing to the emergence of 'Open strategic autonomy', also for the procurement of energy and materials [3]. The Green Deal Industrial Plan (GDIP) launched in 2023 through the Net Zero Industrial Act and the Critical Raw Materials Act is a first major step in this direction. However, the GDIP has unexplored implications for the exploitation of domestic natural resources (e.g. mining) in Europe and for a further push towards recycling and circularity, which brings to the challenge of expanding industrial and innovation capacity in these areas..

References:

[1] Díaz López F.J. Mazzanti M., Zoboli R., 2023, Towards a sustainable, circular, innovative and socially fair economy: An introduction, in Díaz López F.J. Mazzanti M., Zoboli R. (eds.), *Handbook on Innovation, Society and the Environment*, Edward Elgar, Cheltenham, 2-22.

[2] EEA – European Environment Agency, 2022, *Investigating Europe's secondary raw material markets*, EEA Report No 12/2022 (by Malin zu Castell-Rudenhausen, Margareta Wahlström, Dirk Nelen, Yoko Dams, Susanna Paleari, Roberto Zoboli, Henning Wilts, Ioannis Bakas), https://www.eea.europa.eu/publications/investigating-europes-secondary-raw-material

[3] Di Francesco E., Gilli R.S., Jensen P., Manoochehri S., Marin G., Specker A., Tagliapietra S., Zoboli R., 2024, *Environmental Impact of Material Supply Chain Disruptions*, ETC CE Report 2024/3, February, EEA, Copenhagnen, https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2024-3-environmental-impact-of-material-supply-chain-disruptions

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KN-090

Safe and sustainable by design chemicals and materials

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The Chemical Strategy for Sustainability (CSS) establishes a number of actions, including the shift towards chemicals, materials and products that are safe and sustainable by design (SSbD) throughout their life cycles, To support this action, the European Commission's Joint Research Centre (EC-JRC) developed a framework for the definition of SSbD criteria and evaluation procedure for chemicals and materials[1], capitalising on an extensive review of the available approaches and frameworks[2, 3]. The JRC's framework addresses the dimensions, aspects and indicators to be considered, the methods and tools that can be used, and indicate to define criteria in the different steps of the SSbD assessment. It provides a rational and integrative procedure that puts together safety, environmental sustainability and socio-economic dimensions for the first time. It requires that safety and sustainability are considered for the entire life cycle of chemicals, materials and products, and assessed, as far as possible, from the beginning and at all stages of the R&D process. Hence, life cycle thinking and assessment play a pivotal role in the framework. This work underpins the EC Recommendation establishing a European assessment framework for SSbD chemicals and materials[4] that is addressed to Member States, industry, academia and technology organisations. The SSbD framework was tested by EC-JRC, focusing on a case study on alternative plasticizers used in food contact materials[5]. The development of the case studies allowed identifying the challenges in the application of the framework (and on the implementation of the SSbD concept). Those include the integration of the SSbD assessment within the innovation process that normally involves early stage developments for which data is not available and a tiered approach is now under development. Moreover, the EC launched a testing phase for the SSbD framework, which already informed a methodological guidance to foster further scientific research, and the key actions needed to ensure wider applicability of the SSbD[6]. A second testing phase is ongoing and there is a reporting template available to report experiences with the SSbD application.

References:

[1] Caldeira, C. et al (2022a). Safe and Sustainable chemicals by design chemicals and materials - Framework for the definition of criteria and evaluation procedure for chemicals and materials. JRC report. https://doi.org/http://dx.doi.org/10.2760/487955

[2] Caldeira, C. et al (2022b) Safe and Sustainable by Design chemicals and materials Review of safety and sustainability dimensions, aspects, methods, indicators, and tools. JRC report. https://doi.org/http://dx.doi.org/10.2760/68587

[3] Caldeira, C., Abbate, E., Moretti, C., Mancini, L., & Sala, S. (2024). Safe and sustainable chemicals and materials: a review of sustainability assessment frameworks. Green Chemistry. https://doi.org/10.1039/D3GC04598F

[4] EC. (2022). Commission recommendation of 8.12.2022 establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials. Brussels, 8.12.2022 C(2022) 8854 final

[5] Caldeira, C et al. (2024), Safe and Sustainable by Design chemicals and materials - Application of the SSbD framework to case studies, JRC report doi:10.2760/769211

[6] Abbate, E., Garmendia Aguirre, I., Bracalente, G., Mancini, L., Tosches, D., Rasmussen, K., Bennett, M.J., Rauscher, H. and Sala, S., (2024) Safe and Sustainable by Design chemicals and materials - Methodological Guidance. JRC report, doi:10.2760/28450

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Why is gender balance important to chemistry?

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It is incontestable that equal professional opportunities should be granted regardless of one's gender. This applies to chemical practice as well. Most often, this reasoning is based on an analysis of fairness and justice: it is morally wrong to exclude women from practicing chemistry or from enjoying the same professional opportunities as men chemists do.

Yet, there are not only moral reasons that justify gender balance in chemistry or science overall. Feminist philosophy of science explores how gender balance contributes to the growth of knowledge and to scientific progress. Specifically, it is argued that women- as other underrepresented groups of people- hold a unique position in how they view the world which in turn allows them to investigate nature and produce scientific knowledge in novel ways.[1] This idea is called situated knowledge. The feminist standpoint theory takes this idea and claims that women's role in science should be promoted as they hold an advantageous position that can lead to further scientific progress.[2]

This theory has been particularly popular with respect to disciplines that study phenomena which in some way involve gender, such as the social sciences or even primatology. In chemistry however, it is not clear how women's standpoint can inform our understanding of chemical phenomena given that the latter do not (at least in any straightforward manner) involve ideas of gender. This prompts the following question: can women's standpoint contribute to understanding chemical phenomena in ways that have not been previously thought? Or, is gender balance better accommodated by promoting a gender-neutral outlook towards chemistry?

In this talk, I explore these questions by presenting the arguments in favour and against the promotion of a standpoint epistemology in chemistry. I track the historical roots of chemistry as a woman's science and present the research questions that may be benefitted by promoting a gendered perspective towards their examination.[3]

References:

[1] Haraway, D. (1988). Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. *Feminist Studies*, 14(3), 575–599.
[2] S Harding, *The Science Question in Feminism.* Ithaca: Cornell University Press, 1986
[3] Schiebinger, L. (1991). *The mind has no sex?.* Harvard University Press.

KN-092

Understanding Gender+ Approach in Chemistry Research and Innovation: What, How, Who

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Gender+ approach has become a key requirement for accessing research funds granted by the European Union. In particular, increasing female participation in research projects (WHO) and gendered innovations (WHAT and HOW) are included among the objectives of the Gender Equality Strategy 2020-2025.

As concerns the first objective (WHO), facilitating gender parity in research teams aids in bridging the disparities in women's involvement and enhancing their professional careers. In recent decades, two distinct approaches have been employed to facilitate gender equity into research: fix the numbers and fix the institutions. The objective of the first approach is to enhance the inclusion of women in research, such as in the workforce, committees, and events. The objective of the second approach is to modify structures and institutions in order to enhance women's opportunities to attain high-level positions in research domains. Regarding the second objective pertaining to research content (WHAT and HOW), it is imperative to adopt a gender-sensitive approach to research. It necessitates acknowledging the disparities that exist between men and women, whether they arise from biological or gender-related factors. Being aware of the gender dimension in research content improves scientific quality and relevance of results. Gender-sensitive research necessitates the inclusion of gender considerations throughout all stages of the research process, whenever it is deemed suitable. The aforementioned components encompass the development of research inquiries, the assembly of the research team, the arrangement of the study, the determination of the research methodologies employed, the collection and analysis of data, and the presentation and reporting of the obtained results.

In conclusion, addressing the objectives of enhancing gender parity within research teams and adopting a gender-sensitive approach to research are crucial steps towards achieving comprehensive gender equity in scientific domains. By embracing these objectives, we bridge existing disparities and enrich the quality and relevance of research outcomes by harnessing the full spectrum of talent and perspectives within the scientific community.

References:

[1] EIGE, What is gender mainstreaming? Last access 27/03/2024. Link https://eige.europa.eu/gender-mainstreaming/what-is-gender-mainstreaming?language_content_entity=en

[2] European Commission, Gender equality in research and innovation. Link https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/democracy-and-rights/gender-equality-research-and-innovation_en https://ec.europa.eu/research/participants/docs/h2020-funding-guide/other/event220623.htm

[3] Gendered Innovations in Science, Health & Medicine, Engineering and Environment. Link https://genderedinnovations.stanford.edu/index.html. Last access 27/03/2024.

[4] Mainstreaming Gender into UNDP-GEF projects on chemicals and waste, (2018), UNDP Guidance Document: Gender and Chemicals.

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KN-093

Diversity & Inclusion: why it matters and how can we make it work? A perspective from the publisher Elsevier.

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In the presentation, we will present the case for D&I. The moral imperative but also the "business case'': do diverse and inclusive organizations perform better? And if so, how and why exactly?

We will illustrate this by Elsevier's decade-long focus on D&I: a path with successes and setbacks but all in all steady upward progress. Today Elsevier supports inclusive research and inclusive health which we will illustrate with key initiatives.[1]

We will further explore the different dimensions of diversity: gender, race and ethnicity, sexual orientation and gender identity, age, disability, etc. To put this in a broader context we will briefly mention the state of D&I across the publishing world.

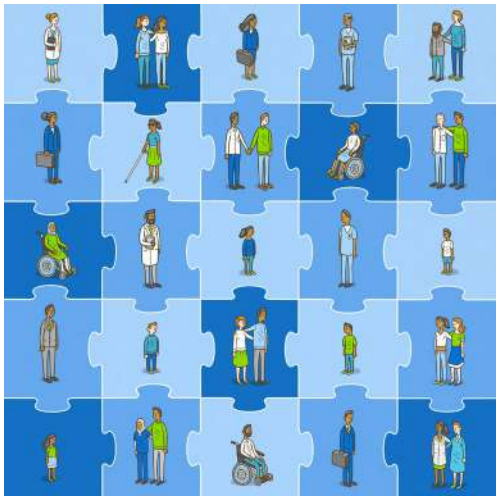

Figure 1: Diversity & Inclusion

References:

[1] https://www.elsevier.com/about/inclusion-diversity-and-equity

KN-094

Ethical aspects of the chemist profession

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Definitions of Ethics: "1. The study of the determination of human conduct and the search for means to actualize it. 2. The set of norms of public and private conduct that, according to one's nature and will, a person or a group of people choose and follow in life or in an activity" (Lo Zanichelli, 1995).Chemistry in Italy has been the main driving force, alongside metallurgy, behind the industrial and economic development of the country after the Great War and especially after the Second World War. During this period, significant discoveries were made in the field of polymers and all their derived materials, in the synthesis of chemical substances, and in the identification of new applications, particularly in pharmaceutical chemistry. Society's perception of the chemist profession became extremely positive, as evidenced by the very high numbers of enrollments in Chemistry and Industrial Chemistry faculties.From the mid-1970s, following the accidents in Seveso, Bhopal in India, society's perception of the profession of chemist completely reversed. Chemistry has been considered dangerous and became unpopular in society. Simultaneously, the chemical community began to reflect on the impact of chemical activities on health and the environment, and consequently on the ethical aspects the profession of chemist entails. The first courses on Environmental Chemistry were born, research focused on the development and study of new products that could replace more polluting ones and the recycling and reuse industry of materials developed.The Code of Ethics highlights that the Chemist must assume social and environmental responsibility in the exercise of his profession. This includes a safe management of chemical products, in order to minimize harmful effects on the environment and public health and promoting sustainable practices. Chemists must carefully consider consequences, both positive and negative, of their discoveries and take informed ethical decisions about the applications and social implications of their research.As citizens, researchers, chemists, are we able to sacrifice, even in part, our professional interests in favor of the broader interests of the social community? A question not easily answered but unavoidable, necessary to change the negative perception that society has about chemistry, in a dialectical relationship.On the other hand, chemists must strive to ensure that the knowledge and research made available by the scientific community do not remain closed within itself but are spread and made available to the whole society obtaining that the use of certain substances (e.g., PPCPs) occurs in the most correct way possible. Not to be ignored is the fact that chemists must follow high ethical standards in their professional practice, that is, "acting with a sense of responsibility and applying chemical and physical knowledge correctly, in accordance with the rules and laws of the State, the Constitution, the European Union's legal system, and within one's own competence with dignity and honorability".Finally, training in a school context has an essential role in promoting ethical and responsible behavior in the chemists of the future. Training shoud help them to understand and face the ethical challenges that may arise in their professional practice.

References:

[1] FNCF Codice deontologico della professione di chimico e fisico – approvato il 11/10/2018 [2] L. Campanella, Atti del Convegno Etica e Scienza per l'Ambiente, Valmontone 2008

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Molecular architecture and mechanism of RNA-modifying ribozymes

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RNA modifications such as methylated nucleotides are conserved throughout evolution and expand the structural and functional diversity of RNA. Besides modulating the native RNA modification landscape, synthetic post-transcriptional RNA modifications for labelling and visualization are critical prerequisites for studying RNA localization, folding and structural dynamics. Ribozymes have emerged as powerful tools for modifying RNA in vitro and in cells.

The first methyltransferase ribozyme (MTR1) was discovered by in vitro selection and shown to catalyze the site-specific installation of the natural modified nucleotide 1-methyladenosine (m^1A) in a target RNA.[1] The ribozyme uses O^6-methylguanine (m^6G) as a small-molecule cofactor and shows a broad RNA sequence scope, as exemplified by site-specific adenosine methylation in native tRNAs and synthetic mRNAs. We solved the crystal structure of MTR1, which represents the post-catalytic state of a split ribozyme in complex with the m^1A-containing RNA product and the demethylated cofactor guanine.[2] The structure revealed an active site reminiscent of natural guanine riboswitches and suggested the mechanistic involvement of a protonated cytidine. A synergistic effect of two 2'-*O*-methylated ribose residues in the active site resulted in accelerated catalysis and tolerance of larger alkyl groups. Further research revealed alkyltransferase ribozymes using established benzylguanine substrates for site-specific fluorescent labelling of RNA,[3] as well as the development of additional ribozymes using alternative bioorthogonal cofactors.

Recently we identified an alkyltransferase ribozyme that uses a synthetic, stabilized *S*-adenosylmethionine (SAM) analogue and catalyses the transfer of a propargyl group to a specific adenosine in the target RNA.[4] The trans-propargylation reaction showed nearly quantitative conversion within one hour. The ribozyme was active under a wide range of reaction conditions in vitro, including physiological magnesium ion concentrations. A genetically encoded version of the SAM analogue-utilizing ribozyme (SAMURI) was expressed in eukaroytic cells, and intracellular propargylation of the target adenosine was confirmed. The transferred alkyne group was efficiently conjugated to different azides, including fluorophores and biotin, to enable studies of RNA localization, folding and structural dynamics. We expect that the ribozymes will also become useful tools for tracking or capturing of target RNAs.

References:

[1] C.P.M. Scheitl, M. GhaemMaghami,A.K. Lenz, C. Höbartner. *Nature* **2020**, *587,* 663-667.
[2] C.P.M. Scheitl M. Mieczkowski, H. Schindelin, C. Höbartner. *Nat Chem Biol* **2022**, 18, 547-555.
[3] C.P.M. Scheitl,T. Okuda, J. Adelmann, C. Höbartner. *Angew Chem Int Ed* **2023**, e202305463.
[4] T. Okuda, A.K. Lenz, F. Seitz, J. Vogel, C. Höbartner, *Nat. Chem*. **2023**, 15, 1523-1531.

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The renaissance era of peptides in drug discovery

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A great challenge in cancer therapy is the selective delivery of anticancer agents or radiotherapeutics to tumour cells reducing the side effects on normal cells. To further improve delivery efficiency and cancer specificity, great efforts have been dedicated to the development of effective systems that can actively target tumours through the molecular recognition of unique cancer-specific "markers" that are overexpressed in the cancerous tissues[1].

The use of peptides as targeting tools has been validated in several applications. Examples are radio-labelled peptides used to deliver radio-therapeutic doses to cancer tissues. In this case, a cytotoxic entity, such as a radionuclide or a chemotherapeutic drug, is driven by the peptide to the transformed cells with higher efficacy than to normal cells[1]. Typically such conjugates, at lower doses, have useful applications for diagnostic applications whereby they are used to visualize even small lesions due to the overexpression of tumour genes.

Often, such conjugates can have poor delivery properties, because of intrinsic high hydrophilicity and nanometric vehicles are employed to overcome this issue , Indeed over the past several years, an explosive development of nanovectors (i.e micelles, liposomes) usable in drug delivery and molecular imaging applications has been reported. Nanoscopic therapeutic systems that incorporate therapeutic agents with molecular targeting capabilities are emerging to improve the therapeutic outcome of drug therapy, and even to improve diagnostic outcomes.

In this lecture, we will present our most recent results on a project that aims at the rational design of targeting peptidomimetic ligands to specific tumour receptors. More specifically, the following topic will be discussed: designing new anticancer drugs and/or a new class of non-invasive diagnostic tracers as suitable tools for $\alpha_v\beta_3$-targeted therapy and imaging[2-5].

References:

[1] L. Zaccaro, A. Del Gatto, C Pedone C, M Saviano, Curr Med Chem 2009, 16, 780 – 795.
[2] A. Del Gatto, L. Zaccaro, P. Grieco, E. Novellino, A. Zannetti, S. Del Vecchio, F. Iommelli, M. Salvatore, C. Pedone, M. Saviano, J Med Chem 2006, 49, 3416 – 3420.
[3] A. Zannetti, S. Del Vecchio, F. Iommelli, A. Del Gatto, S. De Luca, L. Zaccaro, A. Papaccioli, J Sommella, M. Panico, A. Speranza, P. Grieco, E. Novellino, M. Saviano, C. Pedone, M. Salvatore, Clin Cancer Res 2009, 15, 5224 – 5233.
[4] C. Bolzati, N. Salvarese, D. Carpanese, R. Seraglia, L. Meléndez-Alafort, A. Rosato, D. Capasso, M. Saviano, A. Del Gatto, D. Comegna, L. Zaccaro, J Med Chem 2018, 61, 9596 – 9610.
[5] C. Acconcia, A Paladino, M. della Valle, B. Farina, A. Del Gatto, S. Di Gaetano, D. Capasso, M.T. Gentile, G Malgieri, C. Isernia, M. Saviano, R. Fattorusso, L. Zaccaro, L. Russo. Int J Mol Sci 2022, 23, 11039.

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Design and Development of Novel Triazolopyrimidine- and Quinoline-Based NADPH Oxidases Bona-Fide Inhibitors for Cancer and Non-Cancer Diseases

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NADPH oxidases (NOXs) are enzymes responsible for only generating reactive oxygen species (ROS)[1]. The seven NOX isoforms participate in various physiological processes, including cell proliferation[2], and their deregulation has been associated with various cancers, such as colon cancer[3] and leukaemia[4]. To identify *bona-fide* NOXs inhibitors, we firstly explored the structure of the covalent NOX inhibitor **VAS2870**. We observed that replacing of the 2-thiobenzoxazole leaving group with different functional groups abolished NOXs inhibition. By inserting at the *para*-position of the benzyl group of **VAS2870** the pharmacophore moieties able to covalently bind to FAD cofactor, we obtained **MC4762** and **MC4767** that did not provide an adduct with FAD, but **MC4762** selectively inhibited NOX2. Interestingly, **MC4762** was also able to lower ROS levels and to downregulate neuroinflammatory cytokines in BV2 microglia cells. To identify novel *bona-fide* NOXs inhibitors, we also simplified the molecular structure of the lead compound **M41** that we discovered through an *in-silico* screening. We observed that the opening of the central ring (**MC4793**) abolished human NOXs inhibition. Moreover, **MC4876** displayed a significant selectivity towards *h*NOX2, proved in cell target-engagement and proliferation impairment. These results confirmed the feasibility of achieving isoenzyme-specific NOX inhibitors by modifying the **M41**.[5]

References:

[1] Bedard K, Krause KH. *Physiol Rev.* **2007**, *87*, 245-313.
[2] Block K, Gorin Y. *Nat Rev Cancer.* **2012**, *12*, 627-37.
[3] Fukuyama M, Rokutan K, Sano T, Miyake H, Shimada M, Tashiro S. *Cancer Lett.* **2005,** *221*, 97-104.
[4] Aydin E, Hallner A, Grauers Wiktorin H, Staffas A, Hellstrand K, Martner A. *Oncogene*, **2019**, *38*, 1534-1543.
[5] Reis J, Gorgulla C, Massari M, Marchese S, Valente S, Noce B, Basile L, Törner R, Cox III H, Viennet T, Yang M H, Ronan M M, Rees M G, Roth J A, Capasso L, Nebbioso A, Altucci L, Mai A, Arthanari H, Mattevi A. *Nat Chem Biol.* **2023**, *19,* 1540-1550.

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Beyond Traditional Paths: Pioneering Drug Discovery at the Chemistry-Biology-Physics Nexus

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Targeted protein degradation (TPD) has emerged as a revolutionary approach in both drug discovery and chemical biology.[1] This innovative strategy harnesses small molecules (*e.g.,* proteolysis targeting chimeras - PROTACs) to induce the degradation of specific proteins by hijacking the cell's natural protein degradation machinery.[2] While no TPD-based drugs have yet received clinical approval, compounds capable of reducing the levels of disease-causing proteins are advancing in drug discovery pipelines.[3] For chemical biology applications, small molecule degraders can be exploited as chemical probes, allowing to dissect the function and significance of the targeted proteins within living cells.[4]

In this regard, we have recently described a novel paradigm (Pharmacological Protein Inactivation by Folding Intermediate Targeting, PPI-FIT),[5] that leverages the power of chemistry, biology, and physics at the life science interface. PPI-FIT is based on the hypothesis of pharmacologically modulating the expression of a specific protein at the post-translational level by impairing its folding process. The underlying principle is that targeting transient protein conformations - folding intermediates – with a small ligand could promote degradation by the cellular quality control machinery, which recognizes such artificially stabilized intermediates as improperly folded forms. Hence, unlike conventional drug design approaches focusing on native protein structures, PPI-FIT expands the TPD landscape by targeting proteins during the folding process, introducing a new class of small molecule degraders named folding interfering degraders (FIDs). As a result, this breakthrough approach holds great promise for modulating currently undruggable proteins, thereby effectively tackling unmet medical needs.

Some examples of PPI-FIT applications will be presented, specifically showcasing its potential impact in addressing neurodegenerative disorders[5,6] and rare pediatric diseases.

Presently, PPI-FIT is harnessed by Sibylla Biotech S.p.A. (www.sibyllabiotech.it), a preclinical stage company exploiting this pioneering technology in different therapeutic areas.

References:

[1] L. Zhao, J. Zhao, J.K. Zhong et al., *Sig Transduct Target Ther* 2022, 7, 113-125
[2] M. Békés, D.R. Langley, C.M. Crews, *Nat Rev Drug Discov* 2022, 21, 181–200
[3] C. Bouvier, R. Lawrence, F. Cavallo et al., *Cells* 2024, 13, 578-615
[4] V. Němec, M.P. Schwalm, S. Müller, S. Knapp, *Chem Soc Rev* 2022, 51, 7971-7993
[5] G. Spagnolli, T. Massignan, A. Astolfi et al., *Commn Biol* 2021, 4, 1-16
[6] E. Biasini, M.L. Barreca, P. Faccioli, I. Mancini. EP4126225A1/US20230145822A1

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MICRO4ALL: A MAJOR CHANGE IN DRUG DISCOVERY

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The world needs sustainable solutions to cope with an increasing and aging human population. Drug R&D programs are time-consuming, costly, and with no guarantee of success. Given the world population increase, fast and efficient development of new drugs is essential. Natural products have found numerous applications to treat and prevent diseases in humans, animals, and plants, and are widely used as research reagents to probe biological processes. They are a proven and sustainable answer to make the R&D process faster and more successful. *micro4all* is a platform that provides access to an extensive online Catalog of Molecules, present in ready-to-screen samples produced by NAICONS proprietary microbes. NAICONS has a collection of 45,000 microorganisms, among the most diversified in the world, and of 50,000 ready-to-screen extracts, a number that is being expanded continuously. Each microorganism produces hundreds of molecules that are present in the extracts and that are identified using a proprietary automated informatic process. The molecules, the extracts and the producing microorganisms are listed in a growing database called Molecules Gateway. *micro4all* provides a search-and-order engine where Users can access information, molecules, extracts, and the producing microorganisms. We will provide an overview of how the Gateway was created, what it contains and demos on the type of searches Users can perform.

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KN-100

Structural insights into G-quadruplex-protein recognition: the case of anti-thrombin aptamers

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DNA or RNA sequences rich in guanines have the propensity to fold into four-stranded structures, known as G-quadruplexes (G4s), in which tetrads of guanines, organized in cyclic arrays *via* Hoogsteen hydrogen bonds, stack on top of each other. Naturally occurring G4s appear to play crucial roles in the control of fundamental cellular processes such as transcription, translation, and replication.[1] These structures have also been found in several synthetic oligonucleotides, known as aptamers, that selectively bind to a specific target molecule, exerting interesting biological activities.[2]

A particular case is that of the anticoagulant aptamers able to recognize human α-thrombin, the key enzyme of the coagulation cascade.[3] In the last years, researchers have been particularly interested in a new class of anti-thrombin aptamers, in which the binding affinity and/or anticoagulant activity are modulated by the addition of other domains or appendages to the G4 core.[4] The functionalization of the full-G4 TBA aptamer with a hetero duplex generated by aromatic moieties attached at the 5′ and 3′-ends, leads to a modified aptamer, named TBA-NNp/DDp that, in addition to a considerable improvement of the thermal stability and nuclease resistance, shows a moderate increase in anticoagulant activity with respect to unmodified TBA.[5] Notably, a duplex/quadruplex anti-thrombin aptamer, known as M08s-1,[6] exhibits increased anticoagulant activity in comparison to NU172, the only anti-thrombin aptamer currently evaluated in Phase II of clinical trials.[7]

With the aim to shed light on the molecular basis for the improved properties of these aptamers, spectroscopic, calorimetric, and electrophoretic analyses have been performed in order to investigate the conformational behaviour of these oligonucleotides in the free and bound state. In particular, we solved the X-ray structures of thrombin in complex with TBA-NNp/DDp and a truncated form of M08s-1 (named M08s-1_41mer), which have shown peculiar structural features of the two aptamers.[8,9]

References:

[1] D. Rhodes, H.J. Lipps, Nucleic Acids Res 2015, 43, 8627 – 8637.
[2] R. Troisi, N. Balasco, I. Autiero, L. Vitagliano, F. Sica, Int J Mol Sci 2023, 24, 16318.
[3] R. Troisi, N. Balasco, I. Autiero, F. Sica, L. Vitagliano, Res Pract Thromb Haemost 2023, 7, 102160.
[4] W. Kotkowiak, A. Pasternak, Int J Mol Sci 2021, 22, 9948.
[5] K. Pérez de Carvasal, C. Riccardi, I. Russo Krauss, *et al.*, Int J Mol Sci 2021, 22, 9510.
[6] K. Wakui, T. Yoshitomi, A. Yamaguchi, *et al*., Mol Ther Nucleic Acids 2019, 16, 348 – 359.
[7] R. Troisi, V. Napolitano, V. Spiridonova, I. Russo Krauss, F. Sica, Nucleic Acids Res 2018, 46, 12177 – 12185.
[8] R. Troisi, C. Riccardi, K. Pérez de Carvasal, *et al*., Mol Ther Nucleic Acids 2022, 30, 585 – 594.
[9] R. Troisi, V. Napolitano, E. Rossitto, *et al*., Nucleic Acids Res 2023, 51, 8880 – 8890.

KN-101

Antimicrobial peptides and their interaction with model membranes: a biophysical approach

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The resistance to multiple antimicrobial agents (as antibiotics) in bacteria has become a central problem in our community. Many researchers are focusing their efforts on the development of new anti-infective agents and among these, the most promising are antimicrobial peptides (AMPs). AMPs are small, cationic membrane-active peptides that exhibit broad-spectrum activity against bacteria, viruses, and even fungi. Their primary target is represented by the lipid matrix of the pathogens' membrane. Despite their similar physical properties, AMPs exhibit a limited sequence homology and a wide range of secondary structures upon interaction with membranes whereas they show essentially a disordered structure in solution. The mechanisms by which AMPs can interact with membranes depend on the peptides' molecular properties and, importantly, on the lipid composition of the membrane which in turn modulates the physical state of the bilayer and its microscopic properties. In this talk, a brief introduction to AMPs and biomembranes will be given. Then, it will be shown how the application of biophysical techniques, with a particular emphasis on calorimetry, can be used the disentangle the intricate aspects of AMPs-induced perturbation of biophysical properties of lipid double layer mimicking the bacterial membrane.[1]

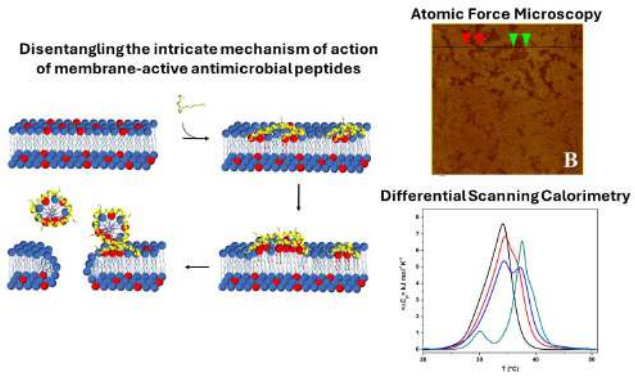

Figure 1: Using a combination of biophysical techniques, including calorimetry, it is possible to reveal the molecular details of peptide-induced perturbation of model biomembranes.

References:

[1] R. Oliva, et al. PCCP 2019, 21, 3989-3998.

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Modulating Biochemical Complexes in Health and Disease: From Glycosylation to Small Molecules

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Protein functions depend on a delicate interplay of structure and dynamics. Ligand binding, post-translational modifications, and interactions with other protein partners provide different levels of control of activities in cells, defining a code that ultimately determines cell life.

Understanding, atomistically, the key physico-chemical elements that rewire the conformational dynamics of proteins, pathologically perturbing functionally-oriented ensembles, is key for development of novel therapeutics. This is particularly relevant for molecular chaperones, hub proteins for the assembly of large multiprotein complexes.

Here, we will present computational studies, integrated with extensive experimental validations, aimed to unveil the links between the perturbation of functionally-oriented dynamics in different biochemical systems and their functional implications. We will discuss how understanding of the effects of *N*-glycosylation of specific residues and ligand-binding can modulate internal dynamics and alters the conformational fitness of regions fundamental for interaction with other partners, and will discuss methods to directly interfere with interactions determined specifically by N-glycosylations. We will also discuss the effects of other modifications in the general framework of conformational selection and long-range functional regulation. Finally, we will discuss how to leverage the knowledge generated to design molecules targeting disease-associated conformational states and assemblies.

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KN-103

A decade of the liposome-protein corona: Lessons learned and future breakthroughs in theranostics

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A decade has passed since the concept of the protein corona, as originally termed by Dawson and coworkers in 2007 [1], was extended to liposomes. Although the protein binding to liposomes has been known since the 1970 s, deep knowledge of the factors triggering its formation and interaction with living systems in vitro and in vivo was not fully understood. Over the last 10 years, multidisciplinary efforts from chemistry, physics, materials science, biology, toxicology, and immunology were put together to understand the synthetic-biological duality of the liposome-protein corona. Here we focus on the methods employed for characterizing the liposome-protein corona, the categories of factors shaping its composition, and the most relevant applications in the field of nanomedicine, where liposomes are designed for targeted drug delivery, vaccination against cancer and infectious diseases, imaging, and diagnostics [2]. We conclude the lecture by contemplating future research directions and appealing to researchers, entrepreneurs, and policymakers to recognize the relevance of this field of research.

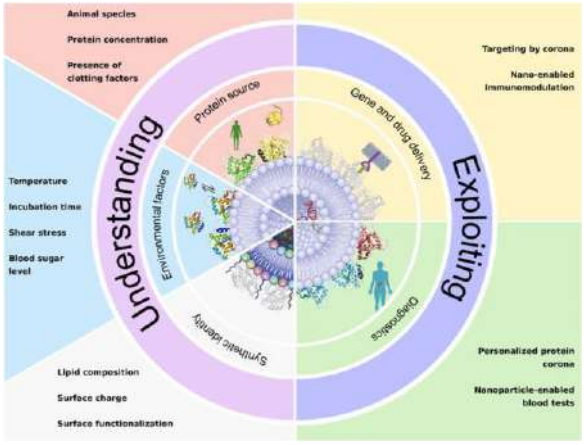

Figure 1: An overview of the main achievements obtained in the field of the liposome protein corona from basic understanding to clinical application.

References:

[1] T. Cederval, et al., Proc. Natl. Acad. Sci., 2007, 104, pp. 2050-2055
[2] E. Quagliarini, et al NanoToday 2022, 47, 101657

KN-104

Fighting stress with food choices?

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In recent years, thanks to the recognition of the involvement of the gut microbiota in mental health and cognitive function, interesting opportunities have emerged to produce benefits for brain functions through the manipulation of the microbiota. Diet has emerged as a major factor shaping the composition and functions of the gut microbiota. In 2013, the term "psychobiotic" was first proposed to describe any exogenous intervention that impacts the brain, mediated by bacteria[1]. Initially greeted with distrust, this line of studies has identified probiotics and prebiotics with promising results as psychobiotic agents, both in animal models and in humans. Furthermore, numerous observational studies suggest a link between healthy eating patterns and a reduction in the risk of common mental illnesses, and emerging data from early intervention studies suggest that improving eating habits can improve depressive symptoms. These studies are conducted in different geographical areas, with different cultures. The research is mainly aimed at highlighting the role of individual foods (for example, unprocessed fruit or vegetables), or at developing new food supplements.

Those studies that focus on the overall diet, which investigate the potential synergistic effect that the different components of the diet could have, both on the composition of the microbiota and on health, perhaps deserve greater attention. The study of "integral" dietary approaches represents a path to be followed carefully for the development of new psychobiotic dietary interventions. It is interesting to observe how among the lifestyles studied there is a version of the Mediterranean diet combined with fermented foods. Recently, a short-term psychobiotic dietary intervention based on these assumptions improved perceived stress in a healthy population, while eliciting specific metabolic changes in the gut microbiota[2]. Results that must be interpreted with caution since improvements in stress responses were observed only within the intervention group, while no significant differences were found between groups after the intervention. However, given the fundamental influence of stress on the risk of developing other chronic diseases such as depression, these findings hold promise as potential therapeutic and preventative approaches. It is foreseeable that the use of dietary and lifestyle approaches to address mental health problems will become increasingly important and may be reflected in future nutritional guidelines. To report the opinion of one of the coordinators of the study, prof. John Cryan (University College Cork, Ireland) "What I like about fermented foods is that they democratize science. They don't cost a lot and you don't have to buy them in some fancy shop. You can make them yourself. In this field, we want to provide solutions for mental health to people of all socioeconomic areas." A shared path that science must take to truly impact the well-being of the entire population.

References:

[1] Dinan TG, Stanton C, Cryan JF. Biol Psychiatry. 2013, 74(10): 720-6. [2] Berding K, Bastiaanssen TFS, Moloney GM, Boscaini S, Strain CR, Anesi A, Long-Smith C, Mattivi F, Stanton C, Clarke G, Dinan TG, Cryan JF. Mol Psychiatry. 2023; 28(2): 601-610.

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Modular and adaptive self-assembling dendrimers for biomedical applications

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Dendrimers are ideal precision materials for elaborating nanomedicine by virtue of their well-defined structure, multivalent cooperativity and nanosize per se. We have pioneered modular and adaptive self-assembling dendrimer nanosystems[1] for the delivery of anticancer drugs[2] and nucleic acid therapeutics[3] as well as imaging agents[4] for cancer detection and treatment. Remarkably, these supramolecular dendrimer nanosystems are able to exploit the in situ tumor-secreted extracellular vesicles for effective delivery and deep penetration in tumor tissue, while overcoming tumor heterogeneity and dynamic evolution.[2] Also, we have recently developed self-assembling dendrimer nanosystems against infectious diseases caused by antimicrobial resistant pathogens.[5] Our findings offer a fresh perspective for exploiting the advantageous features of supramolecular dendrimers to reach the ultimate goal of nanomedicine

References:

[1] Z. Lyu, L. Ding, A. Tintaru, L. Peng, *Acc. Chem. Res.* 2020, *53*, 2936-2946.
[2] a) Y. Jiang, Z. Lyu, B. Ralahy, J. Liu, T. Rousse, L. Ding, J. Tang, A. Kosta, S. Giorgio, R. Tomasini, X-J. Liang, N. Dusetti, J. Iovanna, L. Peng, *Proc. Natl. Acad. Sci. U.S.A.* 2023, *120*, e2215308120; b) T. Wei, C. Chen, J. Liu, C. Liu, P. Posocco, X. Liu, Q. Cheng, S. Huo, Z. Liang, M. Fermeglia, S. Pricl, X.-J. Liang, P. Rocchi, L Peng, *Proc. Natl. Acad. Sci. USA*, 2015, *112*, 2978-2983.
[3] a) J. Chen, D. Zhu, B. Lian, K. Shi, P. Chen, Y. Li, W. Lin, L. Ding, Q. Long, Y. Wang, E. Laurini, W. Lan, Y. Li, A. Tintaru, C. Ju, C. Zhang, S. Pricl, J. Iovanna, X. Liu, L. Peng, *Proc. Natl. Acad. Sci. U.S.A.* 2023, *120*, e2220787120; b) J. Chen, D. Zhu, X. Liu, L. Peng, *Acc. Mater. Res.* 2022, *3*, 5, 484-497.
[4] a) L. Ding, Z. Lyu, T.-A. Perles-Barbacaru, A. Y.-T. Huang, B. Lian, Y. Jiang, T. Roussel, C. Galanakou, S. Giorgio, C.-L. Kao, X. Liu, J. Iovanna, M. Bernard, A. Viola, L. Peng, *Adv Mater.* 2023, 2308262. DOI:10.1002/adma.202308262; b) L. Ding, Z. Lyu, A. Tintaru, E. Laurini, D. Marson, B. Louis, A. Bouhlel, L. Balasse, S. Fernandez, P. Garrigue, E. Mas, S. Giorgio, S. Pricl, B. Guillet, L. Peng, *Chem. Commun.* 2020, *56*, 301-304; c) P. Garrigue, J. Tang, L. Ding, A. Bouhlel, A. Tintaru, E. Laurini, Y. Huang, Z. Lyu, M. Zhang, S. Fernandez, L. Balasse, W. Lan, E. Mas, D. Marson, Y. Weng, X. Liu, S. Giorgio, J. Iovanna, S. Pricl, B. Guillet, L. Peng, *Proc. Natl. Acad. Sci. USA,* 2018, *115*, 11454-11459.
[5] a) N. King, D. Dhumal, S. Q. Lew, S. H. Kuo, C. Galanakou, M. H. Oh, S. Y. Chong, N. Zhang, L. T. O. Lee, Z. Hayouka, L. Peng, and G. W. Lau, *ACS Infectious Diseases*, 2024, *10*, 453-466; b) D. Dhumal, B. Marom, E. Malach, Z. Lyu, L. Ding, D. Marson, E. Laurini, A. Tintaru, B. Ralahy, S. Giorgio, S. Pricl, Z. Hayouka, L. Peng, *Nanoscale*, 2022, *14*, 9286-9296.

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Smart multifunctional hybrid materials as key pillars towards innovation and sustainability: advantages and challenges

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Within the fascinating area of material science, a special place is covered by smart materials, which can respond to external stimuli such as physical parameters (i.e. temperature, humidity, pressure, pH, electrical/magnetic fields) or specific analytes coming from the environmental surroundings. Their production shows several advantages such as increasing the resistance of materials and the product shelf life and reducing the production and maintenance costs.

In this regard, (multi)functional hybrid organic-inorganic materials (HOIM) contribute significantly to this issue, providing unique mixtures of qualities by combining organic-inorganic components at the nanoscale or molecular level to improve strength, conductivity, flexibility, and other final desired properties. The adaptability and innovation of these class of advanced smart materials have gained significant attention due to their potential applications in several industrial sectors, such as buildings, blue-growth, aerospace, healthcare, well-being, optoelectronics, textiles, and renewable energy,[1] also solving complicated issues such as environmental remediation and surface performance implementation. Moreover, the sol-gel method has recently emerged as a sustainable and versatile synthetic approach to obtain smart (multi)functional hybrid materials, thanks to the employed low process temperature, high homogeneity of the final products, absence of cytotoxicity, and high versatility of the silane precursors (also able to stably bind nanofiller/molecules or to anchor to various substrates).[2]

The development and application of smart innovative (multi)functional hybrid materials or nanocomposites, based on an appropriate multicomponent (blended) polymeric matrix featuring functional polymeric precursors/cross-linkers, natural fillers, or molecules, will be described and discussed highlighting the relationship between the designed functionalities and the properties of the obtained systems, also assessing advantages and challenges of a rational "safe and sustainable by design" approach to pave the way to more eco-friendly and innovative products and technologies.[3]

References:

[1] (a) Y. Yin, J.A. Rogers, *Chem. Rev.* **2022**, 122, 5, 4885. (b) V. Trovato, S. Sfameni, G. Rando, G. Rosace, S. Libertino, A. Ferri, M.R. Plutino, *Molecules,* **2022**, *27*, 5709, and refs therein.

[2] G. Rando, S. Sfameni, M.R. Plutino, *Gels*, **2023**, *9*, 9 and refs therein.

[3] Multifunctional hybrid material based on natural clays for environmental recovery and bioremediation, Patent Number WO 2021/124103 A1; Multifunctional hybrid material based on sepiolite for environmental recovery and bioremediation, Patent Number WO 2021/124097 A1.

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Aggregation Induced Emission: An Insight into the Excited State and Aggregate Formation Mechanism

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From biology to optoelectronics, fluorescent materials have long been used as indispensable tools. The phenomenon known as Aggregation-Caused Quenching (ACQ), which occurs when a fluorophore comes into close proximity with other molecules, is a challenge limiting these applications. The opposite phenomenon, the so-called Aggregation-Induced Emission (AIE), offers a straightforward remedy to ACQ. Even though AIE has been observed in several molecular systems, the mechanism underlying this promising effect is still under discussion in the literature. In light of the above, we present an in-depth study of the excited-state dynamics of several donor-acceptor chromophores showing AIE. The investigation employed UV-Vis time-resolved spectroscopies, with nanosecond and femtosecond resolution, allowing for a comprehensive mechanistic insight into the structure-property relationships impacting AIE. The experimental results collected in solution, in water dispersion as well as in the solid-state allow to outline general conclusions upon which to develop new purely organic AIEgens. Interestingly, an increased intramolecular charge transfer character lead to the activation of Room Temperature Phosphorescence (RTP, through spin-orbit charge transfer-induced intersystem crossing) and Thermally-Activated Delayed Fluorescence (TADF, through reduced singlet-to-triplet energy gap). The efficiency of RTP and TADF intriguingly resulted further enhanced upon aggregation. Our findings suggest new opportunities to employ these emitters in the biological field, as photosensitizers for imaging-guided photodynamic therapy, and for the realization of more efficient optoelectronic devices.

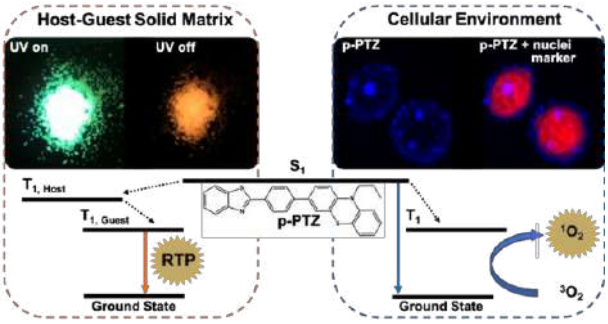

Figure 1: RTP in solid state host-guest matrix (left) and AIE in cellular environment coupled to photo-toxicity toward cancer cells (right).

References:

[1] W. Dai, T. Bianconi, E. Ferraguzzi, X. Wu, Y. Lei, J. Shi, B. Tong, B. Carlotti, Z. Cai, Y. Dong, ACS Materials Lett., 2021, 3, 1767–1777.
[2] A. Cesaretti, T. Bianconi, M. Coccimiglio, N. Montegiove, Y. Rout, P. L. Gentili, R. Misra, B. Carlotti, J. Phys. Chem. C 2022, 126, 10429–10440.
[3] T. Bianconi, A. Cesaretti, P. Mancini, N. Montegiove, E. Calzoni, A. Ekbote, R. Misra, B. Carlotti, J. Phys. Chem. B 2023, 127, 1385–1398.
[4] C. Montanari, T. Bianconi, M. Sheokand, T. Teunens, G. Cavalletti, J. Cornil, R. Misra, B. Carlotti, J. Mater. Chem. C 2023, 11, 10893–10904.

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Multivalent Interactions in the Detection of DNA and Viruses

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Multivalency describes many interactions in Nature, for example, the interaction between viruses and cell membranes.[1] The influenza virus binds through multiple sialyl-terminated carbohydrates (SLNs) non-covalently interacting with hemagglutinin coat proteins of the virus particle. This interaction is weakly multivalent in nature, and therefore it responds very sensitively to the density of carbohydrates. This behavior explains the large differences between virus affinities observed for mutations in the receptor binding domain.

A key aspect of the multivalent interaction of viruses at cell membranes is its strong, non-linear dependence on the receptor density displayed at the surface. We here show the use of surface gradients of receptor-modified supported lipid bilayers (SLBs) to visualize and quantify the receptor density dependence in one microscopic image. This technique is called "Multivalent Affinity Profiling".[2] The fitting of the data by a thermodynamic model allows quantification of the threshold density, comparison of binding selectivities for different virus strains, and thus offers a molecular understanding of the supramolecular binding energy landscape.[3] This supramolecular and nanoscopic picture links fundamental molecular aspects of binding to biological processes of antigenic drift and zoonosis.

The same principles of weak multivalent and superselective binding can be used in the design of a device that selectively captures the cancer biomarker hypermethylated DNA (hmDNA).[4] The selectivity is achieved by careful density control over the surface coverage of the proper receptor for hmDNA, the methyl-binding domaln (MBD) protein.[5] Microfluidic devices coated with monolayers of MBD thus allow purification and up-concentration of hmDNA from solution mixtures with large backgrounds of non-methylated DNA, from cell extracts and from patient samples. This technique promises a faster and cheaper method to employ hmDNA as a biomarker in liquid biopsies, with potential applications as a screening method and for follow-up of treatment.

References:

[1] N. J. Overeem, E. van der Vries, J. Huskens, *Small* **2021**, *17*, 2007214
[2] N. J. Overeem, P. H. Hamming, M. Tieke, E. van der Vries, J. Huskens, *ACS Nano* **2021**, *15*, 8525
[3] N. J. Overeem, P. H. Hamming, O. C. Grant, D. Di Iorio, M. Tieke, M. C. Bertolino, Z. Li, G. Vos, R. P. de Vries, R. J. Woods, N. B. Tito, G.-J. P. H. Boons, E. van der Vries, J. Huskens, *ACS Central Science* **2020**, *6*, 2311
[4] R. Kolkman, L. I. Segerink, J. Huskens, *Adv. Mater. Interfaces* **2022**, *9*, 2201557
[5] R. W. Kolkman, S. Michel-Souzy, D. Wasserberg, L. I. Segerink, J. Huskens, *ACS Appl. Mater. Interfaces* **2022**, *14*, 40579

KN-110

Smart nanocomposites in tendon tissue engineering

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Each year, more than 32 million tendon injuries have been reported mainly caused by sports injuries, and population aging. An innovative approach for the treatment of these injuries is represented by tissue engineered bio-mimetic scaffolds able to support the host cells homing, differentiation, and proliferation. In this context, thermoplastic polymers are of special interest in the tissue engineering field as they allow the production of scaffolds with controlled elastic and mechanical properties, suitable as an effective support during the new tissue formation. However, the polymeric scaffolds alone are insufficient to guarantee a complete healing control, since they lack of adequate hierarchical structure as well as adequate mechanical, chemical, and physical properties to stand the stresses and enhance tissue regeneration. For this purpose, the use of inorganic nanomaterials as doping has gained great interest in tissue engineering applications, due to their wide range of unique properties, such as anti-inflammatory and antibacterial ones.
Given these premises, the design and the development of multifunctional platforms intended for the regeneration of the tendon tissue and doped with inorganics capable of coupling antimicrobial and proliferation enhancement properties will be described.
In particular fibrous scaffolds and highly porous 3D scaffolds have been developed. Thermoplastic polymers as polyurethane and polyhydroxybutyrate have been selected. Natural biomimetic polymers (gelatin or chondroitin sulfate) have been associated to the polymer matrix to enhance bioactive properties. Inorganic doping with cerium, copper and iron oxides gives the scaffolds superior properties of tissue reparation and antimicrobials. The multidisciplinary characterization approach including a physico-chemical characterization (SEM, fibers dimensions, TEM, surface wettability, structural characterization – FTIR, TGA/DSC, SAXS – mechanical properties, degradation properties) and a preclinical characterization (in vitro biocompatibility on tenocytes, release studies, and in vivo safety on murine burn/excisional wound model) allows to pave the way to a translation towards clinics.

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KN-111

Building-up biocompatible functional materials combining inorganic nanoparticles and soft lipid scaffolds

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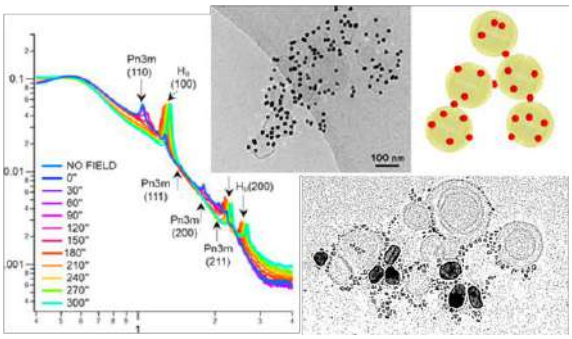
Associating inorganic nanoparticles with soft lipid scaffolds is an attractive strategy to attain functional materials combining the unique properties of inorganic nanoparticles with the biocompatibility, self-assembly properties, and chemical/structural tunability of lipid systems. Over the years, multiple examples of lipid-nanoparticle hybrids have been proposed, such as magnetoliposomes or, more recently, lipid-camouflaged nanoparticles. However, obtaining controlled hybrid systems of desired characteristics often requires complex synthetic pathways and/or manipulation.

In this contribution, different hybrid systems are presented, where functional (magnetic, plasmonic, or magnetoplasmonic) nanoparticles were associated with lipid and lipid/copolymer assemblies through simple self-assembly steps. By carefully exploiting by design lipid/nanoparticle interfacial interactions, such as ligand exchanges, fine control over the structural, morphological, colloidal, and, ultimately, functional properties of the hybrid was attained.



With this strategy, different hybrid systems have been prepared, such as: (i) lipid vesicles-nanoparticles assemblies with discriminating colloidal properties of potential interest for applications in mixed vesicles dispersions separation; (ii) controlled clusters of gold nanoparticles on lipid vesicles, of enhanced plasmonic properties, of interest for Raman imaging applications, (iii) ternary systems made of magnetite and gold/magnetite core-shell nanoparticles hybridized with lipid vesicles, exhibiting combined magnetic and plasmonic properties; (iv) lipid-copolymer hybrid systems with patched-driven assembly of clustered plasmonic properties.

Overall, these results highlight a facile strategy, based on controlled self-assembly of inorganic nanoparticles and lipid interfaces, to prepare complex biocompatible functional materials of broad applicability.

References:

[1] Cardellini et al. Journal of Colloid And Interface Science 654 (2024) 848–858
[2] Cardellini et al. ACS Applied Nanomaterials, in press

KN-112

Advanced Materials requirement for sustainable Food Packaging Equipment design

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Food Packaging industries are looking into sustainable solutions not only for packaging material structure development, but also for Equipment components design optimization. The demanding conditions of those parts are translated into material requirements as excellent chemical resistance to aggressive environment, advanced materials for more efficient components, high quality bulk and surface mechanical properties in complex environments. The scouting and the testing of advanced materials and sustainable polymers and coatings available in the Market it has been done, but few candidates were able to satisfy application constraints and technological development. What is then important for industry to develop? Which are the properties/materials that we are looking at?

Highlight of Food industry chemistry of materials needs , and some examples like: research activities toward polymers sustainability for industrial components, green Tribology, self-lubricant materials, functionalization of surfaces, advanced and carbon based materials.

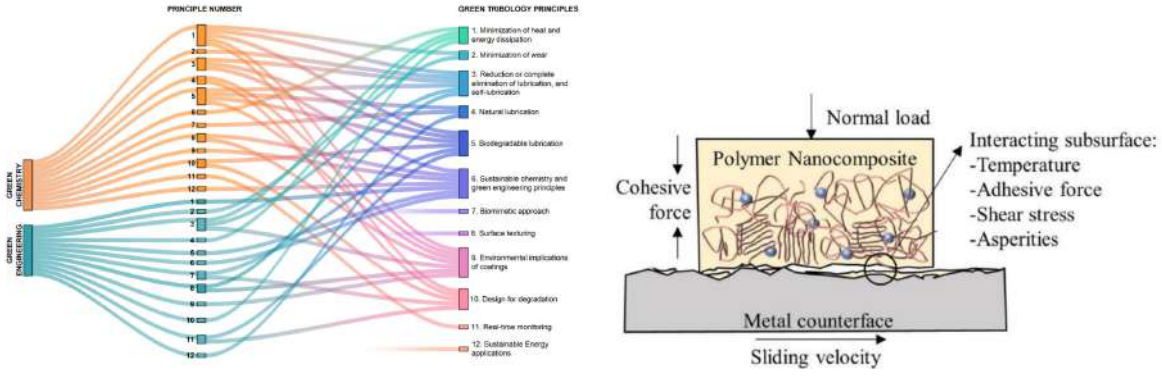

Figure 1: Green Tribology principles (left) and parameters that have a strong influence on transfer film development on tribological system involving polymer nanocomposite (right)

Acknowledgement

Professor Maria Edmondo Benetti, Department of Chemical Sciences of the University of Padova, and Professor Luca Andena, Department of Chemistry, Materials and Materials Engineering, Politecnico di Milano for materials researches inspirations.

References:

1. A. K. Mohanty et al., Sustainable polymers. Nature Reviews Method Primers, 2022, 2(1):46.
2. M. Hong et al., Future Directions for Sustainable Polymers. Trends in Chemistry, 2019, 1(2), 148.
3. Huang P. et al, Recent progress on surface texturing and solid lubricants in tribology: Designs, properties, and mechanisms, Materials Today Communications 2023.

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KN-113

Graphene history – from lab weirdo to breakthrough in industrial innovation

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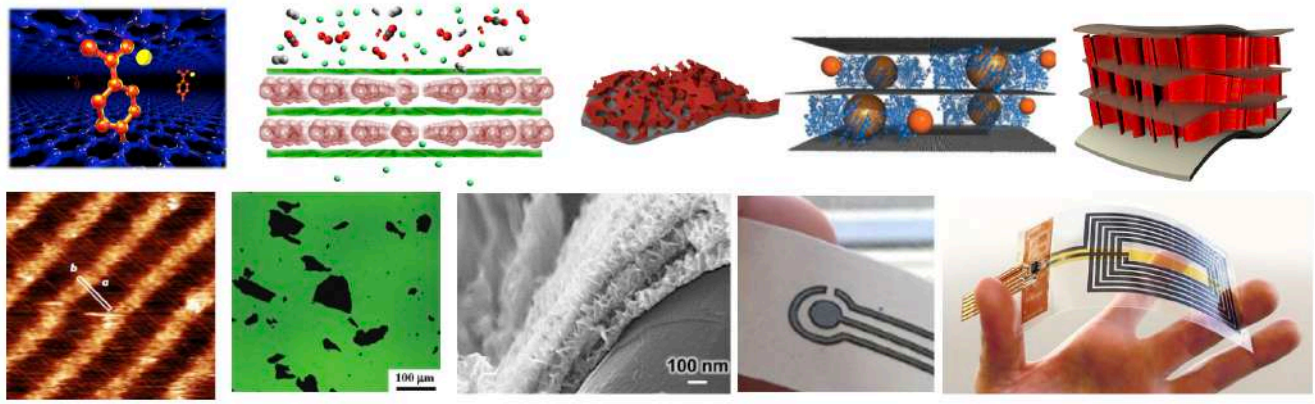
Graphene is a robust, flexible sheet of carbon atoms, one-atom thick. At the beginning of its exciting life, graphene was mostly a game for physicists working in fundamental research, enabling them to investigate relativistic quantum phenomena in benchtop experiments, using simple scotch tape. After a while, chemists entered the stage. In 2008, techniques to produce graphene on large scale were invented. In 2012, the first consumer products based on graphene appeared. Since then, the EC decided to launch an ambitious project (The Graphene Flagship), with the visionary goal to translate this scientific breakthrough into innovation for European industries. 2D nanosheets like graphene can be processed, functionalised and then re-assembled together to create new layered 2D composites with useful applications. When two nanosheets are stacked together, the space between them forms a 2D-confined environment which can capture, transport or store small molecules and ions which normally do not intercalate in graphite or in any other material. Here, we will give an overview of novel layered composites with original structure that we produced recently,[1] with useful applications in the sectors of energy storage using lithium and sodium and in gas purification. The materials we describe, besides showing in all cases good performance versus state-of-the-art, demonstrate also the high maturity and versatility reached by the processing of 2D materials into bulk applications, beyond the random mixtures typically used in composites.



[1] *Review: Surface chemistry and structure manipulation of graphene-related materials to address the challenges of electrochemical energy storage.* **Chemical Communications**, 59 (18), pp. 2571 – 2583(2023), themed collection.

KN-115

Sulfur-rich macromolecular architectures from inverse vulcanization: Novel metamaterials for nanophotonics

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Low materials costs, ease of fabrication and scale-up are making all-polymer photonic structures increasingly researched for light-control applications. However, in their transparency region, most of processable polymers have relatively low and similar refractive indices, which hinder strong light confinement effects. In this respect, polymers with high content of highly polarizable S-S bonds obtained by inverse vulcanization (IV), named inverse vulcanized polymers (IVPs), revealed to be promising as photonic building blocks endowed with very high refractive index and excellent transparency in the near infrared region (NIR).[1,2]

The simple, solvent-free IV process represents indeed an efficient and green method to up-cycle waste elemental Sulfur, which is an abundant by-product of gas and oil industry, as inexpensive resource to obtain sustainable and innovative polymeric materials with unique functional properties. IV process takes advantage of Sulfur's ring-opening and linear chain-forming tendency at high temperatures by binding vinylic (or analogous) monomers to the Sulfur radicals which form when the S_8 ring opens. This leads to novel amorphous macromolecular architectures exploitable for a variety of applications for light emission control, spanning from free-standing dielectric mirros (Distributed Bragg Reflectors) with very high reflectance and microcavities for NIR emitting lasers, to fabrication of metamaterials for advanced nanophotonics. By varying type and amount of vinylic derivatives, it is possible to tune the refractive index, glass transition temperature and solubility, that is the IVPs properties resulting technologically relevant for the foreseen applications and industrial scale-up.

Acknowledgements:
Project PRIN 2020 "PETALS Polymer mETamateriALs for nanophotonicS" (prot. 2020TS9LXS) funded by Italian Ministry for Universities and Research (MUR).
Project "PIVOT Sulfur-based Polymers from Inverse Vulcanization as high refractive index materials for planar photonic crystals: dielectric mirrors and microcavities" (IDROL 20583) funded by Compagnia di San Paolo (Italy).

References:
[1] C. Tavella, G. Luciano, P. Lova, M. Patrini, C. D'Arrigo, D. Comoretto, P. Stagnaro, RSC Adv. 2022, 12, 8924 – 8935.
[2] C. Tavella, P. Lova, M. Marsotto, G. Luciano, M. Patrini, P. Stagnaro, D. Comoretto, Crystals 2020, 10, Art n. 154.

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Molecular Gold Nanoclusters and the Hydrogen/Deuterium Puzzle

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Substituent effects have never been studied by changing a *very large* number of identical substituents. This kind of study obviously requires the use of very special molecules where this kind of substitution is indeed possible. In this context, ultrasmall ligand-protected gold nanoclusters, such as $Au_{25}(SR)_{18}$ where SR is a thiolate, provide the opportunity to test the combined effect of changing 18 identical ligands.[1,2] These systems can be prepared with atomic precision, exhibit truly molecular properties, and their physicochemical, electrochemical, and electron transfer (ET) behaviors can be tuned by acting on both the metal and organic components.[1-9]

We prepared the first *fully deuterated* gold nanocluster, $Au_{25}(SC_4D_9)_{18}$, and compared its electrochemical, ET, solid-state, and photophysical behaviors in comparison with those observed for the corresponding nondeuterated $Au_{25}(SC_4H_9)_{18}$ cluster. We found that the deuterated molecule exhibits several unexpected differences. For example, the rates of heterogeneous ET and, particularly, intercluster ET in films are lower; the rate by which two deuterated clusters react in films to form Au_{38} is significantly lower than for $Au_{25}(SC_4H_9)_{18}$; single crystal X-ray crystallography evidences important differences also between the structures of $Au_{25}(SC_4D_9)_{18}$ and $Au_{25}(SC_4H_9)_{18}$. These and further results indicate that deuterated thiolates are far from being noninnocent ligands. The observed effects may be relevant, *e.g.*, to affect the behavior of nanoclusters when used as building blocks for hierarchical structures.[10]

References:

[1] S. Antonello, G. Arrigoni, T. Dainese, M. De Nardi, G. Parisio, L. Perotti, A. René, A. Venzo, F. Maran. *ACS Nano*, **2014**, 8, 2788.
[2] S. Antonello, T. Dainese, F. Maran. *Electroanal.*, **2016**, 28, 2771.
[3] M. De Nardi, S. Antonello, D. Jiang, F. Pan, K. Rissaen, M. Ruzzi, A. Venzo, A. Zoleo, F. Maran, *ACS Nano*, **2014**, 8, 8505.
[4] S. Antonello, F. Maran. *Curr. Opin. Electrochem*. **2017**, 2, 18.
[5] M. Agrachev, W. Fei, S. Antonello, S. Bonacchi, T. Dainese, A. Zoleo, M. Ruzzi, F. Maran. *Chem. Sci.*, **2020**, 11, 3427.
[6] S. Antonello, T. Dainese, M. De Nardi, L. Perotti, F. Maran. *ChemElectroChem* **2016**, 3, 1237.
[7] W. Fei, S. Antonello, T. Dainese, A. Dolmella, M. Lahtinen, K. Rissanen, A. Venzo, F. Maran. *J. Am. Chem. Soc*., **2019**, 141, 16033.
[8] M. Agrachev, M. Ruzzi, A. Venzo, F. Maran. *Acc. Chem. Res*. **2019**, 52, 44.
[9] M. Reato, T. Dainese, S. Antonello, F. Maran. *Chem. Mater*. **2021**, 33, 4177.
[10] S. Bonacchi, S. Antonello, T. Dainese, F. Maran. *Chem. Eur. J.*, **2021**, 27, 30.

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KN-117

Defects Activity in Metal Halide Perovskite Semiconductors

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Metal halide perovskites (chemical formula ABX3, A = formamidinium (FA^+), methylammonium (MA^+), or Cs^+ , B = Pb^{2+}, Sn^{2+}, X = I^-, Br^-, or Cl^-) have demonstrated a strong potential as a material platform for a new generation of optoelectronic technology. One superior feature of metal halide perovskites is their continuously tunable bandgap from near infrared to ultraviolet by designing the chemical composition of the semiconductor crystalline unit. This enables them to provide top absorbers with matched bandgaps for tandem solar cells and emissive layers for colorful light-emitting diodes (LEDs) just to mention the most common applications.

In this lecture I will assess the most recent advances in elucidating the (photo)chemistry of defects related to the chemical composition of the perovskite crystalline unit. I will show how they define the charge carrier dynamics in the semiconductor. Based on such understanding I will discuss the main electrical and spectroscopic features related to the activity of defects and how to interpret them to improve the figures of merit of optoelectronic devices and their stability.

KN-118

Mapping metabolism in action by mass spectrometry

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Over the past three decades, metabolomics has become the leading technique for analyzing complex mixtures, driven by continuous technological advancements that have dramatically improved speed, sensitivity, and detail. The widespread availability of high-end instruments has democratized access to these sophisticated measurements, prompting a critical question: what are the ultimate limits of this field?

In this presentation, I will discuss the fundamental limitations that persist despite decades of development and hinder our ability to further expand our knowledge. Additionally, I will introduce two emerging approaches that are poised to overcome these barriers, namely the use of electron-induced dissociation for fine-grained structural elucidation and the use of isotopic tracers for the quantification of metabolic conversion rates in complex networks.

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Proteomics in food research

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The "omics" sciences emerged during the last two decades and have been greatly applied in many research fields. In food science, the application of "omics" techniques to improve quality and safety of food product for consumer's health and well-being, and to increase our knowledge on the underlying pathways and mechanisms behind technological and sensorial qualities of foods, is called "foodomics" [1]. Genomics and transcriptomics were derived from new discoveries in genetics. Consequently, due to the presence of mutations in the coding sequence, variations in the starting site for mRNA translation and post-translational modifications, several million protein species are present in tissues that constitute the proteome. The proteome has been defined the complete set of proteins characterized according to their localization, interactions, post-translational modifications, and turnover at a given time point and for a given condition [2].

Proteomics supplements the other "omics" technologies to expound proteins identity, structure, functions, and interactions with other proteins in the control cellular activity [3]. High throughput and large-scale proteomics approaches are important means to analyze not only food quality but also to understand how food processing is affected by the physiology of the product and through this, to enable the optimization of the overall food production process [4]. The main used methodology to investigate proteome develops in two steps: protein extraction and separation from the cell or tissue to reduce sample complexity, and identification and quantification using mass-spectrometry. Obtained data are then processed through statistical tests to list differential protein, bioinformatics analysis and verification of proteins functions and related molecular mechanisms [5]. On this line, proteomics emerged as a multidisciplinary approach to food analysis.

Analyzing through Scopus search engine, all original and review articles on food proteomics published worldwide, it emerged an increase of more than 160% in research activity on the field from 2013 to 2023. Among the food matrices, meat is the most studied with proteomics approaches. Meat quality, safety, technology and impact of specific farming system, feed or supplements on animal proteomes are crucial topics for industries, also in terms of process sustainability, for example with organic productions [4].

In conclusion, the keynote delves into the state of the art of proteomics in food science and aims to spread awareness on this multidisciplinary high-throughput approach as an applicable tool in food research.

References:

[1] P.E. Munekata, M. Pateiro, M. López-Pedrouso, M. Gagaoua, J.M. Lorenzo, Current Opinion in Food Science 2021, 38, 79-85.

[2] B. Santiago, W. Baldassini, O.M. Neto, L.A. Chardulo, R. Torres, G. Pereira, R. Curi, M. Chiaratti, P. Padilha, L. Alessandroni, M. Gagaoua, Journal of Proteomics 2023, 278, 104871

[3] L. Mora, M. Gallego, F. Toldrá Current Opinion in Food Science 2018, 22, 22-7

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Volatomics and Postharvest Handling of Horticultural Crops

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The postharvest handling is crucial to limit loss of fresh horticultural products as they are highly perishable. It is estimated that 30% of produced horticultural products are lost in processes between harvest and consumption [1]. Reduction of these losses is imperative as they impact the overall volume and sustainability of food produced worldwide. Recently, research has been focused on the development of suitable technologies able to positively affect the postharvest quality and shelf life of fruit and vegetables, also improving consumers' preference [1].

Plants biosynthesize an incredible variety of metabolites through different biosynthetic pathways and emit a multitude of volatile organic compounds (VOCs) that mediate their interaction with the environment. During postharvest storage, horticultural commodities undergo various biotic and abiotic stresses. Biotic stress includes the damage caused by microbial contamination and natural senescence mediated by plant-cell enzymes, while abiotic stress factors typically involve low temperatures, high relative humidity, decrease in oxygen, increase in carbon dioxide concentration. Moreover, postharvest mechanical damage during transport and handling from field to storage site are also considered abiotic stress. Additionally, Ready-to-Eat (RTE) products are subject to further postharvest abiotic stress processes, including washing, peeling, cutting and packaging. Each of these factors induces signature alterations in the metabolic pathways of crops, and their combination ultimately leads to complex changes in the composition of the VOCs profile [3]. Therefore, VOCs changes depending on storage conditions and are biomarkers in postharvest storage management. Volatomics, a subset of metabolomics, concerns with the comprehensive characterization of VOCs to assess the quality of horticulture crops along commercial storage, as the results of a complex interplay of factors also including packaging. Volatomics relies on the targeted or untargeted identification of putative volatile markers of freshness using advanced analytical techniques, firstly gas chromatography coupled with mass spectrometry (GC-MS), also integrated with statistical models, multivariate analysis techniques, and shelf-life prediction by innovative (e-nose) non-destructive strategies [3-5].

Such a structured analytical workflow enables the access to in-depth knowledge of the molecular events that occur in the postharvest phase and contribute to rationally plan the processes aimed at preserving the quality of fruit and vegetables and minimizing losses.

References:

[1] S. Tiwari, A. Kate, et al. Trends in Food Science & Technology, 2020, 417-433.
[2] K. Bagawan, M. Roshni, & Jagadeesan, Resonance, 2022, 2183–2211.
[3] R. Cozzolino, A. Martignetti et al. Food Chemistry 2019, 659-668.
[4] R. Cozzolino, et al. LWT- Food Sci Technol 2020, 110408-110416.
[5] R. Cozzolino, M. Palumbo et al. Food Packaging and Shelf Life, 2023, 101130-101141.

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NMR-based metabolomics in food science

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Foods are complex matrices and it is necessary to combine different skills and methodologies to obtain comprehensive information about their composition. Metabolomics is a non-biased identification and quantification of all metabolites in a biological system. This approach has emerged as an important tool in many different fields including food science. Food metabolomics gives the opportunity to gain deeper insights into, and have a better control of the fundamental biochemical basis of the things we eat. In metabolomics, Nuclear Magnetic Resonance (NMR) is recognized as one of the main analytical methodologies giving a complete view of the foodstuffs metabolites and allowing the identification and quantification of many compounds without chemical separation: NMR can bring ''high-throughput'' spectroscopic/structural information on a wide range of metabolites simultaneously with high analytical precision.
Using this methodology together with a suitable statistical analysis it was possible to obtain relevant results in terms of foodstuffs quality, geographical origin, detection of frauds, processing, raw material safety and so on [1,2].

Here, some relevant results will be discussed underlining the strengths and weaknesses of the methodology and highlighting the complementarity with other methodologies.

Finally, the different activities of the Italian group of Magnetic Resonance in Food Science established in the frame of GIDRM will be shown [3].

References:

[1] A. P. Sobolev, C. Ingallina, M. Spano, G. Di Matteo, Luisa Mannina, Molecules 2022, 27, 7906 – 7929
[2] L. Mannina, A. P. Sobolev, S. Viel c, Progress in Nuclear Magnetic Resonance 2012, 66, 1 – 39.
[3] L. Mannina, N. Proietti, V. Di Tullio, A.P. Sobolev, La Risonanza Magnetica nella Scienza degli Alimenti 2023, Ed CEA

KN-122

The metrological approach for the future of analytical chemistry in food science: issues, sinergies and challenges

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Analytical chemistry has become the "enabling discipline of science" capable of answering interdisciplinary questions for many research areas of chemistry and for other scientific fields such as materials science, life sciences, medicine, or food sciences.

The current role of analytical chemistry in opening up new areas of science is the development of new analytical techniques and methodologies that make it possible to extract reliable (bio)chemical information from objects and systems for decision-making purposes to address increasingly challenging problems[1]. In this context, analytical chemistry has to find a balance between its main aims, namely achieving high metrological quality and analytical problem solving, and its overall objectives, which are to provide reliable chemical information and reduce costs and time[2].

Relating to food science, cutting-edge analytical method approaches are being developed in response to emerging food fraud and safety issues, including also assessment of nanomaterials in food. At the same time, great attention has to be paid to the application of metrological tools in response to the ever-evolving challenges of regulatory demands by delivering results compliant with legislation with the speed and accuracy stakeholders expect, while minimizing the risk of recalls: these needs highlight the importance of metrological traceability in achieving comparable analytical results that are independent of temporal or spatial boundaries[3]. Furthermore, considering the growing interest in real-time analysis and process analytical technology (PAT) systems for process control in the food industry, as well as the trend towards the development of smart devices for point-of-need (PON) food safety screening, metrological traceability and reliability of measurements in real-life conditions has to be demonstrated, a challenge not easily met with the analytical tools of PAT and the analytical methods for PON testing[4].

In this lecture, issues, sinergies and challenges of analytical metrology and nanometrology are addressed.

References:

[1] G.M. Whitesides, Angew. Chem. Int. Ed. 2015, 54, 3196–3209.
[2] M. Valcárcel, Anal. Bioanal. Chem 2016, 408, 13–21.
[3] F. Bianchi, M. Giannetto, M. Careri, TrAC Trends Anal. Chem. 2018, 107, 142–150.
[4] M. Mattarozzi, E. Laski, A. Bertucci, M. Giannetto, F. Bianchi, C. Zoani, M. Careri, Anal. Bioanal. Chem. 2023, 415, 119–135.

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Agri-food chain legislation: official control in Italy

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"Regulation (EU) 2017/625 — official controls along the agri-food chain" has applied since 14 December 2019 to set out common rules for European Union (EU) official controls to ensure that agri-food chain legislation to protect human health, animal health and welfare, and plant health, is correctly applied and enforced. The regulation introduced a more harmonised and coherent system of official controls and enforcement measures along the agri-food chain, and strengthens the principle of risk-based controls. Legislative decree 27/2021" Disposizioni per l'adeguamento della normativa nazionale alle disposizioni del regolamento (UE) 2017/625 ai sensi dell'articolo 12, lettere a), b), c), d) ed e) della legge 4 ottobre 2019, n. 117- GU n.60 del 11-3-2021" was published to adapt national legislation to the Regulation (EU) 2017/625.

The Italian Laws set certain exclusive competences to the State (national coordination, international relations, import controls and international disease protection) and defines the areas where competences are shared between the state and the regions, that have responsibility, within their territories, for planning, coordination, guidance, authorization and verification of official controls.

In Italy most of the competencies for animal health, food and feed safety, animal welfare, risk assessment in the food chain and consultation of producers and consumers are assigned at national level to the Directorate-General for Animal Health and Veterinary Medicine (DGAHVM), Directorate-General for Food Hygiene, Food Safety and Nutrition (DGFHFSN) and Directorate General for Collegial Bodies for Health Protection (DGCBHP) of the Ministry of Health. The operational implementation of controls is handled at local level by 110 ASL. Ministry of Agriculture, Food Sovereignty and Forestry (MASAF) as provided for in Decree-Law No 86 of 12 July 2018, is responsible for plant health and for controls on the quality of food, feed and some aspects in the field of plant protection products and fertilisers to plan, schedule, execute, monitor and reporting on official controls. The National Institute of Health (ISS, Istituto Superiore di Sanità) is the main technical and scientific public body of the Italian National Health Service. The ISS, as a national reference laboratory for many areas of activity, coordinates the laboratories of the Italian National Health Service engaged in food and feed control and, in the event of a dispute, performs the second expert opinion. Its activities include research, control, training and consultation in the interest of public health protection.

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Recent trends of allergen analysis in food

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In western countries, about 5 % of adult population and 8 % of children suffers for food allergy. EU Regulation 1169/2011[1] requires the labelling of 14 allergenic ingredients (mainly proteins) when they are included in a foodstuff recipe. Beside immunoenzymatic (ELISA) and bio-molecular assays (PCR) widely used in official controls, in the last fifteen years methods based on liquid-chromatography coupled to mass spectrometry (LC-MS) have been developed, too. By means of a bottom-up approach, LC-MS methods are based on the detection of proteotypic peptides obtained from the enzymatic digestion of allergenic proteins. Despite their high cost, these procedures have two fundamental advantages: high selectivity with the ultimate identification of the allergen then avoiding false positive results and the possibility of the simultaneous determination of more than one peptide also from different allergens enabling multiplexed analysis. Except for gluten[2], there are currently no regulatory limits or action thresholds in Europe to manage the unintentional presence of allergens resulting from potential cross-contamination during food production, despite the fact that objective risk assessment should be based on quantitative evidence. On the one hand, there are several difficulties to compare laboratory results obtained with the various techniques (ELISA, PCR, LC-MS). On the other hand, for LC-MS methods, several quantification approaches based on external and internal standardization have been attempted, including the use of different types of labelled peptides (long and short chain) and concatamers. However, since the initial "analytes" are proteins, when complex foods are analysed, accuracy is not always satisfactory. A review of quantification strategies applied so far is presented here.

References:

[1] Regulation (EU) No. 1169/2011. Official Journal of the European Communities 2011, L 304, 18–63
[2] Commission implementing Regulation (EU) No. 2014/828. Official Journal of the European Communities 2014, L 228, 5-8

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How Food Chemistry can support the safety assessment of Novel Foods

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The food industry's interest in novel foods is rapidly increasing, driven by sustainability goals, innovation, and the pursuit of new market opportunities. Novel foods offer significant potential for discovering new protein sources, bioactive compounds, and innovative uses of familiar ingredients, while also tapping into the vast chemical biodiversity of plant and marine resources.

Ensuring and properly communicating the safety of these novel foods is paramount not only for obtaining their approval in the EU, but also to increase their acceptance among consumers. Safety evaluation goes beyond traditional assessments of known contaminants or toxins; it must also encompass the identification of potential new compounds with biological or toxicological effects, as well as assessing allergenic risks.

In this context, the molecular approach provided by Food Chemistry serves as a powerful tool for evaluating the safety profile of novel foods. This enables companies in the sector to develop new, innovative, and safe products confidently as well as it offers sound information to risk assessors and regulators.

This presentation will highlight various molecular approaches for assessing toxicity, bioactivity, and allergenic potential, using relevant case studies. Special emphasis will be placed on alternative plant protein sources, such as legumes, and innovative plant-derived products like coffee and hemp, bringing clear evidence of the key role played by Food Chemistry methodologies in their evaluation.

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KN-126

The power of analytical chemistry for the traceability of Italian excellences

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Food chemistry studies the chemical processes and interactions of all biological and non-biological components of foods. It is continuously involved in the assessment of food quality and authenticity, the control of technological processes, the determination of nutritional values and the detection of molecules with a possible beneficial effect or a toxic effect on human health.
In this context, analytical methods should be capable to allow the determination of the main components of food samples but also, they should be selective and sensitive enough to determine minor ones.
Surely, chromatography has acquired a central role in food analysis and especially its combination with mass spectrometry provides a unique performance due to the complementarity of the two techniques. Notably, also mass spectrometry itself, due to its high identification power and high sensitivity, might be employed without the support of chromatography.
In recent years, food chemistry, by adopting these methods, helped to solve routine and challenging problems, such as the detailed characterization and quantification of complex natural matrices.
Key aspects of analytical techniques today applied to food chemistry are: miniaturization, automation, reduced environmental impact, speed of analysis, among others. Chromatography and mass spectrometry have for sure moved towards these directions, offering different solution for different laboratories: QA, R&D, industry, academia, advanced research. Nowadays, mass spectrometry enables the obtainment of unique “fingerprints”, with the advantage to be extremely fast ang “greener” since they do not require any sample pre-treatment and analyse the sample as it is (in its native form) without any separation step.
In this lecture, an overview of significant achievements, in the use of different chromatographic and mass spectrometric approaches in food chemistry, useful for the traceability of Italian excellences, are presented.

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Coffee chemotaxonomy markers: focus on diterpenes

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Coffee represents one of the most known traded tropical commodities, however for coffee drinkers it is easy to forget that coffee is, first and foremost, a plant. The coffee plant belongs to the Rubiaceae family, genus *Coffea* which comprises around 130 species distributed through equatorial and sub-equatorial Africa, Madagascar, India, SE Asia and Australasia. The three coffee species with commercial interest are *C. arabica*, *C. canephora* and *C. liberica*, known in the trade as Arabica, Robusta and Liberica, respectively. Coffee taxonomy is undoubtedly a very complex topic, but chemistry can be considered a useful tool to address its complexity. Coffee diterpenes, the major components of the unsaponifiable fraction of coffee oil, have always played an important role for both authenticity and traceability of coffee products. In particular cafestol, kahweol and 16-O-methylcafestol have been the subject of several studies, and their green coffee beans content mainly depends on both botanical species and geographical origin. While chemometric approaches have been widely used to study cultivated coffee species, very little has been done from the perspective of chemotaxonomy of wild species of the genus *Coffea.* We believe that diterpenes, not yet fully exploited from a chemotaxonomic point of view, may also provide useful information on wild coffee species that are currently not of commercial interest or whose taxonomic subdivision is still unclear.

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Quality and safety aspects of food supplements

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In the last decades an increasing attention has been paid to "nutraceutical science", involving different products aimed at enhancing consumers' health: fortified foods, functional foods, some traditional medicine derivatives, and dietary supplements. These products include a spectrum of ingredients ranging from vitamins, minerals, amino acids to botanical preparations. Ensuring the efficacy and safety of nutraceutical products necessitates rigorous quality control measures. Specifically concerning botanicals, particular attention is required for raw materials, including the identification of plant materials, quantification of active molecules responsible for physiological effects as well as adverse effects, the assessment of environmental contaminants or residues from agricultural practices[1]. Another significant challenge in ensuring consumers' safety is related to counterfeits or adulteration with illicit substances such as doping agents or conventional drugs, as documented in scientific literature or in national/international notifications. Quality control procedures require the selection of appropriate analytical methods (according to the objectives), capable to identify/quantify the searched molecules. However, quality aspects are only one of the contributors to the onset of adverse effects.

Consumers' awareness, food-related diseases, specific physiological conditions (pregnancy, lactation, childhood, elderly) and the concomitant drug therapies are considered other important cofactors involved in "safety" concept[2].

References:

[1] C. Di Lorenzo, A.Dopter, S. Vecchio, S. Lude, F. Colombo, F. Orgiu, P. Restani, 2018, Ed. Springer International Publishing AG, 141 – 176.
[2] C. Di Lorenzo, A. Ceschi, H. Kupferschmidt, S. Lüde, E. De Souza Nascimento, A. Dos Santos, F. Colombo, G. Frigerio, K. Nørby, J. Plumb, P. Finglas, P. Restani, 2014, 79, 578-592.

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The pomegranate fruit: not just a simple food

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Pomegranate (*Punica granatum* L.) is a widely recognized edible food and medicinal plant, containing flavonols, anthocyanins, and tannins, with ellagitannins being the most abundant polyphenols. Its cultivation, consumption and scientific interest are strongly increased, due to multiple beneficial effects as well as the chemical differences found among its cultivars.[1] Its fruit is a balausta surrounded by a thick and coloured peel composed of a hard exocarp and a spongy mesocarp with edible arils inside, whose juice can be released by pressing. The edible portion of pomegranate is known for the nutritional profile, and it provides vitamin C, vitamin K, and folate. Pomegranate seeds are a rich source of dietary fiber which is entirely contained in the peel and seeds. The latter are also used to obtain the oil, rich in fatty acids such as punicic acid. The non-edible peel of the fruit and the split fruit, not suitable for the market, although generally disposed as agricultural waste or transformed into animal feed, compost, or biogas, can be also used to extract bioactive components as dietary supplements and other value-added products, providing new opportunities for the pharmaceutical, cosmetic, and food industries.[2] The limited oral bioavailability can be enhanced using suitable encapsulation methods. Green extraction approaches, including pressurized liquid, ultrasound-assisted, microwave-assisted, and enzyme-assisted techniques, or technological processing of this matrix opened new scenarios. Furthermore, pomegranate peel can be utilized as fertilisers for sustaining soil fertility and enriching soil microbiota and in the food industry, improving the nutritional value, organoleptic characteristics, and shelf life of food products, thus limiting the overall organic waste.[3]

References:

[1] D. Balli, L. Cecchi, M. Khatib, M. Bellumori, F. Cairone, S. Carradori, G. Zengin, S. Cesa, M. Innocenti, N. Mulinacci, Antioxidants 2020, 9, 238.
[2] C. Fraschetti, E. Goci, A. Nicolescu, F. Cairone, S. Carradori, A. Filippi, V. Palmieri, A. Mocan, S. Cesa, Foods 2023, 12, 1908.
[3] F. Azmat, M. Safdar, H. Ahmad, M.R.J. Khan, J. Abid, M.S. Naseer, S. Aggarwal, A. Imran, U. Khalid, S.M. Zahra, F. Islam, S.A. Cheema, U. Shehzadi, R. Ali, A.B. Kinki, Y.A. Ali, H.A.R. Suleria, Food Sci Nutr. 2024, 12, 661-674.

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Microplastics in Foods: Origin and Detection Methods

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Microplastics (MPs) are defined as plastic particles ranging in size from 5 mm down to 0.1 µm, further classified as primary and secondary MPs. Primary MPs are intentionally added to specific products, such as skincare or cosmetic formulations. Secondary MPs result from the mechanical wear, UV degradation, or oxidation of plastic waste in the environment.[1] MPs were first detected in marine environments in the 1980s[2]; they were later detected in soils and freshwaters. Not surprisingly, seafoods attracted first the attention of scientist looking for MPs presence[3]. More recently, MPs have been detected in other food, such as packed meat, sugar, beer, honey, milk, salt, as well as fruit and vegetables. Additionally, there have been recent reports indicating that plastic packaging could potentially release plastic particles during use and package opening.

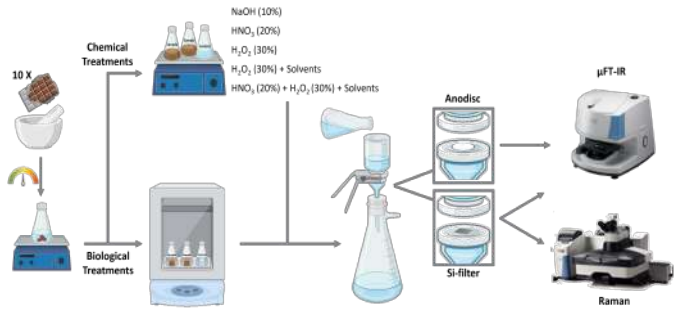

Figure 1: Sample work-up and identification techniques for MPs in chocolate.

In this presentation, the origin of MPs found in food will be addresses, along with the central role taken up by an efficient sample work-up designed to eliminate, or at least reduce, the matrix effects. Examples drawn by the recent literature are discussed, along with some contributions made by the research group at DICAM[4].

References:

[1] R. C. Thompson, Y. Olsen, R. P. Mitchell, A. Davis, S. J. Rowland, A. W. G. John, D. McGonigle, A. E. Russell, Science 2004, 304, 838 - 838
[2] I. E. Napper, R. C. Thompson, Global Challenges 2020, 4, 1900081 - 1900089.
[3] L. G. A. Barboza, A. Dick Vethaak, B. R. B. O. Lavorante, A. K. Lundebye, L. Guilhermino, Marine Pollution Bulletin 2018, 133, 336 - 348
[4] E. Battaglini, P. Miralles, N. Lotti, M. Soccio, M. Fiorini, C. Coscollà, Food Chemistry 2024, 443, 138567 - 138572.

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Upcycling of fishery unsorted side-streams: a case study

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It has been estimated that approximately 35 % of the global fish production is lost or wasted annually, presenting significant economic and environmental challenges. As a result of rising fish consumption, the consequent production of side streams by the fish supply chain (fishing, aquaculture, and the processing sector), namely fishery side streams, is also increasing. Two different types of side streams are commonly generated, the first is made up of whole fishes, coming from unwanted catches, by-catches, and undersized catches. The second type consists of by-products and leftovers from both filleting and/or preservation processes. If in the first case the sorting of different pieces is difficultly feasible, in the second it is feasible, but quite expensive in terms of costs, time and energy. Thus, recovering valuable components before disposal becomes the prime target in the management of solid fishery biomasses and it could be a valid alternative for their upcycling.

Over the years, various conventional techniques have been utilized to exploit these biomasses, including the production of fish meal via wet pressing, fish oil through hydrophobic solvent extraction, and biofuel through esterification. Even if there has been an improvement in fish exploitation, the potential for the generation of fishery side streams remains high due to their highly perishable nature and the presence of inedible fractions. The urgent requirement to shift production systems towards environmentally sustainable alternatives has spurred the EU Commission to formulate and endorse "Blue Growth," a strategic plan designed to promote long-term sustainable growth in the marine and maritime sectors[1]. Many research projects have been funded at the European level, among them EcoeFISHent, which is a project funded under the Horizon 2020 Program - Green Deal (Innovation Action, Grant agreement ID: 101036428)[2]. This project aims at promoting circular economy practices within the fishing sector with the peculiarity to revolve around handling and valorizing of unsorted fishery by-products. In the frame of the EcoeFISHent project, a scalable method represented by a single cascade flowchart for extracting and upcycling proteins from unsorted tuna side streams (both raw and cooked) will be presented as case study[3]. In details, the starting biomasses were made up of a dehydrated mix of canned tuna leftovers stabilised by an innovative industrially patented procedure and the obtained extracts have been addressed to bio-packaging, cosmetic and nutraceutical applications[4].

References:

[1] https://s3platform.jrc.ec.europa.eu/blue-growth
[2] https://ecoefishent.eu/
[3] Grasso F, Méndez-Paz D, Vázquez Sobrado R, Orlandi V, Turrini F, De Negri Atanasio G, Grasselli E, Tiso M, Boggia R. Gels. 2023;9(9):760
[4] Orlandi V, Dondero L, Turrini F, De Negri Atanasio G, Grasso F, Grasselli E, Boggia R. Molecules. 2023, 17;28(22):7637

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Use of lamellar solids as a novel approach to food processing

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Solid phase extraction is nowadays a well validated and powerful technique applicable to chemically complex matrices like edible plant extracts, phytocomplexes, and food preparations in general. This process provides concentration and/or purification of selected chemicals, active principles, and secondary metabolites in general from these matrices for subsequent analysis and isolation, and /or enrichment of food and phytopreparations.

To this concern, during the last five years we developed a novel approach for food processing consisting in the use of solid sorbents belonging to different chemical classes like layered structures (e.g. inorganic and inorganic-organic hydrotalcite and zirconium phosphates), magnesium oxide and hydroxide, and phyllosilicates.

Such techniques have been successfully applied for the selective extraction of anthraquinones from laxative plants[1], of polyphenols and alkaloids from extracts of *Camellia sinensis* (L.) Kuntze (tea plant)[2], of curcumin from *Curcuma longa* L. (turmeric)[3], of bitter principles from leaves and roots of *Gentiana lutea* L. (great yellow gentian)[4,5], of capsaicinoids from different cultivars of *Capsicum annuum* L. (pepper)[6], of oxyprenylated coumarins from *Citrus* fruits[7], of crocetin from *Crocus sativus* L. (saffron)[8], and of polyphenols from *Punica granatum* L. (pomegranate)[9]. In all cases very good extractive yields have been obtained. Finally, the use of the above-mentioned solid sorbents was shown to be useful for the extraction and analysis of some food colorants, like tartrazine (E102) and brilliant blue (E133) from selected food matrices[10]. All solids were recyclable and could be re-used to accomplish additional steps without appreciable loss of adsorption capacity.

References:

[1] F. Epifano, S. Genovese, et al., J. Pharm. Biomed. Anal. 2020, 190, 113515.
[2] S. Genovese, F. Epifano, et al., J. Pharm. Biomed. Anal. 2021, 196, 113945.
[3] S. Fiorito, F. Epifano, et al., Food Anal. Meth. 2021, 14, 1133-1139.
[4] S. Fiorito, F. Epifano, et al., Food Chem. 2021, 364, 130383.
[5] S. Fiorito, F. Epifano, et al., J. Nat. Prod. 2022, 85, 2232-2235.
[6] S. Genovese, F. Epifano, et al., J. Food Compos. Anal. 2021, 102, 104052.
[7] S. Fiorito, F. Epifano, et al., Plant Food Hum. Nutr. 2021, 76, 397-398.
[8] S. Fiorito, L. Palumbo, et al., Food Chem. 2022, 377, 132040.
[9] S. Genovese, F. Epifano, et al., Food Chem. 2022, 387, 132091.
[10] S. Fiorito, F. Epifano, et al., Food Res. Int. 2023, 172, 113094.

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Organometallic Catalysis Applied to the Synthesis of High Value Added Compounds: The Contribution of the Research Group of Industrial and Synthetic Organic Chemistry of the University of Calabria

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In this lecture, I will illustrate some of the most important achievements that have been realized in my lab during the long-lasting experience in the field of homogeneous organometallic catalysis applied to the synthesis of high value added compounds from simple and readily available starting materials.

Particular emphasis will be given on the catalytic activation of carbon oxides (especially, carbon monoxide)[1] for the direct and selective installation of the carbonyl moiety into simple organic substrates (especially, acetylenic derivatives), and on the synthesis of heterocyclic derivatives by metal-catalyzed heterocyclization reactions.[2]

References:

[1] B. Gabriele (Ed.), *Carbon Monoxide in Organic Synthesis – Carbonylation Chemistry*, Wiley-VCH, **2022**.
[2] B. Gabriele, R. Mancuso, L. Veltri, I. Ziccarelli, N., Della Ca', *Eur. J. Org. Chem.* **2019**, 5073 – 5092.

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Aluminum Cocatalysts for Olefin Polymerization: Methylaluminoxane and its "Molecular Cousins"

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Over the last few decades, molecular olefin polymerization catalysis has rapidly emerged from questions of mere academic interest to applications in large-scale industrial production of high-performing materials. This transformation was sparked in the 1980s by the concomitant discovery of thermally stable group 4 metal catalysts and highly efficient activators/cocatalysts.[1] Nonetheless, the subsequent tremendous progress experienced by this field has been mostly driven by the continuous development of novel catalysts,[2] while advancement in cocatalysts has been limited.

The difficulties in developing innovative cocatalysts derives from the complex cross-reactivity between the various components of the catalytic pool and the many subtleties determining catalytic performance.[1] Even widely used cocatalysts, such as methylaluminoxane (MAO), continue to elude comprehensive understanding.

Some recent advancements in cocatalysts discovery and development will be discussed in this presentation. They include insights on the structure and reactivity of MAO and some of its modifications, as well as the analysis of a novel promising class of molecular Al-cocatalyst. The prototype of this latter class consists of a borate salt of an unusual dinuclear Al-alkyl cation, stabilized by an N-donor and a bridging hydride (**AlHAl**, Figure 1).[3] This species proved to combine the ability of MAO to act as a "complete"/stand-alone cocatalyst with the advantage of having a well-defined structure and working at low concentrations. Despite being an Al-alkyl cation, it is stable at room temperature and easy to synthesize. Furthermore, it is potentially amenable to structural variations for reactivity tuning, which we are currently exploring.

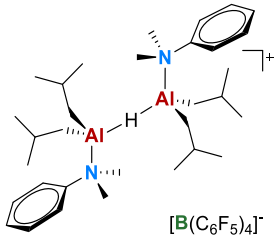

Figure 1: Structure of MAO's "molecular cousin", **AlHAl**.[3]

References:

[1] F. Zaccaria, L. Sian, C. Zuccaccia, A. Macchioni, *Adv. Organomet. Chem.* **2020**, *73*, 1–78.
[2] M. C. Baier, M. A. Zuideveld, S. Mecking, *Angew. Chem. Int. Ed.* **2014**, *53*, 9722–9744.
[3] a) F. Zaccaria, C. Zuccaccia, R. Cipullo, P. H. M. Budzelaar, A. Vittoria, A. Macchioni, V. Busico, C. Ehm, *ACS Catal.* **2021**, *11*, 4464-4475; b) G. Urciuoli, F. Zaccaria, C. Zuccaccia, R. Cipullo, P. H. M. Budzelaar, A. Vittoria, C. Ehm, A. Macchioni, V. Busico, *Polymers* **2023**, *15*, 1378; c) G. Urciuoli, F. Zaccaria, C. Zuccaccia, R. Cipullo, P. H. M. Budzelaar, A. Vittoria, C. Ehm, A. Macchioni, V. Busico, *Dalton Trans.* **2024**, *53*, 2286-2293.

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Novelty in Transfer Hydrogenation and Related Reactions Catalyzed by Ruthenium Catalysts

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Transfer hydrogenation (TH) is a straightforward transformation for the reduction of carbonyl compounds to alcohols using suitable hydrogen donors under mild reaction conditions. Conversely, carbonyl compounds can be obtained by alcohols by means of hydrogen acceptors without the use of hazardous oxidants. As a result of the reversibility of the TH, borrowing hydrogen transformations, namely C-C and C-N forming reactions, can be achieved via C-H activation. In order to have access to selective catalytic processes, the development of well-defined homogenous catalysts, obtained through a fine tuning of non-innocent ligands via metal-ligand cooperativity, is a current research target.[1] In addition, high catalyst productivity is a critical factor for applications and relies on the design of robust catalysts.

This presentation deals with the preparation of ruthenium complexes, containing bidentate and pincer ligands, which display high activity in the TH of carbonyl compounds, Oppenauer-type alcohol oxidation, alcohol racemization, hydrogenation, dehydrogenation, amine alkylation and photochemical TH reactions (Figure 1). Mechanistic studies indicates that Ru-hydrides and Ru-alkoxides are key species involved in the catalytic processes.

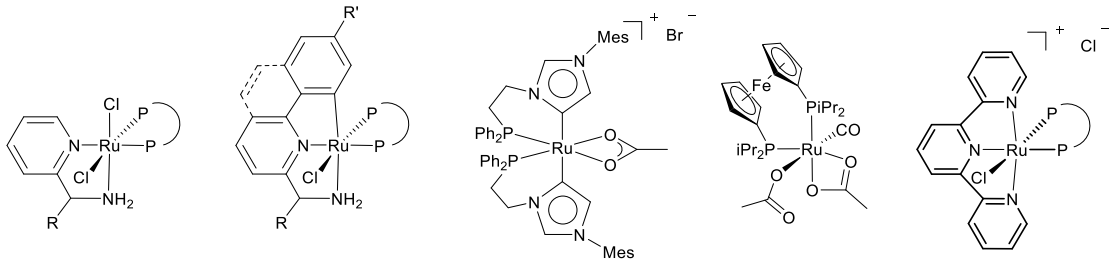

Figure 1

References:
[1] Ramspoth, T. F.; Kootstra, J.; Harutyunyan, S. R. *Chem. Soc. Rev.* **2024**, doi.org/10.1039/D3CS00998J

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A multiscale perspective on charge transfer reactions for connecting experiments and simulations

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The applications of multiscale quantum-classical approaches have experienced a remarkable expansion and diversification in recent times. One of the pivotal objectives of these theoretical modelling approaches is the direct comparison between computed and measured observables, accounting for the intricate interplay between a reaction and the environment in which it takes place. In response to this challenge, we have developed the Perturbed Matrix Method (PMM),[1] a theoretical-computational hybrid quantum/classical methodology to be used in conjunction with molecular dynamics (MD) simulations. This approach has proven its effectiveness as a valuable tool for exploring diverse processes within complex molecular systems. I will highlight two recent applications of the PMM methodology, with a primary focus on charge transfer reactions in biomolecules.

In the first application,[2] we addressed the study of ultrasmall peptide-protected gold nanoclusters (AuNCs), an emerging class of materials with distinct and tunable physicochemical properties that exhibit pH-sensitive photoluminescence (PL). Through the systematic calculation of local environment-dependent deprotonation free energies, we provided insight into how the PL emission intensity of peptide-coated AuNC is related to solution pH, in line with previous experimental observations.

In the second application,[3] we studied the kinetics of the light-induced electron transfer reaction in a flavoenzyme, lactate monooxygenase, that is a good platform for non-natural photoenzymatic catalysis. We investigated the photo-initiated ET at the flavin mononucleotide binding site in the apoenzyme and in the presence of a model substrate. By integrating our computational findings with experimental data obtained from ultrafast spectroscopy, we provided mechanistic insights into the photochemistry of the enzyme.

References:

[1] L. Zanetti-Polzi et al. Phys. Chem. Chem. Phys. 2018, 20.37, 24369-24378.
[2] L. Zanetti-Polzi et al. ACS Nano 2022, 16.12, 20129-20140.
[3] X. Li et al. J. Am. Chem. Soc. 2023, 145.24, 13232–13240.

KN-137

Advanced supercomputing approaches in chemistry and prebiotic chemistry

G. Cassone

Owing to the impressive growth of the computational power and of the development of novel computational techniques, including data-driven approaches, nowadays it is possible to simulate the behavior of matter under disparate conditions with unprecedented reliability. In this brief introduction, I will show how modern *ab initio* molecular dynamics (AIMD) simulations can shed light on one of the simplest – yet intricate – chemical reactions (*i.e.*, proton transfer) fully including the quantum nature of matter [1]. Besides, I will also show how human-based concepts on which the literature has debated for centuries, like the existence of two different ionic states (*i.e.*, Eigen *vs*. Zundel) responsible for the proton transfer mechanism in liquid water, can be revolutionized by agnostic methods exploiting unsupervised learning [2]. After the presentation of the catalytic properties held by external electric fields in triggering molecular dissociations and proton transfer, I will show how those fields can be tailored to generate either a genuine *chemical* [1] or a *physical* response in H-bonded systems [3,4].

The possibility to explicitly simulate disparate external energy sources with the accuracy afforded by Density Functional Theory and Quantum Mechanics, is particularly useful in prebiotic chemistry, where conditions difficult to be reproduced in laboratory are often encountered. During this talk, I aim to present a series of quantum-based simulations where chemical reactions of interest in prebiotic chemistry were reproduced. After a rapid overview of the potentiality offered by disparate techniques, such as AIMD and metadynamics, in chemistry [5] and in the prebiotic realm [6], I will present the results stemming from a series of advanced simulations based on the multi-scale shock-compression technique (MSST) combined with AIMD approaches. By means of those methods, the shock-wave-driven chemistry of mutually colliding isocyanic acid (HNCO)-containing icy grains has been simulated by first principles [7]. At the highest velocity considered (10 km/s), impacts drive the production of diverse carbon-carbon bonded species. In addition to glycine, the building block of alanine and one of the major components of a plethora of amino acids including, *e.g.*, asparagine, cysteine, and leucine, have been detected after shock compression of samples containing the most widespread molecule in the universe (H_2) and the simplest compound bearing all the primary biogenic elements (HNCO). Finally, if time permits, results on the catalytic properties carried by interstellar ices will be presented [8] in conjunction with very recent computational evidence proving the existence of abiotic chemical pathways capable of producing phosphine in the Venusian atmosphere [9].

References:

[1] G. Cassone, *JPCL* **2020**, 11, 8983.
[2] S. Di Pino *et al*. *JPCB* **2023**, 127, 9822.
[3] G. Cassone & F. Martelli, *Nature Communications* **2024**, 15, 1856.
[4] G. Cassone *et al*. *JPCL* **2022**, 13, 9889.
[5] G. Cassone *et al*. *Chem. Sci*. **2017**, 8, 2329.
[6] G. Cassone *et al. Chem. Commun.* **2018**, 54, 3211.
[7] G. Cassone *et al. ApJL* **2018**, 866, L23.
[8] G. Cassone *et al. MNRAS* **2021**, 504, 1565.
[9] K. Mrazikova *et al.*, *Astrobiology* (just accepted)

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KN-138

From β- to Ω-oxidation: NMR targeted metabolomics sheds light on dual enzymatic functions in mitochondrial long-chain fatty acid metabolism

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Fatty acid oxidation (FAO) defects are inherited metabolic diseases caused by deficiency of specific enzyme activities or transport proteins involved in the mitochondrial catabolism of fatty acids. Common disorders of this group include, for instance, very long-chain acyl-CoA dehydrogenase (VLCAD) and acyl-CoA dehydrogenase family member 9 (ACAD9) deficiencies. The clinical features are highly variable, ranging from multi-organ failure in newborns associated with a high mortality rate to late onset milder phenotypes. Understanding the molecular mechanisms governing the oxidation of long-chain fatty acids is essential for effective treatments of FAO defects.

Our investigation unveils a previously unrecognized aspect of mitochondrial long-chain fatty acid metabolism, revealing the coexistence of both β- and Ω-oxidation processes catalysed by two distinct acyl-CoA dehydrogenases. Through the application of ^{13}C NMR metabolomics and MS approaches, we elucidate the intricate interplay between enzymatic functions, providing new insights into the modification of fatty acids. These findings deepen our understanding of lipid metabolism and pave the way for promising biotechnological applications, potentially inspiring the development of novel enzymatic tools for lipid modification and metabolic engineering in various fields.

KN-139

Late-Stage Functionalizations

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Late-stage functionalization reactions reliably functionalize already complex molecules to quickly access value-added molecular diversity. Late-stage functionalization is desirable in many areas of discovery such as in drug or agrochemical development, and a requirement in other areas such as the synthesis of positron-emission tomography (PET) tracers. I will describe the development of novel, modern highly selective reactions in late-stage functionalization, as well as their application in transition-metal-catalyzed and photoredox reactions, with a focus on the synthesis of ^{18}F and ^{19}F containing complex small molecules. In particular, I will describe the development of broadly useful C-H thianthrenation reactions, as well as the conceptual differences and advances of thianthrenium chemistry when compared to conventional reaction chemistry, with development towards applications in catalysis, drug discovery, and medicine.

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Chemistry under extreme pressure conditions

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The Diamond Anvil Cell (DAC) currently represents the most advanced device to generate static high-pressure conditions ranging from few tenths up to hundreds of GPa, offering unique possibilities to investigate the behavior of matter under high-density conditions and to access unexplored regions of the potential energy surface of the investigated systems. These opportunities are further expanded by combining pressure with temperature and selective photo-excitation, unveiling exotic structures and reactivity compared to ambient pressure and leading to the discovery of new phenomena, to the opening of new reactive paths, and to the synthesis of new compounds. In this talk selected highlights from our high-pressure studies about the structural and reactive properties of group 15 elements will be presented and discussed.[1-5] In particular, the talk will focus on the high-pressure and high-temperature synthesis of pnictogen nitrides by the activation of direct chemical reactions of heavier pnictogens with N_2.[3-5] The discoveries of the first crystalline nitrides of arsenic (AsN)[4] and antimony (Sb_3N_5)[5] represent milestones in pnictogen chemistry and open new perspectives for the high-pressure synthesis of an entire class of new advanced materials of energetic and technological relevance, potentially recoverable at ambient pressure as stable or metastable systems.

References:

[1] D. Scelta, A. Baldassarre, M. Serrano-Ruiz, K. Dziubek, A. B. Cairns, M. Peruzzini, R. Bini, M. Ceppatelli, Angew. Chem. Int. Ed. 2017, 56, 14135–14140.
[2] M. Ceppatelli, D. Scelta, M. Serrano-Ruiz, K. Dziubek, G. Garbarino, J. Jacobs, M. Mezouar, R. Bini, M. Peruzzini, Nat. Commun. 2020, 11, 6125.
[3] M. Ceppatelli, D. Scelta, M. Serrano-Ruiz, K. Dziubek, F. Izquierdo-Ruiz, J. M. Recio, G. Garbarino, V. Svitlyk, M. Mezouar, M. Peruzzini, R. Bini, Inorg. Chem. 2022, 61, 12165–12180,.
[4] M. Ceppatelli, D. Scelta, M. Serrano-Ruiz, K. Dziubek, M. Morana, V. Svitlyk, G. Garbarino, T. Poręba, M. Mezouar, M. Peruzzini, R. Bini, Angew. Chem. Int. Ed. 2022, 61, e202114191.
[5] M. Ceppatelli, M. Serrano-Ruiz, M. Morana, K. Dziubek, D. Scelta, G. Garbarino, T. Poręba, M. Mezouar, R. Bini, M. Peruzzini, Angew. Chem. Int. Ed. 2024, 63, e202319278.

KN-141

New modalities: Chemical synthesis of complex bio-inspired molecules and conjugates

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In recent decades, the drug discovery industry has expanded its common R&D landscape beyond that of small molecules. This innovation is represented by new chemical modalities that include peptides, oligonucleotides, antibodies, and their conjugates.[1]

Consequently, the evolution of techniques and technologies for synthesizing complex bio-inspired molecules has become increasingly crucial, reflecting their growing importance in the modern pharmaceutical landscape.

Peptide synthesis has seen significant improvements over the years, ranging from classical solid-phase peptide synthesis (SPPS) to modern techniques such as microwave-assisted synthesis and automated peptide synthesizers. The incorporation of non-standard amino acids and the synthesis of complex peptides, such as stapled, cyclic, and multimeric constructs, has further expanded their potential for therapeutic applications.

Oligonucleotide-based therapeutics have similarly progressed. Since the advent of deoxynucleoside phosphoramidite chemistry in 1981, solid-phase synthesis has been extensively developed for the preparation of antisense oligonucleotides and siRNA. Moreover, a variety of chemical modification and conjugation strategies have been identified to improve the drug-like properties and RNA-binding affinity of oligonucleotides for therapeutic applications.[2]

Meanwhile, conjugation technologies have evolved to allow the synthesis of hybrid molecules with enhanced properties. In particular, linker chemistry has become more sophisticated, enabling the precise connection of different biomolecules to improve target specificity and therapeutic efficacy.

This presentation will cover some aspects of the continuous expansion of synthetic methodologies for the preparation and conjugation of biomolecules, towards the development of more effective and personalized treatments.

References:

[1] M. Blanco, K. M. Gardinier, M. N. Namchuk, ACS Med. Chem. Lett. 2022, 13, 1691 – 1698.
[2] W. B. Wan, P. P. Seth, J. Med. Chem. 2016, 59, 9645 – 9667.

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Electron welfare for biological synthesis of hydrogen and CO_2 valorization

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Living cells are powered by energy stored in the chemical bonds of organic molecules released through multiple reactions catalyzed by enzymes. The electrons necessary to sustain the reactions derive from oxidative pathways, such as splitting of water in the photosynthesis or sugar catabolism (i.e. glycolysis) in the fermentation. Cellular "social legislation" prevent overcrowding of the electrons by physiological mechanisms of energy dissipation in order to maintain the redox homeostasis. In a few anaerobic bacteria, the excess of reductants is dissipated by reduction of hydrogen ion to molecular hydrogen by a hydrogenase-dependent catalysis. The reaction generally competes with the formation of other reduced end products of fermentation, such as lactate or ethanol.

In this lecture, as a case study, I will discuss a novel fermentation pathway named Capnophilic Lactic Fermentation (CLF) that has been identified in the anaerobic hyperthermophilic bacterium *Thermotoga neapolitana*.[1] The CO_2-activated mechanism enables a non-competitive synthesis of hydrogen and L-lactic acid (95% e.e.), which is formed by enzymatic reductive carboxylation of acetate.[2,3,4] Chemical studies of the CLF pathway are at the basis for the comprehension of the cellular mechanisms to sustain multiple NADH-dependent reactions, such as hydrogen synthesis or pyruvate reduction to lactate.[5,6] The biotechnological process based on CLF has been patented and can be exploited for the development of sustainable production of green hydrogen and for CO_2 valorization into commodity chemicals starting from sugars, sugar-based waste and renewable feedstocks.[7,8]

References:

[1] Z. Xu and G. d'Ippolito. Trends Microbiol 2023, 31(1), 107-108;
[2] G. d'Ippolito, S. Landi, N. Esercizio, M. Lanzilli, M. Vastano, L. Dipasquale, N. Pradhan, A. Fontana, Front. Microbiol. 2020, 11, 171
[3] G. d'Ippolito, L. Dipasquale, A. Fontana, ChemSusChem 2014, 7(9), 2678-2683
[4] L. Dipasquale, G. d'Ippolito, A. Fontana, Int. J. Hydrog. Energy 2014, 39(10), 4857-4862
[5] G. d'Ippolito, G. Squadrito, M. Tucci, N. Esercizio, A. Sardo, M. Vastano, M. Lanzilli, A. Fontana, P. Cristiani, Bioresour. Technol. 2021, 319, 124078
[6] N. Esercizio, M. Lanzilli, M. Vastano, Z. Xu, S. Landi, L. Caso, C. Gallo, G. Nuzzo, E. Manzo, A. Fontana, G. d'Ippolito, Microorganisms 2021, 9, 1688
[7] N. Pradhana, G. d'Ippolito, L. Dipasquale, G. Esposito, Antonio Panico, P. N.L. Lens, A. Fontana, Biomass Bioenergy 2019, 125, 17-22
[8] G. d'Ippolito, A. Fontana, La Chimica e l'Industria 2023, n.5, 28-31

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Enabling technologies in organic synthesis: the truth about their industrial scalability

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Currently the sustainability of chemical processes is driving innovation and industrialization in accordance with environmental friendliness, energy efficiency and scalability. Among emerging technologies, continuous-flow chemistry has become mainstream in the development of innovative, highly efficient catalytic syntheses of fine chemicals and active pharmaceutical ingredients (APIs) [1]. Unfortunately, the reproducibility and the claimed scalability reported in several papers are often proven wrong. Conventional conductive heating and mixing in batch reactors is no longer competitive with continuous-flow synthetic methods, and enabling technologies applied in flow-mode can strongly promote reaction kinetics [2]. These advances are leading to faster and simplified downstream processes with easier workup, purification, and scaling-up. In the current Industry 4.0 revolution, new advances based on cyber-physical systems and artificial intelligence will be able to optimize and invigorate synthetic processes by combining cascade reactors with continuous inline monitoring and even predicting solutions in case of unforeseen events. Alternative energy sources such as dielectric [3,4] and ohmic heating [5], ultrasound [6], hydrodynamic cavitation [7], reactive extruders [8] and plasma [9] have revolutionized standard processes. Also worth mentioning are the so-called hybrid or hyphenated techniques, where the combination of two different energy sources often produces synergistic effects. Relevant case studies at pilot and semi-industrial scale of continuous or semi-continuous extraction and synthetic processes under non-conventional techniques will be discussed.

References:

[1] M. Comito, R. Monguzzi, S. Tagliapietra, A. Maspero, G. Palmisano, G. Cravotto, *Pharmaceutics* 2023, 15, 1322.
[2] G. Grillo, P. Cintas, M. Colia, E. Calcio Gaudino, G. Cravotto, *Front. Chem. Eng.* 2022, 4, 966451.
[3] K. Martina, G. Cravotto, R.S. Varma, *J. Org. Chem.* 2021, 86, 13857-13872.
[4] M. Salgado-Ramos, S. Tabasso, E. Calcio Gaudino, G. Cravotto, *Ind. Eng. Chem. Res.* 2024, 63, 7507.
[5] V.L.M. Silva, L.M. Santos, A.M.S. Silva, *Chem. Eur. J.* 2017, 23, 7853.
[6] R.F. Martínez, G. Cravotto, P. Cintas, *J. Org. Chem.* 2021, 86, 13833-13856.
[7] Z. Wu, S. Tagliapietra, A. Giraudo, K. Martina, G. Cravotto, *Ultrason. Sonochem.* 2019, 52, 530-546.
[8] E. Calcio Gaudino, G. Grillo, M. Manzoli, S. Tabasso, S. Maccagnan, G. Cravotto, *Molecules* 2022, 27, 449
[9] F. Verdini, E. Canova, R. Solarino, E. Calcio Gaudino, G. Cravotto, *Environ. Pollut.* 2024, 342, 123041.

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ANA-KN-01

Sample preparation in one click: monolith columns as a case study

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Miniaturization is a fundamental aspect of the green analytical chemistry approach and should also encompass absorbent preparation, considering factors such as energy consumption, quantities, and types of reagents, especially on an industrial scale. In this context, the use of click reactions remains limited in the development of absorbents for sample preparation despite being a well-established approach in organic chemistry. Within the realm of click reactions, multicomponent click reactions combine the advantages of click reactions with the principles of green chemistry such as equimolarity, large-scale purification, high reaction rates, high yields, stability, modularity, broad applicability, chemoselectivity, and a single reaction pathway. Four-component click reactions without metallic catalysts offer additional advantages such as biocompatibility, atomic economy, and cost-effectiveness. These reactions are achieved by selecting monomers suitable for high reactivity and efficient transformations. Specifically, alkynylcarboxylic acid, primary amine, organic boronic acid, and formaldehyde have been employed; these polymeric products generally exhibited film-forming capacity and high thermal stability. These reactions have been exploited to achieve a reduced and one-pot synthesis of a poly(propargyl amine) polymer within a readily available silica-coated PEEK tube. The resulting monolithic columns have been integrated into an autosampling system for the automatized online extraction and purification of small molecules in complex samples. This approach underscores the versatility, cost-effectiveness, and environmentally friendly nature of multicomponent reactions for generating reverse-phase and mixed-mode adsorbents, facilitating the scaling of the entire analytical procedure from extraction preparation onwards. [1]

References:

[1] A. Cerrato, S. E. Aita, C. Cavaliere, A. Laganà A, C. M. Montone, S. Piovesana, E. Taglioni, A. L. Capriotti, Anal. Chem 2024, 96, 11, 4639–4646

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ANA-KN-02

A casebook of selectors and probes in chiral voltammetry: stereogenic elements, interactions, implementation strategies

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In about a decade from the first report by some of us about the outstanding enantiodiscrimination ability of inherently chiral electrodes[1], our research on effective tools and strategies for chiral voltammetry has much grown both in width and depth. A selected casebook will be presented, discussing the following key issues:

(*i*) nature of the stereogenic element(s) (stereocentres, axes, helixes, planes) in selectors and probes[1-8],

(ii) assumptions on selector/probe interactions[9], and possible strategies to enhance them[2,9];

(ii) proposed strategies for effective implementation of chiral selectors at the electrochemical interphase: electrodes modified with inherently chiral oligomer films[1-4], or media of high local order implemented with chirality[5-8] (chiral ionic liquids, ionic liquids with chiral additives, chiral deep eutectic solvents).

References:

[1] F. Sannicolò, S. Arnaboldi, T. Benincori, V. Bonometti, R. Cirilli, L. Dunsch, W. Kutner, G. Longhi, P. R. Mussini, M. Panigati, M. Pierini, S. Rizzo, Angew.Chem. 2014, 53, 2623-2627.

[2] S. Grecchi, G. Bonetti, E. Emanuele, J.Ludvík, L. Koláčná, A. Liška, M. Hromadová, S. Arnaboldi, Dr. R. Cirilli, P. R. Mussini, T. Benincori, Chem.-Eur. J. 2024, e202303530

[3] S. Arnaboldi, S. Cauteruccio, S. Grecchi, T. Benincori, M. Marcaccio, A. Orbelli Biroli, G. Longhi, E. Licandro, P. R. Mussini, Chem. Sci. 2019, 10, 1539-1548

[4] S. Grecchi, S. Arnaboldi, M. Korb, R. Cirilli, S. Araneo, V. Guglielmi, G. Tomboni, M. Magni, T. Benincori, H. Lang, P.R. Mussini, ChemElectroChem 2020,7, 3429-3438

[5] S. Rizzo, S. Arnaboldi, V. Mihali, R. Cirilli, A. Forni, A. Gennaro, A.A. Isse, M. Pierini, P.R. Mussini, F. Sannicolò, Angew Chem. 2017, 56, 2079-2082.

[6] S. Arnaboldi, A. Mezzetta, S. Grecchi, M. Longhi, E. Emanuele, S. Rizzo, F. Arduini, L. Micheli, L. Guazzelli, P.R. Mussini, Electrochim. Acta 2021 380, 138189

[7] V. Zullo, S. Grecchi, S. Araneo, M. Galli, S. Arnaboldi, L. Micheli, A. Mezzetta, L. Guazzelli, A. Iuliano, P.R. Mussini, Electrochim. Acta 2022, 436, 141191.

[8] F. Fontana, B. Bertolotti, S. Grecchi, P.R. Mussini, L. Micheli, R. Cirilli, M. Tommasini, S. Rizzo, Chemosensors 2021, 9, 216.

[9] P.R. Mussini, S. Arnaboldi, M. Magni, S. Grecchi, G. Longhi, T. Benincori, Curr. Opin. Electrochem. 2023, 101128.

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ANA-KN-03

Citizen science: An opportunity for innovation in Analytical Chemistry

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Citizen science has the potential to enhance both the impact in scientific research by democratizing access to scientific knowledge and increasing the participation in the process of data collection, analysis, and interpretation. Historically, instruments for experimentation and monitoring, along with the expertise required to design rigorous measurements and analyse results, have been largely confined to academic and regulatory domains. Yet, citizen science initiatives are disrupting this traditional model by empowering the public to engage and support in scientific inquiry.

In this presentation, we will explore the potential impact of citizen science as a catalyst for innovation in Analytical Chemistry by exploring ongoing citizen science projects and where key challenges remain. We will highlight recent developments that have allowed local communities to contribute to data collection efforts, as well as data analysis. These include leveraging new technologies such as portable sensors and low-cost kits to gather robust information on environmental and public health challenges. We will also highlight where new approaches are required to meet challenges, while keeping an eye out for opportunities on the innovation horizon.

We will showcase best practices in methods development and their application to national scale and community scale citizen science programs focused on emerging aquatic pollution challenges in Europe and Africa. Citizen science offers unique opportunities for innovation in analytical chemistry, highlighting the need for new methodologies for data acquisition and analysis[1]. Citizen scientists require novel tools and techniques to address local and global challenges[2], requiring a new approach to experimental design. New processes of validation and calibration are required to ensure consistency, reliability and applicability across diverse environments.

We will also underscore the benefits of citizen science in fostering collaboration between researchers and communities, promoting knowledge exchange and mutual learning. By engaging citizens in the scientific process, scientists can broaden the scope and scale of their research, as well as promoting public engagement with science, enhancing scientific literacy and encouraging environmental stewardship. Through active involvement in the scientific process and support to address local and national challenges with more robust methods and experimental design, analytical chemists can harness the collective power of communities to pave the way for more inclusive and impactful research outcomes[3].

References:

[1] Thornhill, I., … & Loiselle, S. A. 2017, Science of the Total Environment, 584, 1268-1281.
[2] Loiselle, S.,... & Lewis, V., 2024, Environmental Monitoring and Assessment, 196(2), 1-15.
[2] Fraisl, D.,... & Thiel, V., 2022, Nature Reviews, 25:2(1): 64

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ANA-KN-04

Bioluminescence analytical platforms for One Health: from paper sensors to thread-based analytical devices

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Bioluminescence (BL) is a fascinating phenomenon in which photons are emitted as byproduct of a chemical reaction occurring in living organisms, including bacteria, fireflies, and several marine species.

BL systems possess remarkable features, such as high quantum yield and no need for an external light source, that render them highly valuable bioanalytical tools for developing portable biosensors for monitoring molecules, cells, and bioactivities with applications spanning from agro-food to clinical fields. Therefore, bioluminescent biosensors have a great potential to support the "One Health" approach, to guarantee health to humans, pets, wildlife and our environment.

Here we report the development of novel BL tools and strategies which can be used to improve the analytical performance of paper-based smartphone biosensors. BL showed suitable to develop highly sensitive biosensing paper platforms enabling the detection of target analytes down to the ppb levels in complex biological matrices. The stability of these biosensors has been increased by the obtainment of bio-nanocomposites relying on nanomaterials (metal-organic framework, MOF), thus improving the robustness of the analytical platforms.

Moreover, we explored the combination of bioluminescence biosensing with microfluidic thread-based analytical devices (μTADs), which represent a sustainable and low-cost alternative to paper based biosensing, especially to handle very low volumes of samples (less than 5 μl), showing great potential also for multiplex analysis in combination with chemiluminescence. We report a proof-of-principle application of bio-chemiluminescence biosensing on cotton threads and, to prompt future applications in point-of-care and point-of need settings, we exploited smartphone detection enabling easy detection of the bio-chemiluminescent signal.

Artificial intelligence (AI) algorithms were also combined to smartphone-based bioluminescence detection to provide a user-friendly paper-based toxicity smartphone biosensor.

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ANA-KN-05

When we force equilibrium chemistry out of its comfort zone. A *case study*: recovery of critical metals from exhausted batteries

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The rapid growth in demand for lithium-ion batteries (LIBs) is posing challenges in the management of end-of-life (EoL) systems and the supply of critical raw materials (CRMs), especially Li, Ni, Co, and Mn. New greener routes in hydrometallurgy process must be explored to return such critical raw materials into a more sustainable circular economy [1]. The application of organic acids is gaining even more attention due to the combination of good recovery efficiency, low cost, environmental benefit and reduced energy demand [2].

Preliminary screening on systems such as citric, oxalic and formic acid, in combination with reducing agents, demonstrated their suitability as greener alternatives to classical inorganic acids, even at low process temperatures, for the hydrometallurgical recycling of lithium-ion batteries.

The conditions under which these systems are nowadays explored are far away from the typical domain of equilibrium chemistry, but still under those conditions chemistry is going on, despite of our limited capacity to describe and even less of make prevision.

We proposed a very preliminary attempt to give a sort of method to explore the equilibrium chemistry of brines containing one of the mentioned organic acid, namely citric acid (H_3Cit), towards Co(II), and Ni(II). In detail, two sets of potentiometric titrations have been performed, the first in canonical experimental conditions (at millimolar level), and the second mimicking the conditions of the hydrometallurgic process (H_3Cit ~ 1 mol dm^{-3}; Co(II) ~ 0.2 mol dm^{-3}). In both measurement sets, no background salt was added into the measurement cell, this causing a relevant ionic strength variation upon addition of NaOH causing deprotonation of citric acid. Calibration of the electrode system (glass half-cell with double junction reference electrode) was tested both in internal and external fashions. The results of the analysis of potentiometric measurements at low ionic strength were used to check results in comparison with reference literature data [3], and as reference for data analysis at high concentration. Data analysis of the latter measurements resulted very challenging and was done taking advantage of the feature of BSTAC4 software to analyse data also considering variation of activity coefficients during measurements.

References:

[1] Harper, G.; Sommerville, R.; et al. Nature 2019, 575 (7781), 75–86. https://doi.org/10.1038/s41586-019-1682-5.
[2] Gerold E., Schinnerl C., Antrekowitsch H., Recycling 2022 7(1) 7010004
[3] Kostakis N.; Raptopolou C.P.. et al. Inorg. Chem. 2003, 42 (1), 22-31.

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XPS study and correlation between surface chemistry and catalytic activity of various oxides

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The chemical surface composition of a material is fundamental to determine its properties. Different oxides have been investigated by means of x-ray photoelectron spectroscopy (XPS) to study and correlate the surface chemistry and their performance. The results obtained for oxide and mixed oxide catalysts and paramagnetic iron oxides, will be discussed. XPS results on copper doped-TiO_2 catalysts for H_2 production, in combination with other techniques, revealed the presence of both Cu_2O and CuO deposits on the surface. Notably, the CuO particles reduction to Cu(s) by photogenerated electrons boosting H_2 production rate was assessed, indicating that both Cu_2O and Cu(s) act as co-catalysts for H_2 generation[1]. XPS analyses of MnO_2 and MnO_2/CeO_2 based catalysts were used to correlate their surface properties and catalytic activity in the selective aerobic oxidation of furfural into furoic acid. Also, surface characterization results were used to properly tailor the catalyst surface to obtain the exclusive presence of Mn(IV) species, yielding a mixed oxide with excellent catalytic properties[2]. Various alumina-, silica- and alumino/silicate- supported Ni/Ce catalysts were investigated by XPS to detect the overall nickel loading on the surface, as well as Ni speciation and its interaction with the supports. On the base of $Ni2p_{3/2}$ signal curve fitting and BE values, different abundances of NiO-like and Ni-Aluminate or Ni-Silicate like species were assessed[3], differently interacting with the supports and therefore possessing a diverse reducibility[3]. XPS characterization of magnetite iron oxides was performed through combined information from different Fe spectral regions, namely Fe2p, Fe3p and valence band (VB)[4]. VB region provided useful analytical information like the energy band gap value (Eg) shift for the Cu electrodecorated sample, essential to confirm the occurring of alignment of the Fermi levels at the Cu-Fe material interface[5].

References:

1 G. Vitiello, L. Clarizia, W. Abdelraheem, S. Esposito, B. Bonelli, N. Ditaranto, A. Vergara, M. Nadagouda, D. D. Dionysiou, R. Andreozzi, G. Luciani and R. Marotta, *ChemCatChem*, , DOI:10.1002/cctc.201900818.
2 F. Nocito, N. Ditaranto, D. Linsalata, M. Naschetti, R. Comparelli, M. Aresta and A. Dibenedetto, *ACS Sustain. Chem. Eng.*, , DOI:10.1021/ACSSUSCHEMENG.2C02341.
3 A. M. Venezia, R. Bertoncello and G. Deganello, *Surf. Interface Anal.*, 1995, **23**, 239–247.
4 A. P. Grosvenor, B. A. Kobe, M. C. Biesinger and N. S. McIntyre, *Surf. Interface Anal.*, 2004, **36**, 1564–1574.
5 V. Marchianò, M. Salvador, A. Moyano, G. Gutiérrez, M. Matos, S. Yáñez-Vilar, Y. Piñeiro, J. Rivas, J. C. Martínez-García, D. Peddis, M. C. Blanco-López, M. Rivas, N. Ditaranto, N. Cioffi, *Antibiotics*, 2021, **10**, 119.

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ANA-OR-001

Extractive-Liquid Sampling Electron Ionization-Mass Spectrometry (E-LEI-MS) for real-time targeted and non-targeted analysis of pesticides in light cannabis and drugs

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The Extractive-Liquid Electron Ionization-Mass Spectrometry (E-LEI-MS) is the first analytical approach that combines the ambient sampling of not- or minimal pretreated samples with the electron ionization (EI) process, which results in high identification power. The E-LEI-MS setup includes a solvent-release mechanism for the ambient extraction of analytes. The generated solution is sucked into the EI source by the vacuum generated by the mass spectrometer. An open/close valve allows the aspiration or the system isolation during the extraction or stand-by step. The VMC was recently introduced to better vaporize high-boiling point molecules. The analyses were performed using the E-LEI system coupled with a 7010GC/MS triple quadrupole (QqQ) and a 7250GC/Q-ToF quadrupole time of flight (Q-ToF) MS (Agilent Technologies) both equipped with EI sources. The type and amount of solvent, sampling time, VMC, and source temperatures were modified according to the analyte solubility, signal intensity, boiling point, and/or degradation temperature, respectively.

Chlorpyrifos was used as a reference standard for performing test analyses to evaluate improvements in the advanced configurations of the prototype. The pesticide was analyzed after being spotted on a clean surface and in light cannabis. The E-LEI-QqQ-MS system allowed the identification of nine APIs out of fifteen in various formulations by matching with the NIST library spectra. Six samples were also analyzed in high-resolution using E-LEI-Q-ToF-MS to explore and compare the data obtained. The Agilent HR software for unknown identification indicated sildenafil as the API of commercially available illicit tablets sold as supplements. Several old and new-generation BZDs were analyzed using the E-LEI-Q-Tof-MS system. Six BZDs were selected to fortify gin tonic cocktails at concentrations of 20 and 100 mg/L for simulating their illicit use as rape drugs. Spots of cocktails were dried on a glass surface to simulate their residue in glasses collected for forensic tests. All BZDs were correctly identified at both concentration levels.

E-LEI-MS configuration will be improved to analyze pesticides in several samples of light cannabis and other applications. The E-LEI-Q-ToF MS system is a promising tool for environmental, pharmaceutical, and forensic applications in targeted and untargeted analysis.

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ANA-OR-002

Chromatographic enantioresolution and stereochemical characterization of seized synthetic cannabinoid receptor agonists with Whelk-O®1 chiral stationary phases

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The HPLC-UV enantioseparation of the following six synthetic cannabinoid receptor agonists was obtained for the first time with the two chiral stationary phases (CSPs) (*R*,*R*)- and (*S*,*S*)-Whelk-O®1, under reversed phase conditions: the three valinamide indazole-3-carboxamide-based derivatives AB-CHMINACA, 5Cl-AB-PINACA, AB-FUBINACA, the *tert*-leucinamide indazole-3-carboxamide-based ADB-FUBINACA, and the two phenylalaninamide indazole-3-carboxamide-based derivatives APP-FUBINACA and 5F-APP-PINACA.

The analysis of seized samples performed using a water/ACN/FA-55/45/0.1 (v/v/v) mobile phase and the Whelk-O®1 CSPs revealed: (i) the scalemic nature of AB-CHMINACA [in favour of the (*S*)-enantiomer] and 5Cl-AB-PINACA (newer enantioseparated so far); (ii) the presence of enantiopure (*S*)-AB-FUBINACA and (*S*)-ADB-FUBINACA; (iii) the presence of enantiopure (*R*)-APP-FUBINACA and (*R*)-5F-APP-PINACA.

The enantiopurity of the last four samples was established applying the "Inverted Chirality Columns Approach" [1], while information on the absolute configurations were retrieved by coupling electronic circular dichroism analysis to *in silico* Time-Dependent Density-Functional Theory simulations [2].

In a proof-of-concept study, the optimised enantioselective chromatography conditions were also successfully tested, with only marginal modifications, on a HPLC system coupled to a triple quadrupole mass spectrometer for LC-MS/MS evaluations.

The described enantioselective analysis of authentic specimens derived from a selection of seized synthetic cannabinoid receptor agonists containing samples gleans valuable insights into their enantiomeric composition, thereby unlocking potential intelligence information of relevant forensic significance.

References:

[1] F. Ianni, M. Tiecco, A. Carotti, L. Pucciarini, G. Saluti, R. Galarini, R. Sardella, B. Natalini, Talanta 2019, 20, 147–152.
[2] I. Varfaj, M. Protti, A. Di Michele, A. Macchioni, W. Lindner, A. Carotti, R. Sardella, L. Mercolini, Journal of Chromatography A 2021, 1180, 338928.

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ANA-OR-003

Enhancing Human Volatilome Investigation with Active Carbon Fibers: A Novel Approach for Improved Sampling and Analysis

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The volatilome, comprising volatile metabolites and other organic and inorganic compounds emanating from living organisms, offers valuable insights into metabolic and phenotypic states. Accessible through non-invasive sampling methods, such as breath, skin, and bodily fluid analysis, the volatilome holds promise for medicinal studies and disease diagnostics. In previous studies the potential of active carbon fibers for thermal desorption (TD) in volatilome analysis was investigated demonstrating superior analyte trapping efficiency, even in challenging conditions Moreover, active carbon fibers exhibit reduced impedance and increased stability compared to conventional sorbent materials. Notably, they eliminate the need for quartz fiber frits, enhancing practicality and reliability. Experimental validation includes successful recovery tests in controlled atmospheres and application in analysing exhaust from a biomass combustion plant, where traditional methods falter. The present study explores the potential application as of non-invasive screening techniques for the detection of gastrointestinal diseases. This innovative approach presents a cost-effective and accurate tool for mass screening and early disease diagnosis.

References:

[1] N. Drabińska, C. Flynn, N. Ratcliffe, I. Belluomo, A. Myridakis, O. Gould, M. Fois, A. Smart, T. Devine, B.D.L. Costello, A literature survey of all volatiles from healthy human breath and bodily fluids: the human volatilome, J. Breath Res. 15 (2021) 034001, 1-39.

[2] P. Benedetti, E. Guerriero, C. Crescenzi, Noninvasive detection of cancer biomarkers using a new sampling device for exhaled breath analysis, ACS Meeting ACS Fall 2015 August 16 – 20, Boston, MA, ANYL 212.

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Comprehensive characterization of a Brazilian essential oil exploiting quali-quantitative, enantiomeric, and a preparative GC fast isolation followed by spectroscopy approaches

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The interest towards new bioactive components has been ever increasing over the last years. The standard protocol for retrieval of target molecules with promising biological activities includes synthetic procedures, as the preferred route before testing in further studies. As a greener alternative to synthetic procedure, preparative gas chromatography has been exploited over the years, for its capability to isolate target components from natural sources. The rule of thumb is to introduce the greatest sample amount to guarantee the shortest total collection time, while still maintaining a good chromatographic resolution for the target molecule.
The present study details the utilization of multiple gas chromatography techniques alongside nuclear magnetic resonance spectroscopy to characterize the essential oil of *Piper gaudichaudianum* Kunth from Brazil. Seventy-six components were identified using gas chromatography coupled to mass spectrometry (GC-MS), while enantio-selective multidimensional gas chromatography elucidated the enantiomeric distribution of eight chiral components, for the first time in literature. Following GC-MS analysis, an unidentified component, constituting approximately 27% of the total oil, prompted an isolation step through preparative gas chromatography. To this purpose, a Deans switch transfer device was positioned at the exit of the wide-bore column to alternatively divert the target peak to the collection system or a flame ionization detector (FID). Aiming to obtain the fastest collection time, the highest feasible volume (3 μL) of pure oil compatible with the liner internal volume, was injected in each chromatographic run, allowing its collection for structural elucidation techniques. In detail, the combined use of nuclear magnetic resonance (NMR), GC-Fourier transform infrared spectroscopy (FTIR), and mass spectrometry (MS), allowed the unambiguous identification of the compound of interest.

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Monitoring (semi)volatile poly- & perfluorinated hydrocarbons in environmental samples using GC-MS

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Perfluoroalkyl and polyfluoroalkyl substances (PFASs) are a family of manufactured chemicals that are widely employed in consumer goods and industrial applications because of their special qualities. Chemically, these compounds contain a chain of carbon atoms bonded to multiple fluorine atoms, and with different functional groups at the end of the chain.

A portion of these chemicals exhibit a neutral and volatile nature, and are recently gaining more attention from environmental agencies, since they can be released by consumer goods and detected in the air.

Even at molecular weights over 600 Da, the presence of fluorine atoms in PFAS makes them more volatile than non-fluorinated analogues, due to weak van der Waals interaction properties. Therefore, they are suitable for GC-MS analysis.

In the current research, a parallel GC and GC×GC methodology coupled with both low-resolution and high-resolution TOF-MS was developed for the (semi)volatile PFAS analysis. Specifically, the chemical group under study were fluorotelomer alcohols (FTOH), acrylates (FTAc), and alkyl sulfonamide (N-MeFOSA, N-EtFOSA, N-MeFOSE, and N-EtFOSE) derivatives. Regarding the MS ion source, both electron impact, positive chemical ionization, and negative chemical ionization were exploited to study the spectra of the targeted chemical groups.

Dynamic headspace extraction was used for air sampling, using the most appropriate adsorbent material in terms of selectivity and sensitivity. Initially, the extraction method was optimized in terms of sampling volume and adsorbent type using a mix of PFAS standards (MW range 264-571 Da) and different spiked household goods and various environmental samples (air, water, soil).

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The usefulness of the cryogenic zone compression approach coupled to gas chromatography mass spectrometry for the determination of polycyclic aromatic hydrocarbons in extra-virgin olive oil

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The goal of the research is to develop a simple method for the analysis of polycyclic aromatic hydrocarbons (PAHs) in extra-virgin olive oils using the "Cryogenic zone compression" approach introduced by Marriott *et al.* in 1996[1] and followed applied for the determination of dioxins in human serum[2]. A liquid nitrogen-free jet-cooled thermal modulator, conventionally dedicated to comprehensive two-dimensional gas chromatography, was located at the end of the GC capillary column upstream of the detector. The column was looped in a single stage around a metal support, and centered between the permanent cryogenic jet (-90°C) employed to trap the eluted compounds, and the intermittent hot jet pulse (300°C, 250 ms) used to release the analytes from the cold spots. A miniaturized sample preparation protocol based on a single liquid-liquid extraction, with reduced consumption of organic solvents (500 µL of ACN per sample), has been employed. The sample preparation was characterized by the absence of both purification and concentration steps. Despite this, considering that the cryogenic zone compression process produced narrower and higher peaks, resulting in an enhancement of the overall method sensitivity, the PAHs limits fixed by European legislation for fats and oils[3] was achieved.

References:

[1] P.J. Marriott, R.M. Kinghorn, J. High Resol Chromatogr 1996, 19, 403 – 408.
[2] D.G. Patterson, S.M. Welch, W.E. Turner, A. Sjödin, J.F. Focant, J Chromatogr A, 2011, 1218, 3274 – 3281.
[3] European Commission N° 835/2011. Off. J. Eur. Union 2011, L215, 4 – 8.

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ANA-OR-007

New performing GC columns with unmatched separation capabilities

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Gas chromatography (GC) is widely used for qualitative and quantitative analysis in numerous fields, such as petroleum, chemical industry, agriculture, environmental protection, medicine, and so on, due to its high versatility, high selectivity, simplicity of use, analysis speed, and low sample consumption. The column is the heart of a GC instrumentation, which allows the analyte separation and their recognition and quantification. Commercial columns do not always allow a complete peak separation when compounds (i.e., isomers) are very similar in molecular weight, polarity, and vapor pressure. The choice of the correct stationary phase, with high selectivity towards target analytes, is the key to obtaining the required chromatographic separation and the subsequent qualitative and quantitative analysis.

Considering the rapid polymer science development and the growing demand for new columns with improved resolution capabilities, in this work novel stationary phases for capillary GC have been designed, synthesized, and characterized in terms of polarity range, resolution, column efficiency, thermal stability, film-forming properties, and support-deactivating capacity[1-5]. The separation features of these novel stationary phases allow high-resolution performances for a wide range of compounds, like aromatic anilines, xylenes, aromatic amines, halogenated benzenes, and aromatic aldehydes, with marked capabilities toward isomer separations.

References:

[1] T. Sun, M. Ba, Y. Song, W. Li, Y. Zhang, Z. Cai, S. Hu, X. Liu, D. Nardiello, M. Quinto, Analytica Chimica Acta, 2024, 1291, art. no. 342221.
[2] T. Sun, R. Chen, Q. Huang, M. Ba, Z. Cai, H. Chen, Y. Qi, H. Chen, X. Liu, D. Nardiello, M. Quinto, Analytica Chimica Acta, 2023, 1251, art. no. 340979.
[3] T. Sun, R. Chen, Q. Huang, M. Ba, Z. Cai, S. Hu, X. Liu, D. Nardiello, M. Quinto, ACS Applied Materials and Interfaces, 2022, 14 50, pp. 56132-56142
[4] R. Chen, Z. Cai, W. Li, Q. Huang, D. Nardiello, M. Quinto, X. Liu, S. Hu, T. Sun, Chemistry and Biodiversity, 2022, 19, art. no. e202200829
[5] Q. Huang, Z. Cai, R. Chen, W. Zhang, D. Nardiello, M. Quinto, X. Liu, S. Hu, T. Sun, Microchemical Journal, 2022, 183, art. no. 108084

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Comprehensive Characterization of Egyptian Calendula (Calendula officinalis L.) Essential Oil and Absolute by Rapid Evaporative-Ionization Mass Spectrometry

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Search for alternative and innovative analytical methods, capable to provide rapid and informative results for the analysis of plants rich in precious phytochemical is a topic of ongoing interest. In this context, the aim of this research is to provide a method for a rapid characterisation of the main compounds present in Egyptian Calendula essential oil and absolute, known for their beneficial properties and chosen as an example to test the applicability of the technique. For this purpose, direct Ambient Mass Spectrometry (AMS) analysis were applied and the results were compared with those from conventional gas and liquid chromatography (GC-MS and LC-MS) technique applied as support. All samples were analyzed by a shotgun MS approach, *via* direct samples infusion, through a syringe pump, into an innovative ambient ionization source named REIMS (Rapid Evaporative Ionization Mass Spectrometry) coupled to a quadrupole-time of flight (Q-ToF) detector, capable to generate mass accuracy and tandem MS/MS data for structural elucidation. The employment of REIMS-QToF method has led to a rapid untargeted screening of both Egyptian samples in a very short time (3-4 seconds), without the need of clean-up procedures or chromatographic separations. The peculiar fingerprints obtained by means of MS high-resolution analysis have revealed the presence of phytochemicals compounds belonging to different chemical classes such as carotenoids, lipids, phenolic and volatile compounds, by matching the mass accuracy data in commercial and online database. Mass spectra acquired in both positive and negative ionization mode and MS/MS experiments allowed the identification and confirmation of a large number of bioactive compounds.

The technique here applied led to detect and identify hundreds of compounds, confirmed by conventional chromatographic techniques. However, compared to GC and LC methods that require a very long analysis time and a large amount of solvents, REIMS-QTof technology have revealed to be a rapid, greener and reproducible analytical approach that could be used for fingerprinting analysis of poorly characterized natural matrices with potential biological properties.

References:

[1] M.V. Faustino, A.M.L. Seca, P. Silveira, A.M.S. Silva, D.C.G.A. Pinto, Industrial Crops and Products 2017, 104, 91-98.

[2] K. Arena, E. Trovato, D. Mangraviti, C. Occhiuto, F. Rigano, F. Occhiuto, F. Cacciola, L. Mondello, Journal of Pharmaceutical and Biomedical Analysis 2023, 230, 115399.

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ANA-OR-009

How the aroma profile and cannabinoid content of *Cannabis sativa* L. inflorescences is influenced by drying and storage conditions

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Cannabis (*Cannabis sativa* L.) is one of the most ancient cultivated multipurpose crop plants used for medicinal, industrial and recreational purposes, well known for its therapeutic and psychoactive properties. After harvesting Cannabis plant parts, including inflorescences, undergo drying processes to remove excess of water from the flowers and preserve secondary metabolites including cannabinoids and volatile organic compounds (VOCs) that make the typical cannabis scent. Very often long-term storage in closed containers is also applied. Poor post-harvest handling conditions may cause rapid deterioration of the flowers with consequent changes in precious cannabinoid and VOCs content, thus adversely impacting the quality and potency of the products. From this starting point, we investigated the effects of a novel freeze-drying technology *vs* a conventional tray drying one, and three storage conditions, on the preservation of cannabis secondary metabolites. A multi-trait approach, combining both solid-phase microextraction (SPME) two-dimensional gas chromatography coupled to mass spectrometry (GCxGC-MS) and high-performance liquid chromatography (HPLC), was used for the chemical fingerprint. This approach combined with powerful chemometrics enabled the identification of the best purpose related drying process, with freeze drying resulting useful to preserve cannabinoids preventing their decarboxylation but leading to a substantial loss of VOCs. Among storage conditions, storage in glass bottle seems more beneficial for the retention of the initial VOC profile compared to open to air dry tray and closed high-density polyethylene. However, the glass bottle storage condition causes the formation of neutral cannabinoids at the expense of the highly priced acid forms such as CBGA and CBGA. This is a first step contribution to define and direct producers and stakeholders toward the optimal drying process and storage conditions useful to produce highly valuable and high-quality products for the industry of interest.

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Greening reversed-phase liquid chromatography by using novel eco-friendly solvents as organic modifiers

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Reversed-phase liquid chromatography (RPLC) is the most widely employed analytical method in (bio)pharmaceutical industry, not only for quality control of bulk drugs and formulation, but also for preparative scopes. The most widely employed organic modifier in RPLC is acetonitrile (ACN) due to its exceptional characteristics, such as high elution strength, UV transparency, high miscibility with water and low viscosity. However, ACN is slightly toxic by acute exposure through oral intake, skin contact, and inhalation and it can be converted by the body into cyanide.[1]

For this reason, in the last year, there is much interest around all the possibilities that could increase the greenness of analytical methods applied to pharmaceuticals, in order to reduce the environmental impact commonly associated with manufacturing process and to ensure health safety of operators. Indeed, especially in preparative conditions, the large amount of solvents commonly employed leads to the generation of high quantities of waste to be disposed.[2]

Beside alcohols, whose physico-chemical properties are well-known, also less common solvents have recently attracted the attention for this purpose. One of this is dimethyl carbonate (DMC), which is classified among the "recommended" solvents by solvent selection guides. Indeed, DMC is nowadays produced though a clean process, it is biodegradable, and it is not toxic. Although it is widely employed as solvent in novel applications related to supercapacitors, lithium batteries and other emerging devices for energy storage, DMC has been introduced as organic solvent for LC only in a recent paper where the authors demonstrated its applicability in LC hyphenated to inductively coupled plasma mass spectrometry platforms. [3]

In this work, the possibility of using DMC or other less common alternatives as organic modifier in LC with UV-Vis detection will be discussed through a series of case studies including fundamental studies on retention in linear conditions up to applications in preparative conditions for the purification of pharmaceutically relevant peptides. [4,5]

References:

[1] www.epa.gov
[2] M. Yabré et al., Molecules 2018, 23, 1065.
[3] B. Lajin et al., J. Anal. At. Spectrom. 2021, 36, 1272-1279.
[4] S. Felletti et al., J. Chromatogr. A 2023, 1712, 464477.
[5] D. Bozza et al., J. Chromatogr. A 2023, 1713, 464530.

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ANA-OR-011

Technology transfer from the synergy between academic research and industry: development of innovative packaging in a context of circular economy

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One of the greatest successes of academic research is to become the source of technological progress, providing solutions to global needs. Many studies, rich of potential, are often not exploited, and successful outcomes can be leveraged from the synergy with companies. This can be achieved through technology transfer, offering researchers the opportunity to convey their ideas into effective solutions.

This work shows a real example of synergy between several partners from universities and industries of different countries working together at a common multidisciplinary project. The aim was to find a solution to the request of many companies interested in alternative materials to replace plastic packaging, according to the recent European Regulation. Creating innovative materials within the circular economy, aimed at reducing food waste, represents a great challenge to pursue. The company Greci Industria Alimentare (Parma) supported the finding of useful applications of agro-industrial byproducts usually discarded but rich of bioactive compounds with antioxidant and antibacterial properties[1]. Effective systems of sample extraction, based also on the use of accelerated solvent, were explored at the CIAL Institute of Madrid, and the chemical characterization of active compounds was achieved by LC-MS. The effect of storage on the active properties was also investigated. Innovative formulations to obtain active packaging in form of film, spray or coating were realised, and studies to assess their stability during shelf-life were performed. Velp Scientifica (Usmate, MB), collaborated with the development of a modified Oxitest, an analytical equipment capable to monitor the effects of the formulations on real food samples[2]. Besides, safety assessment experiments based on AMES tests were carried out at the FH Campus of Wien. Finally, a German company concurred in applying the final achievement allowing the production of prototypes of new packaging. All steps of the research have been managed with the cooperation of the interdepartmental centre for Packaging, CIPACK (Technopole of Parma), whose mission is the success of research leading to progress of science and technology.

References:

[1] M. Grimaldi, O. Pitirollo, P. Ornaghi, C. Corradini, A. Cavazza. Food Packag Shelf Life 2022, 33, 100900.
[2] A. Cavazza, S. Corti, C. Mancinelli, C. Bignardi, C. Corradini. J Am Oil Chem Soc 2015, 92, 1593-1599.

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Multicolumn countercurrent chromatography combined with ethanol for the green purification of Crocin-I extracted from saffron

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Crocin-I is a valuable natural compound found in saffron (dried stigmas of *Crocus sativus* L.) showing potential as a new drug lead especially in the field of neurological disorders. To explore its therapeutic value, the development of extraction and purification techniques is required, especially a cost-effective and scalable purification process to isolate considerable amounts of crocin-I from complex natural sources. However, traditional single-column preparative chromatography (batch) poses a yield-purity trade off, meaning that the choice of the collection pool sacrifices either yield in benefit of higher purity, or vice versa[1]. This naturally derives from structural similarities among Crocin-I and other species extracted from the plant.

This study demonstrates how the continuous countercurrent operating mode, namely twin-column MCSGP (Multicolumn Countercurrent Solvent Gradient Purification), resolves this dilemma, by automatically performing an internal recycling of the impure portions to be reprocessed. Saffron stigma was extracted with ethanol, and the extracted feed stability was investigated under varying storage conditions. Concerning the purification, at first the batch process was specifically designed and optimized to separate Crocin-I from impurities having similar structure (e.g., picrocrocin). This step was subsequently followed by the scale-up to the MCSGP process. To ensure a fair comparison, both processes were evaluated under similar conditions (e.g., similar total column volume). The results showed that, at a Crocin-I purity grade of 99.7%, the MCSGP technique led to significant results, namely x3 increase in recovery and productivity and -92% reduction in solvent consumption, with respect to the corresponding batch process[2]. To make the purification process even greener, the only organic solvent employed in all the steps was ethanol. MCSGP proves to be a reliable and eco-friendly technique for purifying Crocin-I from saffron extract, demonstrating for the first time that it can be effectively applied as a powerful approach for process intensification not only for peptides and proteins, as it is well-known from literature, but also for complex natural matrices.

References:

[1] C. De Luca, et al., Molecules 2021, 26, 4688.
[2] M. Hooshyari Ardakani, et al., accepted by Analytical and Bioanalytical Chemistry 2024.

ANA-OR-013

Agrifood residues valorization: chemical profiling of Kombucha beverages by chromatography and mass spectrometry

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Food waste valorisation is one of the most relevant topics in the scientific and social context due to its potential to promote more sustainable food production and the recovery of value-added compounds. A smart bio-valorization of agro-industrial wastes would be their possible conversion into fermented foodstuffs and beverages. Kombucha is a traditional Asian beverage which has just recently gained popularity in the North American market for its antioxidant properties and potential health-promoting effects. Kombucha is traditionally obtained by the fermentation of sucrose-rich tea with a Symbiotic COlony of Bacteria and Yeast known as SCOBY.

In this study, three different Kombucha beverages were prepared varying the carbon and nitrogen sources with agri food waste materials produced worldwide by processing industries and consumers. i.e. citrus residues and used coffee pods, respectively. While several other sugar-content raw materials have been used for the fermentation of Kombucha drink, in only few cases biomass wastes were selected. Moreover, citrus residues were never tested for the tea beverage preparation. Thus, the traditional and waste-based Kombucha formulations were processed over 21 days and the kinetics evaluated by monitoring of cell number, pH variation and trace elements. Considering the potential antioxidant content of the starting materials, the total phenolic and radical scavenging capacity was measured by spectrophotometric tests. Several molecular classes of volatile and volatizable compounds were detected by Head Space Solid Phase micro extraction Gas Chromatography coupled with Mass spectrometry (HS-SPME-GC/MS) and GC/MS, allowing to assess the molecular profile of each Kombucha beverage. The application of chemometric tools makes it possible to evidence similarities and differences among samples, and possible interactions between components.

The results of this research highlight the potentialities of employing food waste carbon and nitrogen sources to get Kombucha drinks enriched in bio-active compounds and then improved in antioxidant activity with respect to traditional formulations.

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CP-MIMS: a new frontier for the real-time monitoring of hazardous chemical migration from food contact materials

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Condensed Phase Membrane Introduction Mass Spectrometry (CP-MIMS) is an innovative technique for direct analysis in absence of sample preparation and chromatographic separation, while providing adequate selectivity for the reliable analysis in complex matrices. This strategy allows for the real-time monitoring of the dynamic processes involving the variation of the concentration of target compounds,[1] making it suitable for monitoring contaminants in food packaging. The migration of hazardous chemicals from food contact materials (FCMs) into food is an issue that analytical chemistry has to face with attention to emerging or re-emerging contaminants.[2] In this context, the recent reduction of the tolerable daily intake of bisphenol A (BPA) by EFSA has renewed interest in evaluating its release from FCMs to verify compliance with the current specific migration limit (50 µg/kg, EU Reg. 2018/213).

In this study, for the first time, a CP-MIMS method was developed and validated for the real-time determination of BPA released from FCMs. A capillary PDMS hollow fiber membrane interface using methanol-heptane as an acceptor phase delivered BPA to an electrospray ionization source and a linear ion trap mass spectrometer operated in the negative MS^2 acquisition mode. A full factorial DoE was applied to optimize four response variables by varying the acceptor phase flow and composition, stirring, temperature, and membrane length. Method validation was performed in drinking water and two simulants, namely ethanol 10% *v/v* and acetic acid 3% *w/v*. Excellent sensitivity and accuracy were achieved, with LOD at low µg/L level, intra- and inter-day precision lower than 18% and 95±6% trueness at the level of interest. Finally, the developed CP-MIMS method allowed the acquisition of the migration profile of BPA over time in the case of plastic FCMs that showed a detectable release. This study provides important insights into the role of CP-MIMS in scientific research across food safety with a focus on migration processes from FCMs.

References:

[1] V. Termopoli, M. Piergiovanni, D. Ballabio, V. Consonni, E. Cruz Muñoz, F. Gosetti, Separations 2023, 10, 139.
[2] M. Mattarozzi, E. Laski, A. Bertucci, M. Giannetto, F. Bianchi, C. Zoani, M. Careri, Analytical and Bioanalytical Chemistry 2023, 415, 119 – 135.

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Electroosmotic Flow in Capillary Zone Electrophoresis: Theoretical and Practical Aspects

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Capillary zone electrophoresis (CZE) is performed applying a constant electric field (E field) across the length of a capillary column, filled with a background electrolyte solution (BGE) of uniform composition. A characteristic feature of CZE is the possible occurrence of an electrically driven flow of the BGE across the separation pathway, the electroosmotic flow (EOF), which is generated by the action of the E-field on the electric double layer formed at the interface between the BGE and the charged inner wall of the capillary tube. Charge density and electric potential of the electric double layer at the solid-liquid interface and, consequently, direction and velocity of EOF, depend on both the surface chemistry of the capillary column and the physicochemical properties of BGE, and may either positively or negatively affect migration behavior and electrophoretic performance of the analytes[1].

This communication discusses the results of an investigation carried out to shed light on the factors influencing the formation of the electric double layer at the solid-liquid interphase of bare fused-silica capillaries and the consequent direction and speed of EOF. Several variables, including pH, viscosity and ionic strength of BGE, as well as the immobilization of ionic species in the so called compact or Stern region of the electric double layer are evaluated. The results of the discussed studies include the measurements of EOF carried out in bare fused-silica capillary tubes using BGEs of different composition containing selected adsorbing ionic species at various concentrations and the requested concentration of a neutral salt (NaCl) to maintain their ionic strength at a constant value. The dependence of EOF on the concentration of a variety of ionic species with affinity for the silanol adsorption sites on the inner surface of bare fused-silica capillaries is evaluated and discussed on the basis of mathematical models describing the electric double at the solid-liquid interface. In addition, the communication illustrates and discusses the approach of controlling the electroosmotic flow in order to modulate sample resolution by increasing the virtual migration distance (l_s), which, according to Rathore and Horvath[3], represents the virtual distance that the charged analytes move under the direct influence of the electric field, calculated as the product of the electrophoretic mobility of the analyte (μ) and its migration time (t_m).

References:

[1] D. Corradini, TrAc, Trends Anal. Chem. 2023, 164, 117080. https://doi.org/10.1016/j.trac.2023.117080.
[2] D. Corradini, Capillary Electromigration Techniques, in Handbook of HPLC, 2nd Ed., D. Corradini Ed., CRC Press, Boca Raton (USA) 2010, pp. 155-206.
[3] A.S. Rathore, Cs Horvath, J. Chromatogr. A 1996, 743, 231-246.

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Identification and quantification of soybean and mustard allergenic proteins in wheat flour using mass spectrometry-based approaches

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Food allergies represent a significant concern for food safety and public health, as largely acknowledged by the World Health Organization (WHO). To safeguard the well-being of sensitive individuals, European Regulation No. 1169/2011 has listed fourteen allergenic ingredients, including gluten-containing cereals, crustaceans, eggs, peanuts, fish, soy, milk, nuts, celery, mustard, sesame, lupin, sulphites, and molluscs. Manufacturers are required to display these ingredients or their potential presence, for instance from *in-situ* contamination during food production, on food labels, utilizing font sizes, styles, or colours different from other listed ingredients[1].

In recent years, considerable efforts have been dedicated to identifying allergenic ingredients in various food products to safeguard consumer health. While immunological assays have been widely adopted due to their user-friendly nature, relatively high productivity, and low detection limits, they can suffer from false positives[2]. Conversely, mass spectrometry (MS) techniques have emerged as powerful tools, offering both high selectivity and sensitivity for multi-allergen monitoring in food products[3,4]. To address this need for more reliable multi-allergen detection, this study aimed to identify and quantify soy and mustard allergenic proteins in trace amounts in wheat and flour samples using a bottom-up proteomic approach. Different and time-efficient protocols were employed to enhance protein extraction by testing environmentally friendly solvent mixtures. The protein extracts were enzymatically digested and analysed using reversed-phase liquid chromatography coupled with high and low-resolution/accuracy MS. Several data acquisition procedures were exploited, including targeted tandem mass spectra, data-dependent analysis (DDA), and multiple reaction monitoring (MRM). The method was validated to assess linearity, limit of detection, limit of quantification, and matrix effect by recurring to selected marker peptides, qualifiers and quantifiers. Quantification of soy and mustard allergenic proteins in wheat and flour samples was also accomplished.

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References:

[1] EUROPEAN PARLIAMENT *Off. J. Eur. Union* **(**2011**)**, *L 304*, 18–63.
[2] Monaci, L.; Visconti, A. *Trends Food Sci. Technol.* **(**2010**)**, *21*, 272–283.
[3] Bianco, M.; Calvano, C.D.; Ventura, G.; Losito, I.; Cataldi, T.R.I. *Food Control* **(**2022**)**, *131*, 108443.
[4] Bianco, M.; Ventura, G.; Calvano, C.D.; Losito, I.; Cataldi, T.R.I. *Food Chem.* **(**2022**)**, *393*, 133319.

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Determination of additives in copper plating baths by dynamic Electrochemical Impedance Spectroscopy (EIS)

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Organic additives are vital for maintaining the quality of metallic coatings in commercial electroplating baths, but their effectiveness wanes over time due to degradation and drag-out. Constant monitoring and dosing are necessary to maintain optimal concentration levels and preserve both technical integrity and aesthetic appeal. Due to the complex formulation and the synergic effect of various additives traditional chromatographic techniques are impractical for routine industrial analysis. Electrochemical methods, such as the Hull cell test [1] and Cyclic Voltammetric Stripping (CVS) [2] measurements, are typically used to adjust additive concentrations based on their overall effects on the electrodeposition process. The Hull cell test, while widely used, relies on trial and error and operator experience, yielding only qualitative assessments. CVS measures the change in the rate of copper deposition, reflecting additive concentration, but may not be suitable for all types of electroplating baths due to their varying complexities.

Previous Electrochemical Impedance Spectroscopy (EIS) studies on copper plating baths qualitatively correlate changes in impedance with aging [3], our goal was to obtain the quantification of additives through EIS. To achieve that, the experimental data were processed in terms of resistive and capacitive components to calculate the distribution of relaxation times (DRT) using Lasso regression [4], and the results were fed to a multivariate analysis to overcome this challenge.

The positive results obtained [5] make this method of great interest in both industrial and academic settings. Its application in the galvanic field is particularly useful for achieving a detailed understanding of the function of each additive, their interactions, and the aging of plating baths.

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References:

[1] D. Wood, Metal Industry 1938, 36, 330-331.
[2] B. Xie et al., J. Electroche. Soc. 2007, 154, D516.
[3] C. Gabrielli et al., J. Appl. Electrochem. 2008, 38, 457–468.
[4] A. Piccioni et al., J. Phys. Chem. C 2023, 127, 7957–7964.
[5] M. Verrucchi et al., J. Electroanal. Chem. 2024, 954, 118045.

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Electrochemically powered dissipative hydrogel films for out-of-equilibrium operations

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Inspired from the ability of living systems to temporally control their structures and functions, much efforts have been devoted in recent years to the exploration of out-of-equilibrium chemical systems. Despite the progress, it remains challenging to program soft materials with adaptable, time-dependent properties and to leverage these properties to develop out-of-equilibrium operations. Success in this endeavour will lead to a new generation of soft-robotic systems and biomedical devices that can autonomously perform complex operations. Here, we present a new platform that integrates a dynamic hydrogel film onto an electrode surface to enable the temporal modulation of the hydrogel mechanical properties under out-of-equilibrium conditions powered by electricity.

We demonstrate that the lifetime of the transient network of the hydrogel film can be effectively controlled by programming the voltage applied at the electrode directing the transient stiffening or softening of the hydrogel network. In the present study, we also present the application of the developed electrochemically-driven transient process for the release of protein cargos from the hydrogel film. Temporally controlled operations of the hydrogel films are demonstrated for the programmable sequential release of multiple protein payloads from electrode arrays. This application provides an example for the transition from classical switchable materials to more life-like materials capable of adaptive, self-regulated behaviour, thereby providing new opportunities for controlling electrochemically complex out-of-equilibrium operations.

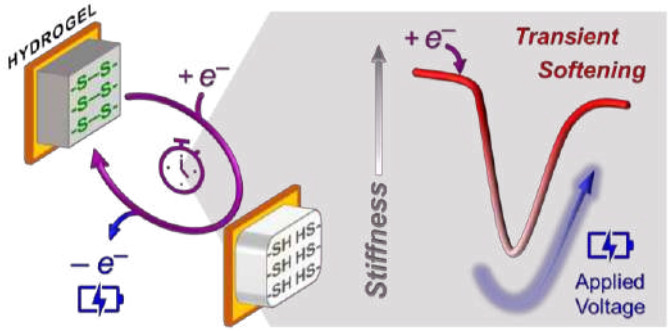

Figure 1: Implementation of electrochemically dissipative cycles enabling the transient modulation of the stiffness properties of hydrogel films.

References:

[1] R. Baretta, M. Frasconi, J. Am. Chem. Soc. 2024, 146, 7408–7418.

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ANA-OR-019

Revolutionizing Alzheimer's disease diagnosis: the advancement of screen-printed electrochemical biosensors for biomarkers detection

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The development of screen-printed electrochemical biosensors represents a significant advancement in the early detection and diagnosis of Alzheimer's disease (AD), a neurodegenerative disorder characterized by progressive cognitive decline and memory loss.[1] Screen-printed electrodes (SPEs) have emerged as promising platforms for the development of disposable, eco-friendly, and cost-effective electrochemical sensors. Their lightweight and versatile nature allows for the integration into paper-based and wearable devices, making them suitable for point-of-care (POC) applications. The fabrication of SPEs involves the deposition of conductive ink on a substrate, which can be easily customized to detect various biomarkers associated with AD, including proteins, peptides, and neurotransmitter, such as amyloid-beta peptides, tau proteins, and microRNAs, that can be detected with high accuracy and specificity.[2] MicroRNAs (miRNAs), were recently highlighted for their promising role as biomarkers for early diagnosis. In particular, miRNA-29 represents a class of miRNAs known to regulate pathogenesis of AD.[3] Considering this, an electrochemical printed strip for the detection of miRNA-29a at low levels was developed. The architecture was characterized by the presence of gold nanoparticles and anti-miRNA-29a probe labelled with a redox mediator, selecting the most appropriate probe density to detect low target concentration. The present tool was capable to detect miRNA-29a both in standard solution and in serum, respectively, down to 0.15 and 0.2 nM. The platform highlighted a good repeatability of ca. 10% and satisfactory selectivity in presence of interfering species. The results demonstrate the suitability of this approach in terms of easiness to use, time of production, sensitivity, and applicability, reducing the time gap between disease and treatment.

References:

[1] K. Kim, MJ. Kim, D.W. Kim, S.Y. Kim, S. Park, C.B. Park. Nat Commun 2020, 11, 119.
[2] H.N. Chan, D. Xu, S.L. Ho, M.S. Wong, H.W. Li. Chemical Science 2017, 8(5), 4012-4018.
[3] S. Silvestro, P. Bramanti, E. Mazzon, Int. J. Mol. Sci. 2019, 20, 3979.

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ANA-OR-020

A ligand-based electrochemical magneto-assay for point-of-care determination of BRD4

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In the context of a research line focused on the development of magneto-electrochemical platforms for the determination of protein biomarkers for Point-of-Care Testing (PoCT) applications,[1,2] a novel electrochemical magneto-assay for the detection of the BRD4 protein was developed. Bromodomain-containing protein 4 (BRD4) is a member of the Bromodomain and Extra-Terminal (BET) protein family, which are well-known epigenetic regulators involved in gene expression mechanisms. BRD4 has been shown to play a significant role in breast and prostate cancer, glioblastoma, and melanoma.[3] Considering that gene downregulation by BRD4 inhibition or degradation has demonstrated significant therapeutic potential for the treatment of several tumour diseases, detection of BRD4 is crucial to assess its overexpression as well as the efficacy of therapeutic protocols based on its inhibition.

Despite the diagnostic relevance of this biomarker in cancer, to the best of our knowledge, there are no literature studies on BRD4 protein biosensors. The proposed method is based on the immobilization of a biotinylated BET-specific ligand on magnetic micro-beads (mMBs) functionalized with streptavidin followed by BRD4 target capture and binding of an HRP-conjugated anti-BRD4 antibody. After enzyme-promoted oxidation of hydroquinone, electrochemical detection was performed by chronoamperometry. This protocol allowed the entire complex to be assembled in a single incubation step in as little as 10 minutes, proving to be extremely fast. The analytical validation was performed in human plasma, with excellent performance in the undiluted matrix, showing no significant differences ($p>0.05$) in the results obtained in PBS buffer, thus proving good sensitivity with a LOD of 1.99 nM. Interestingly, by changing the receptor concentration on mMBs, it is possible to increase the dynamic response range and optimize the analytical performance of the assay.

Finally, the ligand-based magneto-assay was applied to determine BRD4 in untreated cell lysates from HEK cells. The results were consistent with the data obtained using a commercial ELISA kit, demonstrating the potential of the method for developing rapid tests to evaluate the effectiveness of therapeutic treatments and disease progression in PoCT settings.

References:

[1] M. Mattarozzi, M. Giannetto, M. Careri, Talanta 2020, 217, 120991.
[2] S. Fortunati, C. Giliberti, M. Giannetto, A. Bertucci, S. Capodaglio, E. Ricciardi, P. Giacomini, V. Bianchi, A. Boni, I. De Munari, R. Corradini, M. Careri, Biosensors and Bioelectronics: X 2023, 15, 100404.
[3] B. Donati, E. Lorenzini, A. Ciarrocchi, Molecular Cancer 2018, 17, 164.

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ANA-OR-021

An integrated paper-based electrochemical point-of-care device for precision medicine in breast cancer

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Real-time updates regarding the health condition of individuals have become a prominent subject in contemporary medical research activities. Undoubtedly, the ultimate objective is to shift from traditional hospitals to a home-based medical care approach with the aim of enhancing the overall healthcare system[1]. Technological advancements are playing a pivotal role in facilitating this significant transition, as they allow for the development of compact sensing devices, which can replace cumbersome instruments, eliminate uncomfortable wire connections, and deliver straightforward data-transferring procedures based on wireless transmission[2]. In this regard, paper-based technology is an obvious choice as a support material, thanks to its wide range of outstanding properties, such as low cost, eco-sustainability, versatility, affordability, and biocompatibility. Indeed, paper can be used to fabricate microfluidic systems integrated into point-of-care devices, conferring to these smart analytical tools several fascinating features. Herein, we present an innovative point-of-care platform for the home-based and self-assessment of hemoglobin and electrolytes in capillary blood, to support oncology patients at home. The point-of-care platform was combined with a four-leaf clover paper-based microfluidic system for the management of the solution, creating a hydrophobic zone to define a hydrophilic working area. The sensing tool encompasses a double printed electrochemical sensor for hemoglobin detection and three ad-hoc modified printed sensors connected with a multi-chip NFC system consisting of multiple boards for wireless simultaneous detection of the target analytes. The electrochemical performance of the hemoglobin sensor has been tested directly in the real matrix, analyzing more than 40 capillary blood samples, and constructing a calibration curve described by the following equations $y = 0.1x + 0.7$, $R^2 = 0.884$. Moreover, the ionophore-based carbon black-potentiometric sensors for Na^+, K^+, and Ca^{2+} have been tested in standard solution obtaining calibration curves described by the following equations: $y = (0.056 \pm 0.002)\ x + (0.300 \pm 0.004)$, $R^2 = 0.993$, $y = (0.057 \pm 0.001)\ x + (0.595 \pm 0.003)$, $R^2 = 0.986$, and $y = (0.034 \pm 0.001)\ x + (0.319 \pm 0.001)$, $R^2 = 0.997$, respectively. The applicability of this sensing platform was evaluated by measuring capillary blood samples of breast cancer patients, obtaining results in agreement with the reference method.

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References:

[1] https://www.weforum.org/agenda/2016/11/healthcare-in-2030-goodbye-hospital-hello-home-spital/.
[2] Dian, F. J., Vahidnia, R., & Rahmati, A. (2020), IEEE access, 8, 69200-69211.

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ANA-OR-022

Sensitive detection of SARS-CoV-2 spike protein using ACE2-modified graphene field-effect transistors

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COVID-19, caused by the severe acute respiratory syndrome-coronavirus 2 (SARS-CoV-2), originated a global health crisis, causing over 2 million deaths and affecting human daily life all over the world. This pandemic emergency highlighted how the current diagnostic tests have important limitations.[1] Therefore, it is urgent to develop faster, more precise and sensitive sensors. Graphene field effect transistors (GFET) are analytical platforms that enclose several of these requirements. However, the design of a sensitive and robust GFET is challenging. In this work, we report a GFET-based analytical platform for the detection of SARS-CoV2 spike protein using as a receptor the human membrane protein involved in the virus internalisation: Angiotensin Converting enzyme 2 (ACE2).[2] By finely controlling the graphene functionalisation, tuning the Debye length, we have been able to detect the spike protein with a limit of detection of 2.94 aM.[3] Such limit of detection is comparable with the ones obtained with GFET functionalized with selective antibodies. Furthermore, we deeply characterized the ACE2-spike protein interaction with several technique such as AFM, PSR, QCM an nanomechanical measurements. This work demonstrated that the human membrane proteins responsible for the internalization of viruses can be used as receptor for electrochemical analytical platforms, allowing the detection of a broad variety of pathogens, and being a powerful tool in the fight against future pandemics.

References:

[1] G. Liu and J. F. Rusling, ACS Sens., 2021, 6, 593–612.
[2] C. Peng et al, Phys. Chem. Lett., 2020, 11, 10482– 10488.
[3] A. Silvestri et al, Nanoscale, 2023, 15, 1076–1085

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ANA-OR-023

Detection of Phthalates from Mulches: A Nanocomposite-Based Electrochemical Aptasensor

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Mulching is a widespread agricultural technique aiming at *e.g.* improving crop quality, curbing weeds proliferation, preserving soil moisture, etc. This practice often involves the use of plastic-based films: these materials contain and release additives (e.g., phthalates, known as endocrine disruptors) that can enter the food webs via soil biota and crop plants, representing a threat for both human health and the terrestrial environment[1].

A smart and rapid sensing of these substances in soil and crops is thus urgently needed. Poly(amino acids) (PAAs) have been employed as novel conducting polymers with a great potential in biosensing; different types of nanomaterials such as metal nanoparticles have been utilized to functionalize PAAs in order to improve their analytical performance[2]. In this study, a nanocomposite biosensing platform, based on poly(amino acids) and gold nanoparticles is first developed and then employed to build an oligonucleotide-based competitive assay for phthalic acid esters (PAEs) detection with enzymatic amplification. Different assay formats are tested to find out the best experimental conditions for achieving a fast and sensitive PAEs determination: specifically, the aptameric DNA sequence is immobilized by exploiting the thiol-gold affinity, and a competition between the analytes and a biotinylated DNA probe, which is complementary to a portion of the immobilized aptamer, is carried out; a similar competition is also established between an immobilized probe and the aptamer in solution. In both cases, the biotinylated hybrids are coupled with a streptavidin-alkaline phosphatase conjugate: this enzyme catalyses the hydrolysis of 1-naphthyl phosphate enzymatic substrate into 1-naphthol electroactive product, detected by means of differential pulse voltammetry (DPV). The developed biosensor will be applied in real samples, as soil and strawberries extracts, to prove its suitability for *in situ* analysis.

Acknowledgements: this research is supported by the European Union-Next GenerationEU, UNIFI Young Independent Researchers Call – MuSC (*Analysis and sensing of contaminants in agriculture: from Mulches to Soil and Crops*).

References:

[1] B. Xu, F. Liu, … & J. Xu, Critical Reviews in Environmental Science and Technology 2020, 50, 2175–2222.
[2] H. K. Kordasht, M. Hasanzadeh, … & P. M. Alizadeh, Trends in Analytical Chemistry 2021, 140, 116279–116306.

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ANA-OR-024

CELECTOR, AN INNOVATIVE LABEL-FREE TECHNOLOGY FOR THE QUALITY CONTROL OF LIVING CELLS FOR IMPROVED THERAPY MEDICIANL PRODUCTS

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In the last decade, cell-based platforms have been studied for many innovative applications comprising advance therapy medicinal products (ATMPs), disease models, and effective drug screening through individual customized in vitro drug testing. The process for the development of well-established ATMPs is challenging. Many issues must be considered from raw material, manufacturing, safety, and pricing to assure the quality of ATMPs and their implementation as innovative therapeutic tools. As for standard drugs, cell-based ATMPs technologies for quality control, and non-invasive isolation and production of cell-based ATMPs are then needed to ensure their rapidly expanding applications and ameliorate safety and standardization of cell production. Stem cells can be found in every tissue, but access is not always easy and cannot be derived in high numbers. Adipose tissue is a very interesting source of mesenchymal stem cells and its use span from aesthetic medicine, for facial and body rejuvenation, to orthopaedic treatments.

In this work we present a new automated instrumentation, Celector® for tag-less cell sorting and quality control, using a micro-camera for cell detection and a specifically designed software for image acquisition, post-processing and data analysis. The output of the instrument is a multiparametric fractogram representing number, size and shape of the eluted cells as a function of fractionation time and it is the fingerprint of the cell sample. In this work, we investigated the ability of the new technology to identify and sort sub-populations of the heterogenous expanded adipose derived stem cells, for improved cell therapies. Celector® was shown able to select the most potent and homogeneous cell components from heterogeneous stem cell populations of different origins and to purify them from senescent and differentiated cells to improve the success rate of ATMP applications. It also provides predictive data for defining successful isolation procedures of primary cells and optimization of cell culture procedures with interesting features for laboratories that isolate and cryopreserve stem cells for clinical applications.

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Development of analytical methods for quality control of therapeutic proteins using Quality by Design principles: the Infliximab case study

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Recombinant proteins are complex molecules expressed by living organisms that present numerous possible conformations, post-translational modifications and microheterogeneity. Chemical and enzymatic modifications can readily occur during production, extraction, purification, formulation and storage[1]. Among these modifications, some of them are particularly critical for the efficacy and safety and are known as Critical Quality Attributes (CQAs), which affect the Quality Target Product Profile (QTPP). Quality Control (QC) is a key factor in biopharmaceutical development since it allows to assess the quality of the final product and thus its safety and efficacy. It involves a series of analytical procedures designed and validated to monitor the product's CQAs. However, the complexity of recombinant proteins makes analytical method development a challenging task. Analytical Quality by Design (AQbD) could represent a structured approach to analytical method development that can help to ensure a robust procedure across its lifecycle. It consists in a systematic approach to procedure development and validation that begins with predefined objectives and emphasizes procedure performance understanding and control, based on sound science and Quality Risk Management[2].

The QC of therapeutic monoclonal antibody Infliximab by using AQbD approach will be presented as guiding example to obtain high performance analytical procedures. Preliminary results of the set-up analytical platform development will be shown. Liquid chromatography, capillary electrophoresis and mass spectrometry were used as analytical techniques to evaluate the QTPP. The adoption of Risk Assessment facilitated the identification and management of risk factors. The application of multivariate tools, at first using a screening phase and then response surface methodology, made it possible to achieve a high degree of analytical procedure understanding.

[1] N. Nupur, S. Joshi, D. Gulliarme, A.S. Rathore, 2022, 10, article number 832059.
[2] ICH Harmonised Tripartite Guideline, Pharmaceutical Development Q8(R2), 2009.

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ANA-OR-026

Concerted development of Lateral Flow Immunoassays detecting infectious diseases: the case of the foot-and-mouth disease (FMD) virus diagnosis and serotyping.

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Despite of the democratic nature of the analyses performed by the Lateral Flow Immunoassays (LFIA), fulfilling all the criteria for point of care testing [1], their development includes different fields and expertise. The material and analytical chemistry must be focused on the development of the device itself. Biotechnology for the generation of monoclonal antibodies, mAbs. Medical and veterinary knowledge to individuate strategical molecular targets. The connections by reference laboratories for collecting the needs of the territory and the samples for the validation and expertise on the regulation and certification. To this aim the collaboration between the authors institutions has been set up for the concerted development of functional LFIA devices for animal infectious diseases diagnosis [2,3]. In this presentation we will report the case of the concerted development of two multiplex LFIA devices (LFD) for the detection and typing of foot-and-mouth disease (FMD) viruses in clinical sample. The FMD is the most important transboundary viral disease of livestock in the international context, because of its extreme contagiousness, widespread diffusion, and severe impact on animal trade and animal productions. The two devices employed capture mAbs, anchored into reactive lines onto the LFIA strip, and detection mAbs (mAb*), labelled with gold nanoparticles. We used experimental design for optimizing the mAbs* and the positioning of the reactive lines [3]. A rapid and simple extraction & test procedure was proposed for ca 0.2 g of epithelial tissue (assay time <20'). The devices were then tested with various lineages of the virus (n=85), to define the reactive spectra for each serotype. Thus, LFD1 and LFD2 underwent to a wide multicentred validation including samples tested at the Pirbright Institute (UK) WRL, in Turkey, Kenya, and Pakistan, (n=317). The LFD1 sensitivity for diagnosing A, O and Asia 1 serotypes was, respectively, 94.3%, 95.8%, and 82.8% compared to reference ELISA, and 87.1%, 93.3%, and 80.0% compared to PCR. A PAN-reactive line diagnosed the 90% of the ELISA+ and 88% of the PCR+ samples. The LFD2 sensitivity for SAT 1 and SAT 2 serotypes was, respectively, 79.2%, and 82.5% compared to reference ELISA, and 74.6%, and 68.6% compared to PCR. The PAN-reactive line diagnosed the 62% of both the ELISA+ and PCR+ samples. These devices are available and employed on-field, mirroring the efficiency of this expertise-combining approach for generating highly functional LFIAs.

References:

[1] K.J. Land et al., Nature Microbiology 2019, 4, 46-54.
[2] S. Cavalera et al., Talanta 2022, 240, 123-155.
[3] S. Cavalera et al., Microchimica Acta 2024, 191, 9

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ANA-OR-027

Sustainable biomimetics made by the molecular imprinting of silk fibroin: synthesis, properties and applications.

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We report the development of aqueous-soluble nanotraps that behave as biomimetic receptors, starting from a sustainable source, i.e. silk fibroin, that is biocompatible, nontoxic and already in-use in regenerative medicine. Specific molecular recognition was conveyed to the silk nanotraps by a unique way to exploit molecular imprinting (MIPs), so to entail recognition by a template-assisted synthesis[1]. Herein, the sustainable monomers of silk, were used in the MIP process, instead of conventional acrylamido-based monomers. The synthetic protocol was optimized with the aid of surface response method. The silk-nanotraps, called bioMIPs, were physically and functionally characterized, demonstrating high affinity (nM) for the targets and selectivity.[2] Furthermore, the enzymatic degradation of the bioMIPs was studied. The biocompatibility of the nanotraps was confirmed. The nanotraps were further labelled with fluorescent tags and tested for imaging in cell cultures.[3] The bioMIP's synthesis proved a general route for preparing recognition elements both for proteins and small molecules.[2,4] Applications are in diagnostics, imaging and sensing.

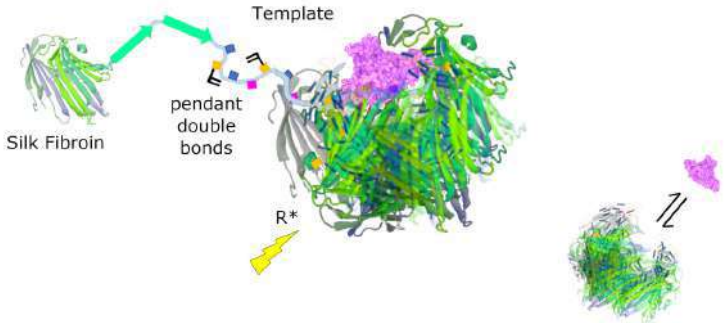

Figure 1: Concept of silk fibroin molecularly imprinted nanotraps.

References:

[1] Y. Hoshino, T. Kodama, Y. Okahata, K.J. Shea J. Am. Chem. Soc. 2008, 130, 15242.
[2] A.M. Bossi, A. Bucciarelli, D. Maniglio, ACS Appl. Mater. Interfaces, 2021, 13, 312431.
[3] A.M. Bossi, D. Maniglio, Microchim. Acta, 2022, 189, 66.
[4] D. Maniglio, F. Agostinacchio, A.M. Bossi, MRS Advances, 2023.

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Characterization of biomimetic vesicle-compatible nanospheres for EV-mediated therapy development with HF5-multidectection

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Polydopamine (PDA) is a melanin like biomimetic material increasingly used in photodynamic therapy, often coupled to recognition systems such as vesicles, due to its excellent biocompatibility, degradability, easy preparation, and photothermal conversion[1]. Despite its various applications understanding the relationship between its properties and its numerous chemical structures remains largely unexplored. Additionally, the simultaneous formation of multiple PDA species during its synthesis protocols is often neglected[2].

To shed light on the topic we exploited a Hollow Fiber Flow Field Flow Fractionation (HF5) platform coupled with UV-Vis, fluorescence and multi angle light scattering detectors. This innovative miniaturized technique allows to study and quantify colloidal content in native conditions, preserve weak supramolecular structures, and separate different colloidal populations providing individual size, morphology, and spectral properties. By monitoring over time a common PDA synthesis, we were able to gather information of the reaction kinetic and detect the presence of two different species, formed independently and at varied rates during dopamine oxidation and self-polymerization. While sharing similar UV absorption spectrum, they displayed differing emissions. The first specie (P), eluting earlier, adopts a coiled polymeric structure with lower molar mass and hydrodynamic radius compared to size standards under similar conditions. The second species consists of monodispersed solid spherical nanoparticles (NP) with a molar mass two orders of magnitude higher than the first, representing a stable supramolecular system with a defined radius, while the first lacks 3D/structural organization.

These results represent an outstanding novelty in the field of elucidating the relationship between different PDA nanoforms since up to now no experimental techniques have been proved to be able to separate the different products of dopamine polymerization in real time. Overall due to its high, fast and unique informativity the presented HF5 platform emerges as extremely powerful tool towards the design and characterization of the most optimal PDA nanoforms for clinical development. Future studies will involve the masking of these materials with vesicular matter to explore their therapeutic potential.

References:

[1] W. Chen, Y. Song, S. Bai, C. He, Z. Guo, Y. Zhu, Z. Zhang, X. Sun, 2023, 17(8), 7733-7749.
[2] A. Mavridi-Printezi, S. Giordani, A. Menichetti, D. Mordini, A. Zattoni, B. Roda, L. Ferrazzano, P. Reschiglian, V. Marassi, M. Montalti, 2024, 16(1), 299-308.

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Rapid and Convenient Quantification of Therapeutic Monoclonal Antibodies in Undiluted Biological Fluids

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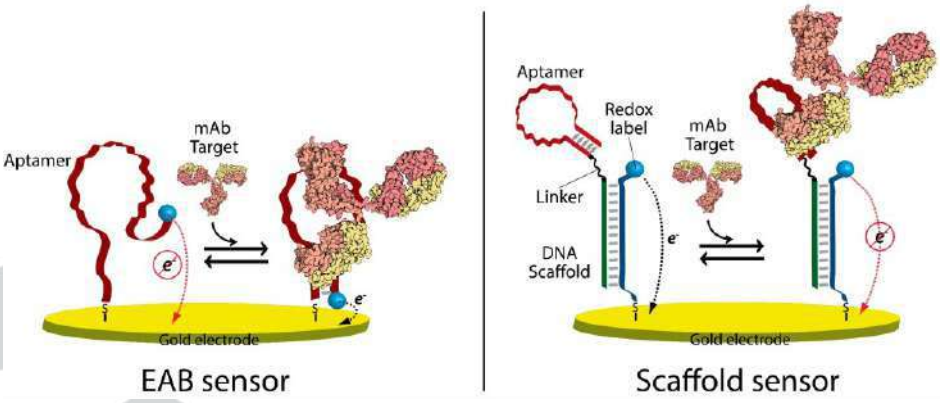
The goal of precision medicine is to tailor treatment precisely to each individual patient. Its achievement would be greatly facilitated by the availability of sensing technologies that enable convenient (one-step) and rapid measurement of drugs and biomarkers directly in undiluted biological fluids. Due to their low cost, ease of use and good analytical performance in complex clinical samples, electrochemical aptamer based (EAB)[1] sensors appear to be a promising means to this end. Therefore, we present here the development of a new EAB sensor for the measurement of therapeutic monoclonal antibodies,[2] which are biological drugs used for the treatment of various diseases such as cancer or infectious diseases.[2] The sensors use a previously reported DNA aptamer capable of recognizing the selected monoclonal antibody. We incorporated these into the EAB platform by truncating them (causing them to undergo a binding-induced conformational change), modifying them with a redox-reporting methylene blue, and covalently attaching them to an interrogation electrode. We then adapted the system to a scaffold approach, using the aptamer as the recognition element attached to a redox-reporting methylene blue double-stranded DNA scaffold. The resulting sensors can measure the monoclonal antibody directly in biological fluids such as blood within minutes. The speed and convenience with which this is achieved suggests that the developed sensors could significantly improve the ease and frequency with which biological drugs can be monitored during the therapeutic treatment.



References:

[1] L. R. Schoukroun-Barnes, F. C. Macazo, B. Gutierrez, J. Lottermoser, J. Liu, R. J. White, Annual Review of Analytical Chemistry 2016, 9, 163-181.
[2] M. S. Castelli, P. McGonigle, P. J. Hornby, Pharmacology research & perspectives 2019, 7, e00535.

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The value of mass spectrometry in exploring challenging plant lipidome

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Plant lipids are like hidden treasures within the plant kingdom, holding the key to understanding plant stress responses and paving the way for exciting new plant-based products. Lipidomics allows us to delve deeper into these intricate networks and unlock their potential. To truly advance plant biology and fuel innovation, robust methods for comprehensive lipid analysis are crucial. This communication explores powerful tools based on chromatography-mass spectrometry, specifically designed to tackle the challenges of plant lipidomics. From identifying and quantifying specific lipids to separating complex isomers, these techniques offer unprecedented insights.

We report how the combination of various strategies as hydrophilic interaction liquid chromatography (HILIC) or reversed-phase LC (RPLC), coupled with electrospray ionization (ESI) and mass spectrometry (MS), operated both in high and low-resolution mode, can be a powerful tool to characterize major phospholipids (PL), glycolipids (GL), glucosinolates or minor arsenosugar phospholipids (As-PL)[1] in plant novel foods. Through the acquisition of single (MS) and tandem (MS/MS) mass spectra, or by the all-ion fragmentation (AIF) operation mode in the quadrupole-Orbitrap mass spectrometer[2], a great number of lipid species are recognized in terms of fatty acyl chains and regiochemistry. More, to characterize the carbon-carbon double bond locations of both sn-1 and sn-2 fatty acyl chains, we carried out a simple oxidation by *m-chloroperoxybenzoic acid* followed by collision-induced dissociation of epoxidized species as deprotonated molecules, $[epoM - H]^-$. RPLC separation and a sequential triple-stage MS (i.e., MS^3) analysis of unsaturated and epoxidized lipid species can be very helpful in their identification, starting from a diagnostic product ion pair with 16.0 Da mass difference[3].

Special attention is given to uncommon lipids as signal receptors and signalling molecules that affect plant growth and responses to environmental challenges. In this communication, interesting results in this field will be presented and discussed.

References

[1] Coniglio D., et al. 2020, J Am Soc Mass Spectrom;31(6):1260-1270
[2] Castellaneta, A. et al. 2022, J Am Soc Mass Spectrom; 33(11):2108-2119
[3] Coniglio D., et al. 2022, J Am Soc Mass Spectrom.;33(5): 823-831

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First proof of concept of a click inverse electron-demand Diels-Alder reaction for pinpointing carbon-carbon double bonds in untargeted lipidomics

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In the latest years, lipidomics has become a prominent tool in clinical chemistry due to the proven connections between lipid dysregulations and the insurgence of pathologies. Despite being the foremost technique for lipidomics, high-resolution mass spectrometry (HRMS) is not sufficient for elucidating the lipid structures, especially when it comes to the regiochemistry of carbon-carbon double bonds[1], which play a major role in determining the properties of cell membranes[2]. Over the years, several approaches have been proposed in combination with HRMS for elucidating the regiochemistry of double bonds, including unconventional fragmentation techniques and derivatization prior to MS analysis[1]. Among the latter, photochemical reactions, e.g., the Paternò–Büchi reaction, have shown great potential for their versatility, but have the unavoidable drawback of generating several oxidation by-products and splitting the MS signal due to the inherent asymmetry of the reaction that generates multiple derivatives. Among other possible approaches for derivatizing electron-rich double bonds, the emerging inverse electron-demand Diels–Alder (IEDDA) reaction with tetrazines stands out thanks to its unmatchable kinetics and so far has found several applications in basic biology, protein imaging, and therapeutics[3].

In the present study, we present the first proof of concept of a catalyst-free click IEDDA reaction to pinpoint carbon-carbon double bonds in free and conjugated fatty acids in untargeted MS-based lipidomics. To assess the applicability of the IEDDA reaction, fatty acid and phospholipid regioisomers were analyzed alone and in combination to evaluate (i) the obtention of diagnostic product ions following MS/MS fragmentation, (ii) the optimum reaction conditions to maximize the reaction yields, and (iii) the possibility of performing relative quantitation of lipid regioisomers. The preliminary data showed that the reaction not only confirmed its kinetics even with the scarcely activated alkene groups on fatty acyl chains but also minimized the splitting of the MS signal thanks to the symmetric nature of tetrazine reagents. Finally, the optimized IEDDA protocol was employed in an untargeted lipidomics study on plasma samples of patients suffering from prostate cancer and benign prostatic conditions to confirm the applicability of the proposed reaction with complex matrices of clinical interest.

References:

[1] J. R. Bonney, B. M. Prentice, Analytical Chemistry 2021, 93, 6311-6322
[2] H. Martinez-Seara, T. Rog, M. Pasenkiewicz-Gierula, I. Vattulainen, M. Karttunen, R. Reigada, Biophysical Journal 2008, 95, 3295-3305
[3] B. L. Oliviera, Z. Guo, G. J. L. Bernardes, Chemical Society Reviews 2017, 46, 4895-4950.

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LipiD7: a Matlab routine for lipids characterization

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Lipidomics [1] has experienced significant advancements, primarily due to progress in mass spectrometry (MS) and computational methodologies [2]. These advancements have not only deepened our understanding of biological mechanisms but have also enabled the analysis of a wide array of lipid classes [2], leading to the identification of previously undiscovered lipid species. Such discoveries hold promise for diagnosing stress conditions or understanding how organisms adapt to environmental changes. Addressing the challenge of identifying and characterizing these new lipid species necessitates propper bioinformatic approaches [3].

This study introduces a Matlab-based software designed to characterize lipids through MS and MS/MS analyses, enabling the identification of both the fatty acyl substituents and regiochemistry. Moreover, with information on the derivatization process, the software can infer the position of double bonds [4]. Specifically tailored for handling HILIC-ESI-MS/MS data, wherein class-specific elution times are readily obtained, the software is versatile enough to process direct infusion, MALDI-MS, or RPLC-ESI-MS/MS data. The identification process commences by comparing the experimental retention time (RT), if available, with preset windows. If the RT aligns with the elution window of certain lipid classes, the corresponding lipid precursor mass is searched in a database containing exact masses of selected adducts. Subsequently, the fragmentation pattern is examined to characterize precursor species based on established rules. The software generates an output table summarizing spectrum details and annotated MS/MS spectra. Various functionalities have been developed to handle different lipid types, including glycerophospholipids (alkyl or ether lipids), sphingolipids, glycerolipids, and unconventional natural phospholipids such as GlcA-DAG [5] or As-PL [4]. The software is capable of interpreting spectra from both positive and negative ion modes and is platform-independent, requiring only an Excel file as input. Furthermore, it includes a distinct function to analyse MS/MS spectra related to lipid species not documented in the literature, providing hints on lipid formulas and sum compositions, thereby facilitating the discovery of new lipid species.

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References:

[1] X.Han, 2016, 12, 668-679.
[2] T. Züllig, et al., 2020, 412, 2191-2209.
[3] Z. Ni, M. Wölk, et al., 2023, 20, 193-204.
[4] D. Coniglio, G. Ventura, et al., 2023, 235, 115628.
[5] G. Ventura, C. D. Calvano, et al., 2021, 32, 2227-2240.

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Microplastics as vehicles for toxic metal ions: an adsorption study

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The widespread occurrence of plastic waste in aquatic environments and its impact on animals and humans health is a major topic of scientific research worldwide[1,2]. Plastics and bioplastic polymers dispersed in the environment undergo several degradation processes, resulting in significant changes in their morphological properties and in their very small particle sizes. Of greatest concern to the scientific community is the fact that so-called microplastics (MPs), *i.e.* polymeric particles with a diameter below 5 mm, enter in the food chain and can accumulate in the tissues and organs of humans and animals[1,2]. The hazard of MPs is highlighted by its ability to adsorb pollutants from the surrounding aquatic environment, making it a vehicle of toxic substances[2,3]. In this work we report the adsorption of Pb^{2+} ions on MPs of polystyrene (PS), of PS functionalized with carboxylic groups (PS-COOH) and of polylactic acid (PLA). The adsorption capacity of MPs toward Pb^{2+} ions were investigated at different experimental conditions, i.e. in water, in $NaNO_3$ or NaCl 0.1 mol L^{-1} and with small amounts of the surfactant sodium dodecyl sulfate (SDS). Atomic spectroscopy and voltammetry were used to determine the concentration of Pb^{2+} ions. Electrochemical impedance spectroscopy (EIS), scanning electron microscopy with energy dispersive X-ray analysis (SEM-EDX), ξ-potential and FT-IR measurements were performed to evaluate the mechanism of Pb^{2+} ions adsorption onto MPs. The results show that the adsorption capacities of MPs towards Pb^{2+} ions vary from a few hundred μg g^{-1} to a few mg g^{-1} as function of experimental conditions of aqueous suspensions.

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References:
[1] N. Kataria, S. Yadav, V.K. Garg, E.R. Rene et al., Environ. Geochem. Health, 2024, 46, 98.
[2] X. Xiong, J. Wang, J. Liu, T. Xiao, Environ. Pollut., 2024, 340, 122754.
[3] S. Liu, J. Huang, W. Zhang, L. Shi et al., J. Environ. Manage., 2022, 302, 113995.

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Synthetic strategy and application of cellulose acetate microbeads from waste sources for water remediation applications

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The increasing presence of a wide variety of contaminants in the environment calls for the development of new strategies aimed at removing and minimizing their adverse impact on natural ecosystems. In particular, the environmental sector that requires a prompt action is the hydrosphere. As global population continues increasing, the pressure on water supplies is inevitably intensifying and the development of new technologies is an urgent need. In this study, the main objective was the realization of a nanocomposite sorbent, prepared through the recycling of cellulose acetate (CA) from waste products such as cigarettes' butts. A washing procedure was optimized to regenerate the raw material. Among the wide group of solvents tested for the CA regeneration, tetrahydrofuran (THF) was chosen as the dissolving agent [1]. With the technique of the emulsion precipitation, the organic phase saturated with CA was combined with a water solution, saturated with sodium chloride. As a result of the salting out effect, the organic and aqueous phases were immiscible, and a cloudy solution was formed under magnetic stirring. The addition, drop by drop, of water to the emulsion broke the emulsion and promoted the precipitation of CA in the form of microspheres (50-500 µm). The optimization of the synthetic procedure was performed changing one by one the involved procedural parameters. With the aim of obtaining sorbent material for xenobiotic capture from water, CA microspheres were tested alone and with the addition of active carbon. The secondary component of the composite was added to the organic CA solution in THF. The removal ability was tested in flow through mode, packing the synthetized microbeads in glass cartridges. As regards the treatment parameters, the optimization of the sorbent quantity, the amount of active carbon and the flow of the contaminated aqueous solution was performed building breakthrough curves. To this end, an 2^3 factorial design was conducted. Once optimized the best conditions of microsphere synthesis and treatment parameters, an entire characterization study was conducted via SEM analysis, as well as FTIR spectroscopy for the qualitative confirmation of the obtained material composition.
Performance studies over more than 60 contaminants have shown the broad applicability of the material and its versatility against different classes of xenobiotics. Through competitive removal analysis, differential removal of xenobiotics of different polarity was studied, by returning retention capacity ranging from 0.5 to some dozens of µg per mg.

References

[1] Lorenzo Antonelli, Maria Chiara Frondaroli, Massimo Giuseppe De Cesaris, Nina Felli, Chiara Dal Bosco, Elena Lucci, Alessandra Gentili, Nanocomposite microbeads made of recycled polylactic acid for the magnetic solid phase extraction of xenobiotics from human urine, Microchimica acta, being published.

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PEGDA-based Ion Imprinted Polymer for Lithium Adsorption

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During the last few years, the demand for lithium has increased exponentially due to environmental regulation and technological transition, this high rate of demand has included lithium in the critical material list and therefore is considered an element of limited availability. Many methodologies are available for the recovery of lithium from leaching solutions from electronic batteries but most of them present disadvantages related to huge amounts of precipitating agent or the large use of organic solvent for extraction to be used. Moreover, they are inefficient when lithium concentration in the leaching solution is too low[1]. In this way, the ionic imprinting technique could be an innovative approach because it could directly be applied to the leaching solutions.

This work presents an original approach to obtain (ionic imprinted polymer, IIP) selective adsorbent materials for lithium from diluted solutions, exploiting the most traditional bulk polymerization technique. IIPs are obtained from linear bi-functional monomers, as polyethylene glycol diacrylate (PEGDA), that can spontaneously cyclopolymerize and give structures that are mimics of pseudo crown ethers able to stabilize cations thanks to the so-called macrocyclic effect[3]; in this way, the use and functionalization of real crown ethers are avoided.

To assess the validity of this strategy, we studied the effects of different molar ratios of PEGDA: Li (I). For each polymer parameters of affinity and binding capacity are obtained through equilibrium partition adsorption isotherm determined by IC analysis. In addition, the selectivity of the material toward competing ions (Na(I),K(I)) is evaluated and an imprinting factor (IF) is determined related to the presence of Li(I) during the imprinting step. As a result, we obtained at last a capacity of about 0.190 mg/g with the highest selectivity and IF towards lithium. To improve this capacity, different reaction solvents (DMSO and water) and leaching solutions (basic and acidic) are explored and tested. Results show a general increase in binding capacity with the combination of the use of water as a reaction solvent and a basic leaching solution such as Na_2CO_3. This allowed us to obtain an improvement in the capacity of up to 1.70 mg/g of lithium adsorbed, with a good reusability of the material up to 6 cycles after recovery. This improved polymer capability is also compared with the ones obtained by the most innovative Inverse suspension polymerization technique (DMSO/Water in Mineral Oil).

References:

[1] Garcia, L.V.; Ho, Y.C.; Myo Thant, M.M.; *Langmuir*, 2023,*11(2),*1-24.
[2] Oral, I., Tamm, S., Herrmann, C. & Abetz, V. ; Sep Purif Technol, 2022, 294, 121142

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Gallic acid for the sequestration of Cd^{2+} and Pb^{2+} in aqueous solutions

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Gallic acid (*GA*), whose structure is reported in **Figure 1**, is a naturally occurring polyphenol present in citrus fruit peels, in grapes, hops, oak bark, green tea, displaying antioxidant properties[1].

This contribution reports the preliminary results of a potentiometric study on the acid-base properties of *GA* at $T = 298.15$ K and $0.10 \leq I/\text{mol dm}^{-3} \leq 1.00$ in NaCl, KCl and $(CH_3)_4NCl$ ionic media. The gallic acid binding ability towards two natural systems contaminants such as Cd^{2+} and Pb^{2+} was also investigated at various ionic strengths in $NaCl_{(aq)}$ by means of potentiometry and UV-Vis spectrophotometry, to evaluate the ligand potential as a sequestering agent for the mentioned cationic pollutants in environmental matrices.

The analysis of the acid-base data allowed the determination of the gallic acid protonation constants, which were found to be in good agreement with literature findings[2]. The weak association constants of Na^+/GA and K^+/GA species were determined using the ΔpK method[3]. The dependence of the thermodynamic parameters on ionic strength was modelled using an extended Debye-Hückel type equation. Furthermore, the ligand sequestering ability and the affinity towards the selected cationic contaminants were evaluated by means of the calculation of $pL_{0.5}$[4] and pM[5] parameters at various conditions including pH ~ 8.1 and $I \sim 0.70$ mol dm^{-3}, typical of seawater. Lastly, speciation diagrams on the gallic acid behaviour towards Cd^{2+} and Pb^{2+} were drawn in the presence of the natural components of seawater as well.

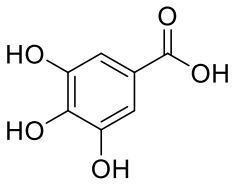

Figure 1. Structure of gallic acid or 3,4,5-trihydroxybenzoic acid.

References:

[1] S. Hussain, S. A. Farooqui, Rahim, Int. J. Emerg. Technol. Appl. Eng. Technol. Sci. 2013, 6-7, 276-279.
[2] H. K. J. Powell, M. C, Taylor, Aust. J. Chem. 1982, 35, 739-756.
[3] P.G. Daniele, C. Foti, A. Gianguzza, E. Prenesti, S. Sammartano, Coord. Chem. Rev. 2008, 252, 1093–1107.
[4] F. Crea, C. De Stefano, C. Foti, D. Milea, S. Sammartano, Curr. Med. Chem. 2014, 21, 3819-3836.
[5] K. N. Raymond, C. J. Carrano, Acc. Chem. Res. 1979, 12, 183-190.

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Reconfigurable cellulose-supported ZnO microflowers for environmental remediation: from emerging pollutants photodegradation to smart antibacterial interfaces

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The misuse/overuse of antibiotics in the last 20 years has caused a dramatic evolution of antimicrobial resistance[1]. To this aim, new strategies to overcome this challenge can by the employ of new rationally designed materials. Among the possible candidates, ZnO-based materials are increasingly studied, given their optimal photocatalytic properties and excellent biocompatibility as reported by the Food and Drug Administration (21CFR182.8991)[2]. The study focuses on the synthesis of ZnO microflowers (MFs) and their incorporation into cellulose foils or powder for the light-triggerable release of ROS (reactive oxygen species). It is demonstrated a synthetic approach of highly photocatalytic active ZnO MFs based on a central composite experimental design in which the synthesis parameters - such as zinc ions and KCl concentrations and synthesis temperature - are all investigated to obtain the optimal photodegradation response of dye pollutants (e.g. methylene blue). The ZnO MFs synthesis is further optimized to induce biologically-inspired dissipative motion for capturing pollutants[3], by ZnO-based microrobots in the form of Ag/ZnO heterojunctions, resulting in promising features. The morphology and the physico-chemical properties of the materials are analysed by instrumental techniques (DRS, SEM, XPS, XRD, UV-Vis and ζ-potential). It is found an optimal ZnO loading to enhance the photocatalytic properties as a result of surface-to-bulk dispersion[4]. In parallel, preliminary antibacterial activity of the ZnO-based systems are studied on gram-positive and gram-negative strains.

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References:

[1] F. Campanile, M. Wootton, L. Davies, A. Aprile, A. Mirabile, S. Pomponio, F. Demetrio, D. Bongiorno, T. R. Walsh, S. Stefani, M.L. Mezzatesta, J Glob Antimicrob Resist. 2020, 23, 334-337.

[2] E. Fortunati, D. Puglia, I. Armentano, A. Valdés, M. Ramos, N. Juárez, M.C. Garrigós, J.M. Kenny, Nanotechnol. Agri-Food Ind., Academic Press, 2017, 265–303.

[3] C.M. Oral, M. Ussia, and M. Pumera, Small 2022, 18, 2202600.

[4] G. Arrabito, A. Delisi, G. Giuliano, G. Prestopino, P.G. Medaglia, V. Ferrara, F. Arcidiacono, M. Scopelliti, D.F. Chillura Martino, and B. Pignataro, ACS Appl. Eng. Mater. 2023, 1, 5, 1384–1396.

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ANA-OR-038

Sewage sludge biochar as green d–SPE adsorbent in QuEChERS clean-up process for the multi-residue LC-MS/MS analysis of emerging micropollutants in edible crops

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QuEChERS extraction is a widely used method for the multi-residue analysis of micropollutants in food matrices[1]. Due to the complexity of these matrices, QuEChERS methods usually require a clean-up stage of the extract, which in most cases uses the dispersive solid-phase extraction (d-SPE) technique, exploiting various types of materials (e.g., styrene-divinylbenzene and graphitized carbon black), characterized by significant costs. For this reason, a recycled carbonaceous material derived from the pyrolysis of sewage sludge (BC) was developed as a green alternative to commercial d–SPE adsorbent and applied to the clean-up procedure of high-pigmented edible crop extracts (i.e., rocket, tomato, and strawberry) for the determination of a wide variety of contaminants of emerging concern (CECs), such as pharmaceuticals, sunscreen agents, and PFASs listed in recent European decisions[2]. The use of 50 mg of BC proved to be reliable and cost-effective for the d–SPE clean-up of 23 analytes belonging to the aforementioned classes, being capable of reducing the matrix effect to less than |27%|. Although there were some limitations in recovering a group of CECs, BC allowed for achieving pseudo-quantitative recoveries and insignificant matrix effects for 8 pharmaceuticals, 1 sunscreen agent, and all 8 perfluoroalkyl substances studied. Furthermore, combining 5 mg or 10 mg of BC with 20 mg of styrene-divinylbenzene clean-up performances were improved, achieving quantitative recoveries for most CECs with matrix effects < |29%| (see **Figure 1**). The proposed analytical methodology was applied to the analysis of impacted crop samples, providing method sensitivities comparable to or lower than the limits proposed by the European community.

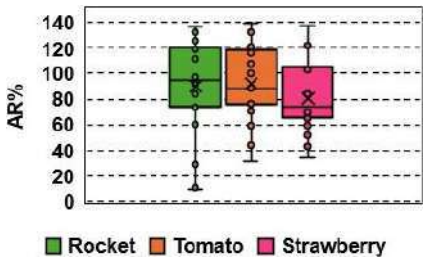

Figure 1: Mean apparent recoveries (AR%) of target CECs in food samples after d-SPE clean-up.

References:
[1] L. Kim, D. Lee, Trends in Environmental Analytical Chemistry 2019, 22 e00063.
[2] C.V.A. Scordo, L. Checchini, Journal of Chromatography A 2020, 1621 461038.

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ANA-OR-039

A "white" analytical method for the determination of emerging contaminants in water: optimization of the analytes' extraction by a bio-degradable polymeric film

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The growing interest in greener approaches in many scientific fields generated the need for a green analytical chemistry. Nevertheless, in many analytical applications, essential method requirements cannot be overlooked, such as performance and time and cost-effectiveness. These aspects are not always easily fulfilled through the greenest strategies. Therefore, Nowak et al recently introduced the concept of "White analytical chemistry"[1](WAC), which highlights the importance of being "greener" without neglecting the value of method performance (accuracy, precision, specificity…) and feasibility. In the environmental analysis of emerging contaminants (ECs), WAC embodies the use of green and sustainable sample preparation, coupled to reliable, accurate and sensitive analytical determinations.

In this framework, the present work deals with the multivariate optimization of an extraction method based on the use of a biodegradable polymeric film (Mater-Bi), coupled to analysis by liquid chromatography-tandem mass spectrometry, for the determination of ECs in treated wastewater.

The interaction among 39 ECs with varying chemico-physical properties and the Mater-Bi film (a patented blend of polybutylene-terephthalate, starch and fatty acids) was investigated by two sequential experimental designs[2], to simultaneously study several factors and optimize extraction efficiency. The results indicated that hydrophobic and weakly acidic analytes were the most prone to interact with the material, resulting in good recovery from water samples. The final method, which basically resembled a fabric phase sorptive extraction, involved pH and ionic strength modification of the sample, 1 h extraction and desorption in ethanol. Satisfactory recoveries from real wastewater were obtained for sixteen analytes (56-116%), as well as excellent precision (inter-day relative standard deviations below 10% for most compounds). Matrix effect was investigated at two dilution factors, with good or acceptable results in both cases. Limits of detection in matrix, from 0.004 to 0.159 μg L^{-1}, were lower than or comparable to those from recent studies employing green extraction procedures. The method demonstrated its applicability to samples from wastewater treatment plants, allowing quantification of pharmaceuticals and UV filters at the μg L^{-1} and ng L^{-1} levels, respectively.

The optimized protocol allows a green, simple and extremely cheap extraction of several ECs from treated wastewater, by using a material so-far unexplored in analytical chemistry. The method guarantees very good analytical performance and demonstrated to comply with WAC principles.

References:

[1] P.M. Nowak, R. Wietecha-Posłuszny, J. Pawliszyn, Trends in Analytical Chemistry 2021, 138, 116223.
[2] B. Benedetti, V. Caponigro, F. Ardini, Critical Reviews in Analytical Chemistry 2022, 52, 1015-1028.

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ANA-OR-040

Wood-derived biochar in biodegradable membrane for pharmaceuticals thin-film microextraction in environmental waters

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The occurrence of organic contaminants, particularly antimicrobials, in aquatic environments is a global threat due to the growing evidence of adverse effects, such as the selection and spread of multidrug resistant bacteria and genes. Sensitive and accurate monitoring studies are a challenge with important but also contradictory aspects, since they help to detect the presence of such pollutants even at very low concentrations, but at the same time they can have an inherent environmental impact due to the resources involved. Recent trends pursue the goal of the sustainability through a simplification of the sample treatments and the use of natural and/or renewable materials[1]. In such a scenario, the focus of this work is the synthesis of efficient, green and biodegradable polymeric membranes for the multiclass thin film microextraction (TF-ME) of antimicrobials, namely fluoroquinolones, sulphonamides, tetracyclines, macrolides, diaminopyrimidines and glycopeptides. With the aim of not only serving the purpose of sample preparation but also avoiding secondary pollution, polycaprolactone has been selected as polymer due to its biodegradability, whereas a wood-derived biochar (Cabot) and a wood-derived activated biochar (Nuchar) have been tested as carbon precursors with the added benefit of extending the life-cycle. The films are home-made prepared, studying different compositions based on the solvent (chloroform or acetic acid) for solubilizing the polymer, the type and amount of char entrapped in the polymeric matrix. The preliminary TF-ME tests allow to evaluate the extraction efficiency (EE%) at different times (5 min ÷ 24 h) for each membrane. The use of acetic acid causes a partial acid hydrolysis of the lactone ring making the membrane less stable and hence less efficient, thus $CHCl_3$ has been selected despite its toxicity which is mitigated by its low consumption (1 mL). The adsorption capacity of the neat polymer was negligible (EE% < 8%) for all analytes, but it increased significantly in presence of Nuchar (15%w/w, EE% ≥ 80% at 8h). This biochar possesses a higher affinity in respect to Cabot (15% w/w, EE% < 15% at 8h) ascribable to the different functional groups and surface area. The results also show that the extraction efficiency is strictly dependent on the amount (15-30% w/w) of Nuchar incorporated in the polymeric matrix, and finally the film with 24% of Nuchar has been chosen as it guarantees quantitative extraction of all compounds in 4h. Different elution conditions, viz. solvent type and volume, type and time of stirring are being studied together with the analytical evaluation of the method in river and wastewater samples.

References:

[1] Á.I. López-Lorente, F. Pena-Pereira, S. Pedersen-Bjergaard, V.G. Zuin, S.A. Ozkan, E. Psillakis, *Trend. Anal. Chem.* 2022, 148, 116530.

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ANA-OR-041

Controlled Periodic Illumination (CPI) for enhancing the photonic efficiency of a photocatalytic system

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Semiconductor photocatalysis for water treatment and water photo splitting is plagued by low photonic efficiency and slow mass transfer of intermediate/products from/to the interface, hindering its exploitation[1]. Usually, Photonic efficiency measurements of the photoinduced processes at semiconductor surfaces for pollutant abatement and H_2 evolution (HER) are usually carried out under continuous irradiation of the catalyst. In the last decades Controlled Periodic Illumination (CPI) was proposed to increase the photonic efficiency of irradiated semiconductor systems. CPI consists in the modulation of the incident radiant power, alternating light and dark periods with given duty cycle, intensity, and frequency. The rationale underlying the use of CPI to enhance photonic efficiency is the exploitation of dark periods to allow slow reactions proceed, to induce new reactions or to free up space on the surface of the catalyst. In this work we demonstrated how: i - in the photocatalytic abatement of organic pollutants in aerobic conditions using semiconductor nanoparticles (usually TiO_2) CPI is not able to increase the photonic efficiency at the same average photon flux compared with continuous illumination[2]; ii – conversely, it is effective in the HER using metals like Pt, Pd and Rh alone or in combination with TiO_2.[3] The supposed mechanisms fall under the surface catalytic resonance theory and the differences between active and not-active metals can be explained invoking the Volmer-Tafel or Volmer-Heyrovsky mechanisms.

Acknowledgements:

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References:

[1] S.K. Loeb et al, Environmental Science and Technology 2019, 53, 2937–2947.
[2] M. Prozzi, F. Sordello, S. Barletta, M. Zangirolami, F. Pellegrino, A. Bianco Prevot, V. Maurino, ACS Catalysis 2020, 10, 9612-9623
[3] F. Sordello, F. Pellegrino, M. Prozzi, C. Minero, V. Maurino, ACS Catalysis 2021, 11, 6484−6488

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ANA-OR-042

Electrochemical degradation of oxolinic acid on BDD electrodes

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Oxolinic acid (OA)belongs to the first generation of quinolone antibiotics that are widely used in veterinary medicine and aquaculture. OA can be employed both as a prophylactic to prevent diseases and as a chemotherapy agent, because it is effective against the most common bacterial infections. However, the overuse and misuse of antibiotics have led to increased antibiotic resistance in pathogenic bacteria. The residues of OA and other antibiotics have been found in the environment, waste and urban waters due to incomplete elimination of these compounds in wastewater treatment plants. In this study, we studied the electrochemical degradation of OA in galvanostatic mode simulating real aquaculture effluents. Two boron-doped diamond (BDD) - electrodes with 9 cm² area were used as working electrode (anode) and counter electrode (cathode) along with OA concentration of 10 µM. Supporting electrolytes were chosen to understand the role of the different components of sea water, e.g. NaCl, NaBr, Na_2SO_4, $NaHCO_3$, $NaBO_2$ and their interactions. HPLC-UV results showed that degradation efficiencies were between 50 and 100% within 2 hours depending on the electrolyte tested. OA degradation was almost independent on current density, whereas larger currents generally led to improved mineralization at the expense of energy consumption. Degradations were particularly effective (> 90%) in NaBr-containing electrolytes already at 1 mA cm^{-2} current density with the least amount of energy supplied to the system (1.9 kWh m^{-3}). The addition of supporting electrolyte to Br-containing solutions led to similar degradation and mineralization efficiency but significantly reduced energy input, improving efficiency. While Br^- can improve OA degradation, reactive bromine species can also be responsible for the formation of harmful compounds. In fact, we detected bromate ion through ion chromatography and we hypothesize the formation of a brominated intermediate, but its identity will be investigated in future tests.

References:

[1] Orimolade, B. O., Oladipo, A. O., Idris, A. O., Usisipho, F., Azizi, S., Maaza, M., & Mamba, B. B. (2023). *Science of The Total Environment*, *881*, 163522.

[2] Turiel, E., Bordin, G., & Rodríguez, A. R. (2005). *Journal of environmental monitoring*, *7*(3), 189-195.

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Debunking the need (and existence) of "pure" g-C_3N_4 to optimize its photocatalytic properties for environmental applications

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Graphitic carbon nitride (g-CN) is a metal-free semiconductor gaining interest within the scientific community for its simple preparation, low cost, and photo-electrochemical properties.[1] Noteworthy, there is no clear consensus on its optimal synthesis due to the several parameters affecting it, such as, precursor, employed gas on the oven, temperature, or even if the precursor should be compressed or covered to reduce sublimation.[2] In views of standardizing its preparation and optimize its properties for environmental applications, in this work, we have calcinated melamine at different temperatures within the range 350 – 650 °C under anoxic controlled atmosphere and in presence and absence of an aluminium cover to reduce or enhance melamine sublimation, respectively.

Obtained materials were characterised by several techniques, and their photocatalytic performance evaluated as H_2O_2 generation (with methanol as hole scavenger) and phenol oxidative degradation under UVA and visible light, respectively. Results indicated that under UVA light, the best performance was obtained with the g-CN prepared at 425°C with the aluminium cover, leading to 6 mM production of H_2O_2 in 3 h, as well as a 3.4×10^{-2} min^{-1} phenol oxidation rate with an initial concentration of the organic substrate of 100 μM. To correlate the huge amount of data (21 variables analysed for 10 types of g-CN) a Principal Component Analysis was carried out[3], indicating that to maximize the photocatalytic performance under UVA light irradiation, employed temperatures should not exceed the 500 °C, contrarily to what is currently found in literature. On the contrary, for visible light experiments, reduction of band gap by doping the g-CN with nitrogen (employing higher temperatures, thus, observing a higher polymerisation degree and a C:N ratio close to stoichiometric 3/4 value) is required as usually observed in other works.

This work intends to shed light into the basic properties of g-CN and into the correlation between its photocatalytic properties and its physico-chemical features, as well as to promote the use of UVA light in views of saving synthesis costs of this semiconductor.

References:

[1] F. Sordello, P. Calza, C. Minero, S. Malato, M. Minella, Catalysts. 12 (2022) 1572. https://doi.org/10.3390/catal12121572.

[2] M. Minella, F. Sordello, C. Minero, Graphitic carbon nitride-based metal-free photocatalyst, in: Mater. Sci. Photocatal., Elsevier, 2021: pp. 449–484. https://doi.org/10.1016/B978-0-12-821859-4.00025-8.

[3] R. Leardi, C. Melzi, G. Polotti, CAT (Chemometric Agile Tool), freely downloadable, (n.d.). http://gruppochemiometria.it/index.php/software (accessed July 4, 2023).

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Principal Component Analysis describes soil features through Rare Earth Element distributions overcoming normalization challenges

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Exploration of Rare Earth Elements (REE) as potential biogeochemical tracers is constantly gaining attention across various fields of research, thanks to their unique properties. The common method for investigating the data coming from REE quantification by ICP-MS typically involves a visual evaluation of REE distribution, after normalization to a lithological reference. However, this approach has an inherent limitation because the choice of such lithological reference is subjective and therefore the interpretation of the distribution and identification of anomalies may depend on this choice.

In the present study, a new approach for analysing REE concentration profiles is proposed, applying Principal Component Analysis (PCA) for the creation of REE chemometric maps, which allow a simple and direct evaluation of similarities and differences to be performed in the geographical region under study. Moreover, PCA describes the profiles of REE in soils, facilitating the interpretability of results to exploit the chemical information embedded in concentration profiles. Results reveal that loading plots of PC1, PC2, and PC3 distinguish between light and heavy REE while highlighting anomalies of specific elements and REE groups. Data compression allows visualization of REE behaviour using an RGB colour scale (PC1= red channel; PC2= green channel; PC3= blue channel) directly on a geographical map.

Interestingly, similarities in agrochemical conditions were observed among soils belonging to the same lithological family when exhibiting similar REE distribution patterns. This underlines relationships between REE distribution and the diverse array of soil characteristics, supporting traceability studies and environmental monitoring.

Of particular significance is the fact that the application of the proposed methodology to non-normalized data yields results consistent with those derived from normalized datasets. For the first time, it was shown that similarities and differences in distributions can be found starting from raw concentration data, devoid of preconceived normalization biases.

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Self-Organizing Maps: An AI Tool for Identifying Unexpected Source Signatures in Non-Target Screening Analysis of Urban Wastewater by HPLC-HRMS

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The monitoring of effluent in water treatment plants has a key role in identifying possible pollutants that can be released into the environment. A non-target analysis approach can be used to identify unknown substances and isolate multipollutant signatures related to specific sources using powerful analytical techniques such as high performance liquid chromatography-high resolution mass spectrometry (HPLC-HRMS). However, HPLC-HRMS techniques focused on non-target screening (NTS) produce a huge amount of high-dimensional data, often with noisy and collinear structures; thus, it is necessary to use multi-step workflows involving extensive data processing and multivariate data analysis techniques to handle data sets appropriately and to further obtain interpretable results. Here we present the results from a case study in which urban and industrial wastewater effluent were examined by HPLC-HRMS for NTS[1]. The anomalous infiltration of industrial wastewater into urban wastewater was detected by analysing the information-rich mass spectrometry data of "unknown common" compounds using principal component analysis (PCA) and Self-Organizing Maps (SOMs). SOMs are a rather old type of artificial intelligence (AI) that employs unsupervised learning to convert high-dimensional input data into a lower-dimensional grid composed of nodes or neurons.

SOMs have several advantages over classical chemometrics methods such as PCA, including the ability to capture non-linear relationships and structure in the data, the ability to deal with complex high-dimensional datasets, meaningful visualisation of the outcomes in 2D maps, tolerance and robustness to outliers, the ease with which the latter can be identified, and the simplicity with which the results can be related to the experimental variable importance. In this case study, we compared the outcomes from PCA and SOMs, demonstrating that the PCA model could not fully perceive the differences among the different samples. Moreover, since PCA involves the calculation of new variables based on the original experimental ones, it is not possible to reconstruct a chromatogram that displays the recurring patterns in the urban wastewater samples. This can be easily achieved using the SOM outcomes.

References:

[1] V. Gelao, S. Fornasaro, S. Briguglio, M. Mattiussi, S. De Martin, A.M. Astel, P. Barbieri, S. Licen, Toxics 2024, 12 113 1-12

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ANA-OR-046

OPTIMIZATION OF AN LC-MS ANALYTICAL METHOD FOR THE DETERMINATION OF MULTI-CLASS POLAR EMERGING CONTAMINANTS IN RECLAIMED WATER

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Food and agriculture account for most of the human demand for water, due to the huge amounts required for crops and livestock. Within the whole agricultural, municipal, industrial and energy sectors, 70% of water is used for cultures and farming. The current available water resources need an aware management to meet the growing global demand for food [1]. Thus, the possible use of reclaimed water for irrigation represents a great opportunity for water conservation and fits in the circular economy approach.

In this study, the optimization of an analytical method based on liquid chromatography-mass spectrometry (LC-MS) was carried out for the determination of 33 polar emerging contaminants in wastewater. The contaminants encompassed various classes including pharmaceuticals, personal care products, and other emerging pollutants.

Due to the high polarity of the analytes under study, hydrophilic interaction liquid chromatography (HILIC) was employed, by testing a zwitterionic stationary phase. To enhance the efficiency of the analysis, response surface methodology (RSM) utilizing a Fractional Factorial Design [2] was employed to optimize the experimental parameters. Indeed, multiple factors influence the chromatographic separation in HILIC, such as initial mobile phase percentage, gradient time, column temperature, type and concentration of salt and flow rate, which were investigated to achieve the best separation and sensitivity for the target analytes. Finally, the optimized method was combined to a suitable sample pre-treatment and applied to different reclaimed water samples. Thus, the method performance could be evaluated in real matrices and the presence of the considered contaminants in treated water was investigated.

References:

[1] UNESCO, 2012. https://unesdoc.unesco.org/ark:/48223/pf0000215644
[2] Box, G.E.; Hunter, J.S.; Hunter,W.G. (2005). Statistics for Experimenters: Design, Innovation, and Discovery, 2nd Edition. Wiley. ISBN 0-471-71813-0.

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ANA-OR-047

Multivariate analysis of the photoaging of four types of microplastics by Micro-IR spectroscopy

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Understanding the origins of microplastics and evaluating the consequences of plastic pollution hinges upon precise chemical information. In this regard, a remarkable challenge lies in the chemical changes that microplastics undergo due to photoaging, which could hinder spectroscopic matching and identification.[1] Micro-IR is currently one of the go-to techniques for the screening of microplastics, coupling the possibility of collecting optical images of the particles with the chemical information provided by the IR spectra. The sensitivity of reflectance Micro-IR spectroscopy to the thickness of the particles and to chemical changes induced by photodegradation on one hand hinders the automated recognition by spectral matching, but on the other hand contains layers of information that lie beyond the reaching of conventional data analysis. In this study, we conducted multivariate analysis on four types of microplastics obtained by common objects: two conventional (PE and PS) and two compostable bioplastics (PLA and PBAT). These microplastics underwent artificially accelerated photoaging and were analysed by Micro-IR spectroscopy in the medium infrared range. Principal component analysis (PCA) was able to classify the polymers and show degradation trends, highlighting even subtle changes in the spectra. The issue of reflection "artifacts" in spectra obtained from particles thicker than 100 µm was also addressed.

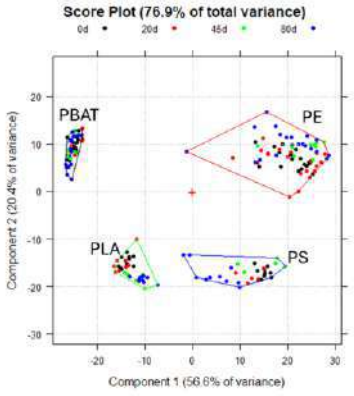

Figure 1: PCA scores plot of the four types of microplastics.

References:

[1] C. Rathore, M. Saha, P. Gupta, M. Kumar, A. Naik and J. De Boer, Sci. Total Environ. 2023, 888, 164157.

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Accurate pH monitoring of highly concentrated saline aqueous solutions (Seawater-like) with a pH Colorimetric Sensor Array

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The increase in the atmospheric CO_2 concentration is causing a decrease in surface ocean pH by ≈ 0.002 pH units per year with a long-term pH decrease from 8.25 to 8.10 in the last two centuries[1]. Caldeira and Wicket predicted further decreases in seawater pH of up to 0.80 pH units by 2300[2]. Monitoring the seawater pH is therefore more and more important to determine negative effects on the environment. In particular, "in situ" real-time pH sensors are more and more necessary[3]. In this context, a pH Colorimetric Sensor Array (CSA) was prepared on a nitrocellulose membrane and used for accurate pH measurement in highly concentrated saline solutions. The CSAs consisted of sensing spots made of a suitable *OrMoSil* polymer prepared from organo-fluorinated-silane precursors and/or organo-silane with tetraethyl orthosilicate hosting an acid-base indicator. Four CSAs were prepared: D, 1F, 2F, and 3F[4]. In D a non-fluorinated organo-silane was present. From 1F to 3F the concentration of the fluorinated organo-silane increased and improved the pH measurement accuracy in highly saline concentrations. No re-calibrations were required and the analytical signal was stable in time[5]. D, 1F, 2F, and 3F were deposited in triplicate and they were prepared to work in the seawater pH interval (7.50-8.50). The use of fluorinated precursors led to a lower pH prediction error and tailored the interval of the CSA at more basic pH values so that the inflection points of the sigmoidal calibrations of D, 1F, 2F, and 3F moved from 6.97 to 7.98. The overall pH prediction error was 0.10 pH units (1F), 0.02 pH units (2F), and 0.04 pH units (3F)[6]. The CSAs were stable, reversible, reusable, and independent of salinity (S) between 20 and 40. The performances of the CSA were compared with those of the glass electrode whose pH_{NIST} values were converted in the pH_{SWS} scale through a conversion equation. Being unaffected by the typical drawback of the glass electrode, the CSAs can be used directly in seawater real samples and it validated the proposed conversion equation[7].

References:

[1] J. S. Clarke, E. P. Achterberg, V. M. C. Rérolle, S. Abi Kaed Bey, C. F. A. Floquet, and M. C. Mowlem, Anal. Chim. Acta, vol. 897, pp. 69–80, 2015.
[2] K. Caldeira and M. E. Wickett, Nature, vol. 425, no. 6956, p. 365, 2003.
[3] B. R. Carter, J. A. Radich, H. L. Doyle, and A. G. Dickson, Limnol. Oceanogr. Methods, vol. 11, pp. 16–27, 2013,.
[4] A. Pastore, D. Badocco, and P. Pastore, Microchem. J., vol. 177, no. February, p. 107288, 2022.
[5] A. Pastore, D. Badocco, and P. Pastore, Talanta, vol. 219, no. April, pp. 1–7, 2020.
[6] A. Pastore et al., ACS Sensors, 2024, doi: 10.1021/acssensors.3c02585.
[7] D. Badocco et al., Talanta, vol. 225, no. September 2020, p. 122051, 2021.

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ANA-OR-049

Towards Nano- and Microplastic sensors: Identification of Nano- and Micro plastic particles via Artificial Intelligence combined with a Plasmonic probe functionalized with an Estrogen Receptor

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Nano- and microplastic particles are a global and emerging environmental issue. The present work exploits artificial intelligence (AI) to identify nano- and microplastics in water by monitoring the interaction of the sample with a sensitive surface. An Estrogen Receptor (ER) was grafted onto a gold surface[1], realising a plastic optical fiber (POF) platform in order to excite a surface plasmon resonance (SPR) phenomenon.

The ER-SPR-POF interface offers output data useful for exploiting a machine learning-based approach to achieve nano- and microplastic particle sensors. This work developed a proof of concept sensor through a training phase carried out by different particles in terms of materials and size. The experimental results have demonstrated that the proposed "smart" ER-SPR-POF interface combined with AI can be used to identify the kind of particles in terms of materials (polystyrene; polymethylmethacrylate) and size (20 μm; 100 nm) with an accuracy of 90.3%.

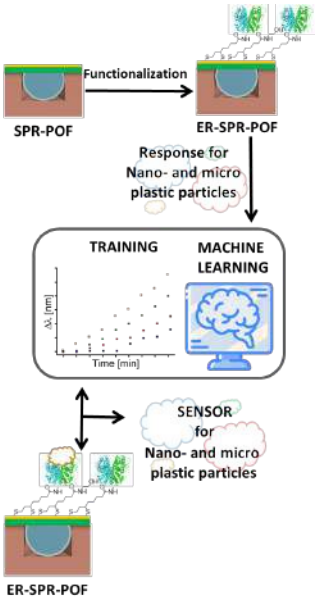

Figure 1: Scheme of sensing strategy.

References:

[1] M Seggio, F. Arcadio, N. Cennamo, L. Zeni, A.M. Bossi, Talanta 2024, 267, 125211.

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Lab-made electroanalytical devices equipped with CO_2 laser-assembled nanostructured materials

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This presentation will be focused on the production of functional surfaces and NMs-films via CO_2-laser plotter and their integration within completely lab-made analytical devices. In particular, an overview of the development of (ii) freestanding laser-induced nanostructured films and their integration in (bio)analytical devices, and (ii) the laser-induced activation/nanodecoration of carbon-based inks for sensors and biosensors development will be given. Particular attention will be paid to nanostructured surface nano-/micro-architectures laser-assisted assembling, and fabrication of disposable devices using low-cost/sustainable substrates (i.e., flexible polymers, nitrocellulose, paper, recycled paper, etc.) via benchtop microfabrication technologies such as stencil-printing, cutter-plotting, CO_2-laser molding, thermal-lamination, etc.

The exploitability of the developed devices will be demonstrated for the analysis of agri-food quality and safety markers, and biological interest compounds in model solutions and real samples. Among others, will be presented the development of (i) laser-activated inks/graphene-based third-generation biosensors for the determination of fructose in food and biological samples, (ii) laser-assembled paper-based analytical devices that integrate and automate analysis steps i.e., (ii) an integrated paper/graphene 3D pop-up device for the quantitative sensing of carbaryl in grains at EU-law limits [2] and (iii) a laser-nanodecorated electrochemical lab-on-strip device for the rapid pretreatment-free evaluation of antioxidant capacity in extra virgin olive oil; moreover, (iv) electrochemical sensors based on laser-induced reduced graphene oxide (rGO) films integrated onto different recycled papers and paper produced from wastes will be also shown.

This presentation aims to prove how CO_2-laser plotter technologies are able to generate nanostructured transferable films and decorate different kinds of conductive surfaces, and how the coupling with benchtop technologies can allow the integration of them within cost-effective, flexible, and sustainable substrates, to give rise to effective everyone reach analytical devices.

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Optimization of bioplastic films' properties for colorimetric sensing applications in the food sector

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Plastic materials are worldwide distributed and employed in several fields, thanks to their unique properties, but, unfortunately, they are often wrongly recycled or even just thrown away at the end of their life, resulting in an environmental impact no longer negligible.[1] This latter aspect has paved the way to a wide and miscellaneous group of materials generally referred to as "bioplastics" whose main features are i) renewable starting materials, ii) less energy consuming productive processes, iii) degradability in natural environments and, last but not least, iv) properties comparable to conventional plastic-based materials.[2] While the first features are promptly achieved, developing bioplastics actually showing comparable properties to plastics is not as easy as it seems: indeed, these multicomponent materials can range between extremely different behaviours just minimally modifying either the type of starting compounds or their ratios.[3] Therefore, the usage of multiparameter optimization approaches, such as the Design of Experiments, is mandatory to tune the properties and achieve the goal.[3] Focusing on the development of sensing devices, especially referring to those meant for the food sector, similar issues are emerging since bioplastics are everyday synthesized, generally as recipes found in literature or even in online tutorials describe, and used as they are, thus missing the countless opportunities these multicomponent materials are offering to tune their properties.

Our innovative approach in this scenario relies on the application of Design of Experiments methodology to optimize bioplastics films made of starch, glycerol and carboxymethylcellulose (CMC); we focus on multiple properties in order to produce materials suitable for environmental conditions in food packaging, such as high humidity and low storage temperatures. Then we add pH indicators from sulfonephthaleins class, which have been already reported in literature to monitor the degradation of various perishable foodstuffs efficiently,[4] and we further optimize all the preparation steps to develop sensitive and resistant bioplastic-based colorimetric sensors for freshness detection. As for the target food, we opt for fresh dairy products as case studies that are rarely discussed in literature due to their extremely challenging characteristics like high perishability, high humidity inside the package and low ratio between headspace atmosphere and food amount.

References:

[1] E. Shlush, M. Davidovich-Pinhas, Trends Food Sci. Technol. 2022, 125, 66-80
[2] S. Shaikh, M. Yaqoob, P. Aggarwal, Curr. Res. Food Sci. 2021, 4, 503–520
[3] L.R. Magnaghi, M. Guembe-Garcia, V. Cerone, P. Perugini, G. Alberti, R. Biesuz, Chemom. Intell. Lab. Syst. 2024, 244, 105044
[4] L.R. Magnaghi, C. Zanoni, G. Alberti, R. Biesuz, Anal. Chim. Acta 2023, 1281, 341807

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ANA-OR-052

Analysis of clinical samples of pancreatic cyst's lesions with a multi-analyte bioelectronic SiMoT array benchmarked against ultrasensitive chemiluminescent immunoassay.

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Pancreatic cancer, ranking as the third factor in cancer-related deaths, necessitates enhanced diagnostic measures through early detection. In response, SiMoT-Single-molecule with a large Transistor[1,2,3] multiplexing array, achieving a Technology Readiness Level of 5, is proposed for a timely identification of pancreatic cancer precursor cysts and is benchmarked against the commercially available chemiluminescent immunoassay SIMOA (Single molecule array) SP-X System. A cohort of 39 samples, comprising 33 cyst fluids and 6 blood plasma specimens, undergoes detailed examination with both technologies[4]. The SiMoT array targets oncoproteins MUC1 and CD55, and oncogene KRAS, while the SIMOA SP-X planar technology exclusively focuses on MUC1 and CD55. Employing Principal Component Analysis (PCA) for multivariate data processing, the SiMoT array demonstrates effective discrimination of malignant/pre-invasive high-grade or potentially malignant low-grade pancreatic cysts from benign non-mucinous cysts. Conversely, PCA analysis applied to SIMOA assay reveals less effective differentiation ability among the three cyst classes. Notably, SiMoT unique capability of concurrently analyzing protein and genetic markers with the threshold of one single molecule in 0.1 mL positions it as a comprehensive and reliable diagnostic tool. The electronic response generated by the SiMoT array facilitates direct digital data communication, suggesting potential applications in the development of field-deployable liquid biopsy[5].

References:

[1] Macchia E., Kovács-Vajna Z.M., Loconsole D., Sci. Adv. 2022,8, eabo0881;
[2] Macchia E., Manoli K., Holzer B., Nature Comm. 2018,9, 3223;
[3] Genco E., Modena F., Sarcina L., Adv. Mater. 2023, 35, 2370303;
[4] Scandurra C., Björkström K., Caputo M., Adv. Sci. 2024, 17:e2308141;
[5] Macchia E., Torricelli F., Caputo M., et al, Adv. Mater. 2023, 2309705.

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ANA-OR-053

Synthetic transcriptional cell-free systems for diagnostic and drug delivery applications

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Nucleic acid nanotechnology, which uses synthetic nucleic strands (DNA and RNA) as engineered materials to create functional devices and structures with nanoscale precision, has offered in the last decades new opportunities to handle and regulate biomolecules at the nanoscale level. Synthetic nucleic acids, with their high programmability, low-cost, ease of synthesis, biocompatibility and chemical versatility, have been extensively exploited to develop programmable nanodevices and sensors that can be used as powerful tools for a variety of applications, including sensing and diagnostics.[1] Despite these achievements, several nanotechnological diagnostic tools reported still suffer from a poor trade-off between sensitivity, specificity, simplicity, cost and time for analysis.[2] In response, cell-free transcription/translation systems, which contain the enzymes essential for transcription and translation and are capable of performing the basic processes of the central dogma (DNA➔RNA➔protein) independently of a living cell, are emerging as a new class of analytical tools with excellent sensitivity and specificity, offering exciting approaches for point-of-care diagnostics.[3] Motivated by this, in the last years we have recently developed optical and electrochemical cell-free transcription systems for the multiplexed detection of antibodies and other protein biomarkers in blood serum,[4,5] for controlling the loading and release of molecular ligands from synthetic nucleic acid receptors,[6] and for tuning the amount of transcribed RNA molecules over a large dynamic range in order to coordinate downstream processes of interconnected networks by mimicking strategies used by cellular pathways.[7]

References:

[1] N. C. Seeman, H. F. Sleiman, Nat Rev Mater 2018, 3, 17068.
[2] M. Xiao, W. Lai, T. Man, B. Chang, L. Li, A. R. Chandrasekaran, H. Pei, Chem Rev 2019, 119, 11631–11717.
[3] A. Tinafar, K. Jaenes, K. Pardee, BMC Biol 2019, 17, 64.
[4] A. Patino Diaz, S. Bracaglia, S. Ranallo, T. Patino, A. Porchetta, F. Ricci, J. Am. Chem. Soc. 2022, 144, 5820–5826.
[5] S. Bracaglia, S. Ranallo, F. Ricci, Angew. Chem. Int. Ed. 2023, 62, e202216512.
[6] D. Sorrentino, S. Simona, E. Nakamura, E. Franco, F. Ricci, Angew. Chem. Int. Ed. 2024, e202319382.
[7] D. Sorrentino, S. Simona, E. Franco, F. Ricci, bioRxiv 2024, doi.org/10.1101/2024.03.14.585044.

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Bio-electronic platforms for fast and ultra-sensitive virus detection

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The recognition of biomolecules and pathogens related to severe disease states is one of the most challenging tasks in biomedical practices. Indeed, there is an unprecedented need for advanced detection methods that can achieve early and highly sensitive recognition, given the impact that late interventions have on single human beings, as well as on the population's well-being.

Typically, the biomarkers employed in biosensors are oligonucleotide-based strands (such as DNA, RNA, mRNA) and proteins/antigens. Their detection is achieved through biological recognition elements enclosed with the transducing interface of the sensor.[1] A systematic study of the interface bio-functionalization strategy and the affinity interaction between immobilized recognition elements and analytes is a prerequisite in the development of a new biomedical sensor. Especially, for the assessment of portable devices for virus infection identification, the biofunctionalized surface should guarantee high selectivity along with extreme sensitivity to minimize false negative and false positive responses.

A highly sensitive portable platform for the bioelectronic assay of virus biomarkers will be presented. The device, addressed as SiMoT (Single Molecule with a large Transistor), is based on the electrolyte-gated field-effect transistor structure, encompassing a gate electrode gold surface modified with the bio-recognition elements chosen for the selective detection of a virus capsid protein. Several pathogens have been tested with this technique such as the HIV-1 and SARS-CoV-2 virus, through their capsid protein p24 and spikeS1, respectively.[2,3] We demonstrate the feasibility of the platform for the early detection of those biomarkers at the single-molecule level, in a range of concentrations of $10^{-21}/10^{-18}$M. These performances can ensure the discovery of the infection in an early stage and prevent severe degeneration. Moreover, these results are promising for the development of portable devices for the screening of other high-risk infections such as the HPV-16 and -18 virus types. Indeed, the study is ongoing for the assessment of a highly reliable and cost-effective device for the detection of such a cancer-related virus.

References:

[1] E. Macchia, F. Torricelli, M. Caputo, et al. Adv Mater. 2023 Dec; 18:e2309705.
[2] E. Macchia, L. Sarcina, R.A. Picca, et al. Anal Bioanal Chem. 2020 Feb;412(4):811-818.
[3] E. Macchia, Z.M. Kovács-Vajna, D. Loconsole, et al. Sci Adv. 2022 Jul 8;8(27):eabo0881.

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Conductive-Ink Formulations for Flexible and Wearable Enzyme-based Biosensors for Alcohol Abuse Detection

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Developing disposable and low-cost electrochemical devices for biomedical applications has significantly increased with the diffusion of remote diagnostics. This is probably due to the need for regeneration of the conventional sensor surfaces and the demand for production processes that allow the manufacture of disposable and portable electrochemical devices promoting the reduction of the volume of samples, *in-situ* detections, and lower cost. [1]

Conductive inks are used for the development of disposable electrochemical sensors. They trigger the possibility of building screen- or stencil-printed electrodes with similar efficiency with respect to solid electrodes. [2] In particular, biocompatible inks are formulated and stencil-printed on a flexible support that could be easily integrated within smart-devices for the continuous and minimally invasive monitoring of lactate and glucose. First, the conductive ink formulation has been optimized based on electrochemical and rheological measurements implemented within a multivariate analysis model. Afterwards, the active carbon electrode was modified with methylene blue (MB) and Hemin to establish an electronic connection with enzymes, since neither alcohol dehydrogenase (ADH) nor alcohol oxidase (AOx) are able to directly transfer electrons. [3,4] Finally, both biosensors have been tested in model solution and sweat to determine the analytical figures of merit (*e.g.,* LOD, LOQ, linear range, sensitivity, selectivity, reproducibility, stability, storability *etc.*).

References:

1. Bollella, P. Enzyme-based amperometric biosensors: 60 years later…Quo Vadis? Anal. Chim. Acta, 340517 (2022).
2. Tricase, A., et al. Water-Based Conductive Ink Formulations for Enzyme-Based Wearable Biosensors. Adv. Sensor Res., 2300036 (2023).
3. Marchianò, V., et al., High Voltage Flexible Glucose/O2 Fully Printed Hydrogel-based Enzymatic Fuel Cell, J. Phys. D, accepted.
4. Marchianò, V., et al., Tailoring Water-based Graphite Conductive Ink Formulation for Enzyme Stencil-Printing: Experimental Design to Enhance Wearable Biosensors Performance, Chem. Mat., accepted.

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Single-Stroke laser scribing of optical-active nanostructures on cellulosic substrates for colorimetric and photoluminescent-based sensing strategies

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The implementation of affordable technologies to manufacture optical and colorimetric paper-based analytical devices (PAD) integrating optical active nanostructures is still a challenge. Therefore, the development of strategies to fabricate colorimetric PAD integrating nanostructured sensing surfaces with a controlled pattern is of great interest.

Recently, our group proposed an innovative and versatile approach to in-situ synthesize optical active gold, silver, platinum, copper, nickel, and aluminum (Al) metal nanoparticles (MNPs) on paper, employing a CO_2-laser plotter[1]. This approach allows laser-induce MNPs well anchored onto paper substrates according to customized designs; these laser-induced MNPs (LIMs) demonstrated captivating and useful features, including (i) localized surface plasmon resonance, (ii) catalytic and (iii) photoluminescent feature-related to the MNPs chemistry and morphology.

In this presentation, completely lab-made PADs integrating LIM coupled with smartphone-based readouts will be discussed. In detail, a photoluminescent Al-based paper-nanostructure employed for the implementation of a fluorometric PAD for the selective detection of o-diphenols will be presented; in this case, the Al-nanostructure fluorescence turn-on, induced by the interaction with the phenolic structures, is exploited for their detection. This peculiar optical behavior was investigated according to the laser-induced nanostructure synthesis, studying the Al-fluorescence turn-on mechanism towards several phenolic structures. Further, a laser approach to induce paper nanostructuration and carbon dots (CDs) formation will be also presented; in particular, the synthesis of laser-induced CDs (LiCDs) doped with different surface functionalizations (i.e., -SH, -COOH, -OH, etc.) will be shown. LiCDs give rise to enhanced fluorescence phenomena according to the surface chemistry; the use of the latter for (bio)sensing purposes will per presented.

Summing up, the proposed CO_2 laser strategy is particularly prone to generate colorimetric and photoluminescent sensing zones in tailored paper-based devices, resulting in a new sustainable nanopatterning technique useful for (bio)sensing and nanochemistry.

References:

[1] A. Scroccarello, F. Della Pelle, T. Di Giulio, E. Mazzotta, C. Malitesta, D. Compagnone, ACS Sustainable Chemistry & Engineering, 2024, , 12, 8, 3196–3208

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Are there any valuable alternatives to antibodies when developing (bio-)sensing architectures for protein cancer biomarkers and therapeutic drugs?

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The interest in synthetic bioreceptors to develop (bio-)sensing platforms has increased quite rapidly in recent years. Ligand binding assay, which employs a receptor to capture the analyte, relies on the affinity of the receptor toward the binding ligand. In this respect, antibodies (Abs) are still playing a fundamental role. However, they suffer of high production costs to meet the requirements of specificity and selectivity for each analyte of interest. Immunoassays, in fact, rely on a couple of Abs that selectively bind two different epitopes of the same protein cancer biomarker. This aspect is crucial to develop biosensing platforms. Moreover, it is usually very difficult for researchers worldwide to find commercially available Ab couple that meet such requirements. Furthermore, Abs are not particularly useful to detect small molecules, such as chemotherapeutic drugs, as the detection system may imply the use of highly sophisticated equipment. However, there are innovative and valuable solutions represented by aptamers and peptides. In this presentation, we will show few interesting and recent applications of aptamers and of a new class of bicyclic peptides. The former ones have been employed to monitor a chemotherapeutic drug in plasma in an SPR-based sensing platform.[1] Whereas the latter ones have been devised in an electrochemical sensing platform to detect a cancer protein biomarker.[2,3]

References:

[1] S. Tartaggia, A. Meneghello, O. Bellotto, A. S. Poetto, M. Zanchetta, B. Posocco, D. Bunka, F. Polo, G. Toffoli, Analyst 2021, 146, 1714-1724.
[2] G. Moro, L. Ferrari, A. Angelini, F. Polo, Chemosensors 2023, 11, 234 – 246.
[3] G. Moro, P.S. Sfragano, J. Ghirardo, Y. Mazzocato, A. Angelini, I. Palchetti, F. Polo, Biosens. Bioelectron. 2022, 213, 114477.

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ANA-OR-059

Chemiluminescence biosensors for H_2O_2 and oxidases substrates quantification employing DNAzyme-mimicking activity self-assembled guanosine-hydrogel

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Chemiluminescence (CL) is widely used for hydrogen peroxide detection, mainly exploiting the highly sensitive peroxidase-luminol-H_2O_2 system. Hydrogen peroxide plays an important role in several physiological and pathological processes and is produced by oxidases, thus providing a straightforward way to quantify these enzymes and their substrates[1]. Recently, biomolecular self-assembled materials obtained by guanosine and its derivatives and displaying peroxidase enzyme-like catalytic activity have received great interest for hydrogen peroxide biosensing[2]. These soft materials are highly biocompatible and can incorporate foreign substances while preserving a benign environment for biosensing events. In this work, a binary guanosine hydrogel prepared using a mixture of guanosine and guanosine 5′-monophosphate in the presence of K^+ ions are loaded with a CL reagent (luminol) and a catalytic cofactor (hemin), to produce a functional material showing peroxidase-like activity to the CL reaction of luminol with H_2O_2. The hydrogel is then functionalized with a specific oxidase enzyme to enable marker biosensing: the hydrogen peroxide produced by analyte oxidation reacts, in the presence of the self-assembled guanosine/hemin gel mixture, with luminol to produce photon emission. The biosensor takes advantage of both the features of CL detection, offering high detectability and amenability to miniaturization, and of the 3D porous structure of hydrogel, as providing increased stability and catalytic activity even in alkaline and oxidizing conditions of incorporated enzymes. In this work we show the development of four guanosine hydrogel – based biosensors for the detection of glucose, xanthine, uric acid and lactate by simple incorporation of corresponding oxidases: glucose oxidase (GOx)[3], xanthine oxidase (XOD), urate oxidase (UO) and lactate oxidase (LOx). Exploiting 3D printing technology, smartphone-based portable devices for CL biosensors were developed, verifying the applicability to quantify biomarkers of clinical interest at the point-of-care (POC).

References:

[1] V. Patel, et al. Biosensors 2020, 11, 9.
[2] T. Bhattacharyya, et al. ACS Biomater. Sci. Eng. 2017, 3, 2358–2365
[3] D. Calabria, et al. Biosensors 2023, 13(6), 650

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Light-up DNA nanostructures as programmable imaging sensors for enzymatic substrates

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The high programmability of synthetic DNA makes this biomaterial particularly suitable for the development of nanostructures with predefined geometries at the nanoscale. Over the past decades, many efforts have been dedicated to the fabrication of responsive DNA-based nanostructures. Taking advantage of their precise spatial addressability, it is possible to decorate them with various functional elements and develop DNA nanostructures that respond to a variety of different targets, offering potential applications in the fields of sensing, imaging and drug-delivery [1].

Recently, we have re-engineered supramolecular tile-based DNA nanostructures to respond to different chemical and biological inputs. We have also demonstrated several strategies to control their assembly, disassembly and reconfiguration in response to different external inputs [2,3]. Furthermore, we propose here a novel approach to develop light-up DNA-based nanostructures as programmable imaging sensors for enzymatic substrates. To achieve this, we have re-engineered tile-based DNA nanostructures to be decorated with different pH-dependent DNA-based responsive units, and we have initially developed light-up imaging sensors that respond to pH-changes. We have then shown that such decorated DNA nanostructures can be used as imaging sensors for specific enzymatic reactions (and their corresponding substrates) that change the pH of the solution (i.e. urea and glucose). Our approach also offers the possibility to engineer an integrated DNA-based imaging sensor that is functionalized with both, the enzyme (urease) and the responsive unit. This would be crucial for the development of an imaging sensor capable of measuring local concentrations of specific enzymatic substrates.

References:

[1] L. Shen, P. Wang, Y. Ke. Adv. Healthcare Mater. 2021, 10, 2002205.
[2] S. Gentile, E. Del Grosso, L. J. Prins, F. Ricci. Angew. Chem. Int. Ed. 2021, 60, 12911-12917
[3] N. Farag, G. Ercolani, E. Del Grosso, F. Ricci. Angew. Chem. Int. Ed. 2022, 61, e202208367.

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Liposomes-based Biosensing: innovative electrochemical characterisation strategies for vesicle encapsulation, functionalisation, and sensing mechanisms

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Liposomes are artificial microscopic spherical structures composed of lipid bilayers enclosing an aqueous core [1]. These technologies are commonly utilised in a variety of applications due to their biocompatibility, ability to penetrate biological barriers, and capacity to encapsulate hydrophilic and hydrophobic molecules. Liposomes are often employed as carriers in nanodevices, for drug and gene delivery, and as mimics of cell membranes [2,3].

Herein, the production, functionalization, and sensing application of small unilamellar vesicles (SUV, diameter of around 100 nm) made of L-a-Phosphatidylcholine, 1,2-Dipalmitoyl-rac-glycero-3-phosphoethanolamine, and cholesterol in a molar ratio of 1:1:1 is presented. These SUVs, produced by the thin layer hydration (TLH) method, were initially encapsulated with a redox probe (i.e., $[Fe(CN)_6]^{3-/4-}$, L-ascorbic acid). Dynamic light scattering (DLS) is used to evaluate the dimension of vesicles while electrochemical methods like cyclic voltammetry and square wave voltammetry are used to characterize the efficacy of SUV entrapment and breakdown mechanism. After that, SUV functionalization was investigated by leveraging the nucleophilic reactivity inherent in the free amine groups of liposomes. A carbodiimide amide coupling reaction, involving EDC/NHS, was employed to covalently functionalize SUV by linking the free amine groups of liposomes with the free carboxylic groups of antibodies. Labelled and label-free bioreceptors (enzyme-labelled IgG and IgG) were utilised to functionalize SUV, whereas CV, SWV, and absorption spectroscopy were employed to assess method reliability. Finally, interleukin-6 (IL-6) selective Immuno-SUVs were prepared functionalizing SUVs with anti-IL-6 clone-5[4,5]. These liposomes showed promising analytical performances when tested in serum samples, with a low limit of detection (LOD=0.5pg/mL) and good reproducibility (RSD%<12%). Thereby, opening up the possibility of Immune-SUV employment for effective sensing purposes in complex matrices.

References:

[1] V. P Torchilin. 2005. Nat Rev Drug Discov. 4, 145–160.
[2] S. Choi, et al. 2023. Sci Rep 13, 4728.
[3] Z. Zhang, et al. 2023. Nat Commun 14, 5256 ().
[4] R. Cancelliere et al. 2022. Biosensors and Bioelectronics 213, 114467.
[5] R. Cancelliere, et al. 2023. Front. Chem. 11, 1251360.

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Towards magneto-assay approaches for the electrochemical detection of extracellular vesicles

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Extracellular vesicles (EVs) are biological membrane-enclosed nanometric particles whose classification and role remain unclear. Among them, exosomes are of particular interest. Initially considered simple debris, emerging evidence is now showing important correlations between EV expression and cancer diseases. Over the last few years, multiple methodologies have been applied for the detection and characterisation of EVs, although entailing limitations that include the high costs of the sophisticated instrumentation required, the necessity of high volumes of sample, and the incompatibility with point-of-care approaches. A simpler and cost-effective solution is lately increasingly being found in the field of biosensors.

In this work, a versatile biosensing scheme based on electrochemical readout and superparamagnetic microparticles (magneto-assay) was studied for the capture and determination of EVs. The beads were coated with different biorecognition molecules, testing the flexibility of the assay on a variety of analytes, including DNA. The magneto-assay was further successfully adapted to work in a microfluidic card in a semi-automated approach[1]. The procedure was then adjusted to work in the case of EVs. Indeed, the lack of standardised workflows and the limited literature-reported examples with these analytes, especially involving magnetic beads, required careful optimisation of the procedure[2]. The main challenge was mainly linked to the EVs' sensitivity to stresses during handling procedures. After assessing and optimising critical points of the analysis (*e.g.*, mixing, incubations, and storage conditions), multiple commercially available magnetic particles were preliminarily tested, differing especially in coating and size. Particularly, antibodies and aptamers were considered for use as bioreceptors to capture and immobilise EVs on the beads, exploiting a (hybrid) sandwich-like structure targeting tetraspanins expressed on the surface of the vesicles. The assay was then applied to the detection of EVs extracted from breast cancer, colon cancer, and glioblastoma cell lines. Preliminary results showed limits of detection of sub-nanograms/microliter levels of EVs in buffer, corresponding to ~10^6 EVs/µL.

Regione Toscana Bando Salute 2018 (Research project CUP n. D78D20000870002) and the European Climate, Infrastructure and Environment Executive Agency, HORIZON-MISS-2022-OCEAN-01, project iMERMAID, grant number 101112824, are acknowledged for financial support.

References:

[1] P.S. Sfragano, E.C. Reynoso, N.E. Rojas-Ruíz, S. Laschi, G. Rossi, M. Buchinger, E. Torres, I. Palchetti. Talanta 2024, 271, 125718.
[2] P.S. Sfragano, S. Pillozzi, G. Condorelli, I. Palchetti. Analytical and Bioanalytical Chemistry 2023, 415, 1087-1106.

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ANA-OR-063

Unravelling the binding features for the recognition equilibria of quercetin and its zinc(II)-complex into a macrocyclic-based micellar aggregate

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Quercetin (Que) is one of the most popular and biologically active flavonoids which shows a broad spectrum of physiological activities such as anti- or pro-oxidant, anti-inflammatory, anticancer and antimicrobial effects.[1] The coordination properties of Que were exploited to obtain stable metal complexes with an improved biological action than the free flavonoid. Indeed, the coordination of metal ions changes the redox potential of the ligand thus modifying its antioxidant activity.[2] Moreover, the changes in the flavonoid structure after complexation are responsible for the higher antibacterial activity of the metal complexes which can easily interact with various intracellular components.[3]

Despite the promising broad spectrum of pharmacologically relevant properties, applications are severely confined due to their low *in vivo* bioavailability, poor water solubility, low stability, and short half-life. Various drug carriers were proposed to ameliorate the solubility and stability of Que and, consequently, to increase the biological activity and availability of the flavonoid to produce significant therapeutic effects.[4]

Within this framework, we investigated the capability of a *p*-sulfonate-calix[4]arene derivative,[5] able to form micellar aggregates, to include the flavonoid and its zinc(II)-complex thus enhancing their stability.

The interactions of Que or its Zn(II) complex with the calixarene-based system in the micellar, monomeric or non-amphiphilic forms were investigated by isothermal titration calorimetry (ITC) in aqueous solution at 25 °C and pH 7.4 to determine the binding parameters and driving forces of the molecular recognition equilibria in solution.[5] NMR experiments enabled us to estimate the ability of the micellar system to interact with the flavonoid and its metal complex as well as to unveil the main functional groups involved in the binding process. The micellar aggregates were thoroughly characterized to determine their size and charge. Finally, kinetic stability measurements were performed to assess the ability of the micellar systems to increase the half-life of the flavonoid and the Zn(II) complex.

Overall, these studies provided an in-depth characterization in solution of the drug-carrier assembly which is essential for the development of efficient delivery systems with potential biological applications.

References:

[1] M.M. Kasprzak et al., RSC Advanced 2015, 5 (57), 45853-45877.
[2] S.B. Bukhari et al., Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 2009, 71(5), 1901-190.
[3] M. Samsonowicz et al., Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 2017, 173, 757-771.
[4] G.D.G Santonoceta et al., Molecules 2023, 28(14), 5581.
[5] R. Migliore et al., Nanomaterials 2021, 11(11), 2930.

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ANA-OR-064

Solution equilibria studies on similarities between Fe(III) and Ga(III) hydroxypyrone complexes

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Iron uptake systems can be targeted as strategy to enhance the uptake of antimicrobial cargos. Actually, the pathogenic microbes produce Fe-scavenging molecules that sequester iron from their extracellular environment and transporting proteins.

In this frame, we carried out the solution equilibria studies on Fe(III) and Ga(III) hydroxypyrone complexes.

Gallium(III) is an effective iron(III) mimic but redox inert under physiological conditions.

On the other hand, hydroxypyrone compounds, namely kojic acid derivatives, are a class of chelating agents widely suitable for *hard* metal ions [1,2].

Therefore, the complementary use of potentiometric and spectrophotometric techniques has allowed a solution characterization of the different species involved in the equilibria. Solution equilibria studies of Fe(III) complexes were carried out firstly [ref Toso], and then the corresponding ones with Ga(III) for evaluating the similarity between these two metal ions. The results are clearly consistent with the formation of 2:3 metal:ligand complexes already at high acidic pH, differently protonated with both metal ions. The stability constants calculated for Ga(III) system strictly resemble those calculated for Fe(III).

Moreover, the synthesis in solid state and the characterization by NMR spectroscopy and mass spectrometry gave evidence of the 2:3 stoichiometry.

Lastly, biological test demonstrated that Ga(III)-complexes exhibit promising activity against *A. fumigatus* and gram-negative bacteria.

References:

[1] L. Toso *et al*., Journal of Inorganic Biochemistry 2013, 127, 220 – 231.
[2] R. Cappai *et al*., New Journal of Chemistry 2018, 42, 8050 – 8061.

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ANA-OR-065

Thermodynamic Insights into Trans-Aconitate Interactions with different cations of biological and environmental importance.

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Among naturally occurring chelating agents, an excellent candidate to be exploited in metal ions removing from water is trans-aconitic acid (H_3L, Scheme 1), a molecule largely present in sugar cane (about 60 % w/w), or that can be isolated from by-products of the sugar industry. It was found that the amount of trans-aconitic acid available in the molasses is between 7.1 and 23.4 g/kg of dry product. The thermodynamics of interaction of trans-aconitate with proton, sodium, potassium, cadmium, manganese, and lead cations has already published[1]. Considering the obtained results and the lack of data in the literature, it was decided to study additional interactions with other metals. The choice of these metals was influenced by the importance of certain cations in natural and biological matrices, as well as their technological significance, such as the La^{3+}. The complexing ability of trans-aconitic acid toward Ca^{2+}, Mg^{2+}, Cu^{2+} , Zn^{2+}, Co^{2+}, La^{3+} and Fe^{3+} was studied by potentiometry, UV-vis spectroscopy and ^1H NMR techniques, in chloride aqueous solutions at different ionic strength values ($0.1 \leq I/\text{mol dm}^{-3} \leq 1.0$) and at $T = 298.15$ K. The ligand sequestering ability and affinity toward M^{2+} and M^{3+} cations were evaluated by determining the $pL_{0.5}$ and pM parameters at different pHs and ionic strengths. The data reported in this study can provide information on the possible employment of a small molecule like trans-aconitic acid, as a chelating and sequestering agent in aqueous solution.

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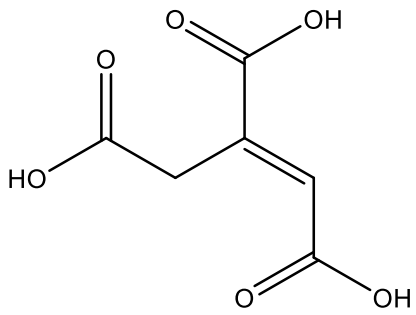

Scheme 1: *Trans*-aconitic acid (H_3L).

References:
[1] G. Lando, C. Bretti, D. Milea, C. De Stefano, O. Gómez-Laserna, P. Cardiano, Journal of Molecular Liquids 2023, 387, 2023, 122702-122711.

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An overview of the speciation and antioxidant ability of morin, quercetin and their M^{2+}-, M^{3+}-complexes under physiological conditions

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Morin (Figure 1), a naturally occurring polyphenol, and its metal-complex species have attracted increasing interest from the scientific community for their bioactivity, particularly as antioxidants. Knowing their speciation may help assess their pharmaceutical, nutraceutical and therapeutic potential, which –in turn- could be exploited for the design of advanced antioxidant drugs. The bioactivity of morin, as well as that of its 3'-OH isomer, quercetin, is related to the ionization state of the hydroxyl groups in its chemical structure and metal-chelating abilities.[1] To this end, a speciation study was first performed under physiological conditions of ionic strength and temperature (I=0.15 mol L^{-1} (NaCl) and t=37°C) to determine the protonation constants of morin and quercetin, whose values are controversial in the literature. Therefore, thermodynamic interaction parameters of morin with bivalent (M^{2+}, such as Mg^{2+}, Mn^{2+} and Zn^{2+}) and trivalent (M^{3+}, such as Al^{3+}) metal cations, as well as their antioxidant ability were also studied by the 2,2'-diphenyl-1-benzopyran-4-one (DPPH) method.[2] This investigation sheds light on the different pH-dependent species of morin, quercetin and their M^{2+}-, M^{3+}- complex forms in aqueous solutions, also highlighting the effect of coordination on the resulting antioxidant abilities.

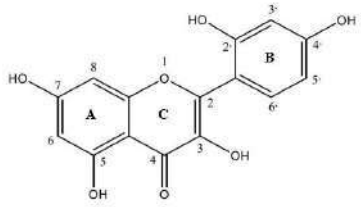

Figure 1: chemical structure of morin.

References:
[1] E. Rodríguez-Arce, M. Saldías, Biomedicine & Pharmacotherapy 2021, 143, 112236.
[2] W. Brand-Williams, M.E. Cuvelier, C. Berset, LWT - Food Science and Technology 1995, 28, 25-30.

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Beyond the thermodynamics of metal-peptide complexes: new perspectives for antimicrobial agents

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The importance of antibiotics to fight infectious diseases is undoubtedly well recognised worldwide. However, the antimicrobial resistance of many microorganisms has forced to reevaluate their application. Antimicrobial peptides are promising alternatives to classical antibiotics. Their bioactivity can arise from different mechanisms, one of which is known as nutritional immunity and has metal micronutrients and metal-binding biomolecules as its main players. The human antimicrobial peptide calcitermin is an example. It has been previously studied by our research group aiming to evaluate its metal chelating ability and bioactivity against various pathogens *in vitro*.[1]

A systematic study was further undertaken on calcitermin derivatives. Chemical modifications have been introduced in the native sequence to verify the impact of divalent Cu(II) and Zn(II) ions on the stability, coordination and antimicrobial activity of the formed complexes.[2,3] A deep investigation of complex formation equilibria and coordination chemistry of the formed species has been obtained by means of potentiometric titrations, mass spectrometry, UV-Vis spectrophotometry, circular dichroism and electronic paramagnetic resonance. Antimicrobial assays provided information on the bioactivity of the compounds against a wide panel of microorganisms and highlighted the crucial role of metal ions. Given the obtained results, the characterization of the thermodynamic properties in solution of metal-peptide complexes represents a stepping-stone for the development of new metal-based antimicrobial agents.

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References:

[1] D. Bellotti, M. Toniolo, D. Dudek, A. Mikołajczyk, R. Guerrini, A. Matera-Witkiewicz, M. Remelli, M. Rowińska-Żyrek, Dalton Trans., 2019, 48(36), 13740-13752.
[2] K.J. Cutrona, B.A. Kaufman, D.M. Figueroa, D.E. Elmore, FEBS Lett., 2015, 589, 3915-3920.
[3] M. D'Accolti, D. Bellotti, E. Dzień, C. Leonetti, S. Leveraro, V. Albanese, E. Marzola, R. Guerrini, E. Caselli, M. Rowińska-Żyrek, M. Remelli, Sci. Rep., 2023, 13, 18228.

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Speciation Investigation of Gadolinium Based Contrasting Agents in Wastewater and Seawater of the Northern Adriatic Sea

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The contaminants of emerging concern is a class in constant evolution since new compounds which may present toxicity towards the biota are continuously detected in the environment, especially in water bodies. Among these substances, gadolinium based contrasting agents (GBCAs) are regarded as possible contaminants of relevance due to their widespread use in medicine[1]. Substances containing gadolinium are used as contrasting agents in magnetic resonance imaging (MRI) analyses due to the paramagnetic properties of Gd; since gadolinium ion in its free from, Gd^{3+}, is highly toxic, it is administered before MRI examination as a complex with an organic ligand which ensure a high stability of the compound avoiding the release of free Gd ions into the body fluids[1]. The high stability implicates that GBCAs are persistent also in the environment, and indeed their concentration in the aquatic ecosystems is expected to increase, possibly leading to adverse effects.

In this work, we investigated the presence of two GBCAs, namely gadoterate meglumine (Gd-DOTA) and gadoteridol (Gd-HP-DO3A), in two different aqueous matrices, wastewater both at the entrance and at the exit of a wastewater treatment plant in Trieste, and seawater collected in the gulf of Trieste near the WWTP's pipeline.The wastewater samples were pre-concentrated by evaporation, while the seawater samples, presenting a high salinity, needed a specific treatment consisting in a solid phase extraction to remove the saline components in order to prevent interferences during analysis[2]. The determination of GBCAs was carried out by HPLC-ICP-MS using an anion exchange column and a mixture of 125 mM ammonium nitrate buffer at pH 9 and MilliQ water in a 25:75 ratio as a mobile phase. The isotopes ^{157}Gd and ^{158}Gd were monitored.

The high recoveries obtained for Gd-DOTA and Gd-HP-DO3A proved the validity of the two sample preparation methods. The results showed the presence of both substances in the samples analysed, in the range between 0.1 and 50 ng/L; indeed, higher concentrations were found in the wastewater matrices, while the concentration was lower in the seawater samples, providing information on the environmental pathway of these compounds.

References:

[1] R. Brünjes, T. Hofmann, Water Research 2020, 182, 115966.
[2] M. Horstmann, R. Gonzalez de Vega, D.P. Bishop, U. Karst, P.A. Doble, D. Clases, Journal of Analytical Atomic Spectrometry 2021, 36, 767 – 775.

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Rare Earth Elements Translocation in Soil-Rice Systems

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Rice is a staple food for over half of the global population and plays a crucial role in the worldwide economy. To ensure consumers' health, it is essential to continuously monitor the presence of both essential and potentially hazardous elements in food. This is particularly important for rice, which has the tendency to accumulate toxic elements from the soil-water system. Rare earth elements (REEs) are the class of trace elements that are frequently studied in food, due to their emerging contaminant status and their use in geo-referencing purposes[1]. Therefore, researchers are evaluating the toxicity and translocation of these elements from abiotic ecosystems to living organisms[2].

Elements mobility is primarily influenced by soil features and their interactions among microorganisms and rhizosphere, in turn influencing the bioavailability of REEs[3,4]. This study aimed to investigate the translocation of REEs throughout the soil-rice system at varying of irrigation techniques, and a comprehensive analytical procedure was developed for this purpose.

Soil, roots, stems, leaves, panicles, husks, and rice grains from the *Sprint* rice genotype (Indica subspecies) were collected at the Santa Lucia experimental farm of Sassari University, Sardinia, Italy.

The study considered three irrigation methods: continuous flooding, saturation irrigation, and sprinkler irrigation[5]. The matrices underwent mineralization using a microwave-assisted acid/oxidant digestion with an ultraWAVE device from Milestone. The quantification of REEs was performed using an inductively coupled plasma mass spectrometry NexION 300X from Perkin Elmer.

References:

[1] A. Mara et al., Foods 2024, 13(2), 243.
[2] G.P. Danezis et al., Trends in Analytical Chemistry 2016, 85(Part A), 123 – 132.
[3] N. Grosjean et al., Advances in Botanical Research 2024, 109, 19 – 61.
[4] G. Tyler, Plant and Soil 2004, 267, 191 – 206.
[5] A. Spanu et al., Science of The Total Environment 2020, 748, 142484.

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ANA-OR-070

ICP-MS analysis of trace and ultra-trace metals in agricultural goods for a multivariate geographical identification of products of the Chianti wine and EVOO supply chain

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To fight counterfeits, and to protect the consumer, the interest in certifying the origin of agricultural goods has been growing in the last years. To increase the accuracy of zoning models, a multivariate approach is needed. This has been proven to be better suitable than univariate analysis when it comes to the investigation of geographical origin of agri-food goods[1] especially when trying to move past the state-of-the-art challenge of discriminating products coming from extremely close regions[2] (sometimes in a range of under 20km). By means of ICP-MS, samples coming from the 2022 and 2023 sampling campaign were analysed for their metal content and these levels used in the construction of simple discriminant models that have been proven successful to separate samples coming from the Tuscany countryside. Furthermore, by collecting samples of soil, plant matter and finished product it was possible to investigate the direct link between geographical location and agri-food goods, without the possibility of any interferences from the production chain[3] introduced in the samples masking potential correlations. Lastly, metabolomic profiles, which are known to be modulated by abiotic factors[4,5], were correlated with the chemical composition of the soil, with the aim of further understanding the difference in characteristic of agri-food goods due to geographical locations.

This study was carried out within the Agritech National Research Center (Spoke 9) and supported by the European Union Next-Generation EU (D.D. 1032 17/06/2022, CN00000022).

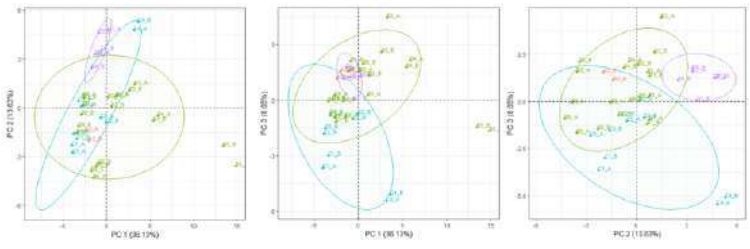

Figure 1: PCA analysis of Sangiovese samples coming from four areas of the Chianti Region in Tuscany.

References:

[1] M. C. Baqueta et al., Microchemical Journal 2024, 196, 109603
[2] C. Telloli et al., Food Chemistry 2023. 402, 134247
[3] M. Fabjanowicz and J. Plotka-Wasylka, Trends in Food Science & Technology 2021, 122, 382-390
[4] M. Rienth et al., Frontiers in Plant Science 2021, 12, 643258
[5] Y. Zhang et al., Food Research International 2022, 157, 111207

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ANA-OR-071

Chemical fingerprints of European tea gardens: advancing authenticity and traceability

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Growing tea in Europe is a new frontier, offering opportunities for research and development [1]. This study provides an in-depth examination of the elemental compositions found in tea leaves sourced from multiple European gardens (**Figure 1**), focusing on the determination of 21 essential and potentially toxic elements in tea leaves (fresh, dried and processed to produce green and black tea) and soils, in relation to processing methods and garden locations. The findings indicate no accumulation of toxic elements from soil to leaves. No significant variations in elemental content based on tea leaf processing techniques were registered. However, the application of chemometric and machine learning techniques (RDA, PCA, PLS-DA, LDA and SVM analysis) revealed distinct elemental profiles among tea leaves originating from different European regions. This study underscores the potential utility of these elemental profiles in improving the traceability of European tea products.

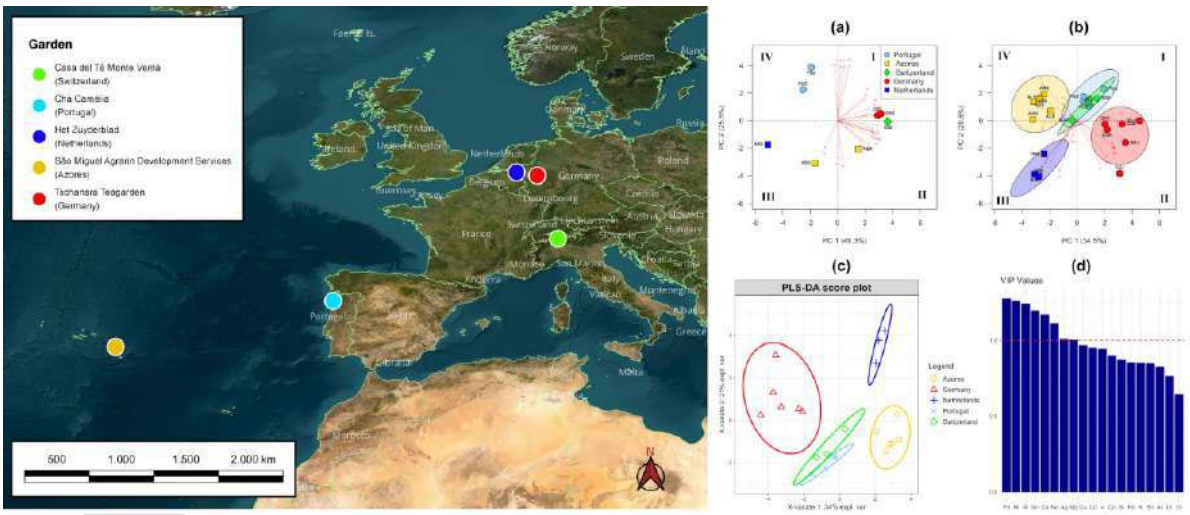

Figure 1: sampling locations across Europe and main results: PCA on soil (**a**) and tea leaves (**b**) samples, PLS-DA (**c**) and VIP values bar plot (**d**) of tea leaves.

References:

[1] F. Girolametti, F., A. Annibaldi, S. Illuminati, E. Damiani, P. Carloni, C. Truzzi, C., Molecules 2023, 28, 3802.

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ANA-OR-072

Valorization of a variety of historical wheat (San Pastore) along the bread production chain using omics and multivariate methods

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In the perspective of the protection and valorisation of typical products, the role played by analytical chemistry appears of primary importance in order to provide consumers and workers in the production chain with useful information on the characterization of the products. The study presented here was developed within the "Pa.N.E." project. – Panem Nostrum Every Day" (PSR 2014-2020, Measure 16 – 16.1.1), aimed at the recovery of a historical variety of soft wheat, the San Pastore variety, widely used in the Piedmont area until the 1960s, then fallen into disuse, and now the almost exclusive prerogative of a few research and conservation centres, the most authoritative of which in Italy is the Morando Bolognini Foundation.

The project involved the valorisation of San Pastore wheat along the entire supply chain, from wheat to flour to bread, rediscovering the modernity of a traditional wheat, with the aim of combining innovation with tradition.

From a characterization point of view, the supply chain was followed from different points of view:

- Characterization of wheat: 4 different varieties of San Pastore (San Pastore and 3 variants) were studied and compared with 4 other varieties, 2 of which were modern and 2 historical, with the aim of characterizing their proteomic, lipidomics and small molecule profiles;
- Flour authentication study: the stone-milled San Pastore wholemeal flour was mixed with increasing contents of flours of two modern soft grains, in order to evaluate the possibility of identifying any adulterations with less valuable products;
- Authentication study on bread: the bread produced from San Pastore flour currently in production was studied to evaluate whether variations to the recipe could be detected (type of oil, yeast, flour, operator), as part of the identification of commercial frauds. The study was approached using experimental design techniques to study the effect of the recipe on the chemical characteristics of the final product.

All phases of the research were followed through a characterization obtained by a multi-omics approach. Wheat, flour and bread samples were pre-treated to extract proteins, lipids and small molecules which were identified and quantified using UHPLC-HRMS (proteomics and lipidomics) and GCxGC-MS (small molecules). The data were processed using chemometric pattern recognition techniques (PCA, cluster analysis, Kohonen autoassociative maps, MFA) and classification methods (PLS-DA, SIMCA, Artificial neural networks), also coupled with variable selection methods.

Acknowledgements:

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ANA-OR-073

Metabolomic Profiling of 'Patata di Montese': Authenticity Assessment and Regional Discrimination Using uHPLC-MS and ROI-MCR Method

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European Union prioritizes protecting and promoting mountain products, introducing Mountain Product indication in 2012 to enhance their recognition and indirectly support mountain economies. This indication applies strictly to food items sourced or processed in mountain areas, contributing significantly to Italy's PDO products, particularly in Emilia-Romagna, necessitating research to uphold authenticity and consumer choice. In this context, metabolomic profiling aids in ensuring food authenticity, with applications ranging from targeted quantitative analysis to untargeted pattern acquisition, vital for identifying unique markers on food products. In this study, the research activity focused on analyzing the metabolomic profile of potato cultivar samples labeled as 'Patata di Montese,' an authentic and traditional product of the Emilian Apennines. Ultra-high-performance liquid chromatography coupled with mass spectrometry (uHPLC-MS) was utilized to delineate the molecular fingerprint of the investigated samples. In the first part of this work, influential instrumental parameters affecting chromatographic separation were optimized using experimental design techniques (Face Centered Central Composite Design, FC-CCD) to achieve resolved chromatographic signals in the shortest possible time. In the second part, the optimized analytical method was used to characterize the metabolomic profile of samples from the same potato cultivars grown in mountain (Montese, MO) and plain (Castelfranco, MO) regions. ROI-MCR method[1] was employed in order to reduce the complexity of the chromatographic signals correcting noise or undesirable effects (peak shifts, baseline drift) that could obscure useful information for analysis. The algorithm performs extensive data filtering and compression operations to transform the original structure into a matrix of potential "features" (Region of interest, ROI) and resolve the relative chromatographic profiles of the various components representative of the entire sample. Once these features were extracted, they were compared with data from the literature[2] and specific databases, such as Compound Discoverer, to achieve a preliminary identification of the present compounds/metabolites. Finally, Principal Component Analysis (PCA) was used as an exploratory method directly on the final datasets containing the features to identify the most influential metabolites in differentiating between the two categories in the space defined by the principal components.

References:

[1] E. Gorrochategui, J. Jaumot, R. Tauler, BMC bioinformatics 2019, 20, 1 – 17.
[2] R. Munyai, M. V. Raletsena, D. M. Modise, Metabolites 2022, 12(3), 221.

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ANA-OR-074

Application of high pressure liquid chromatography coupled to mass spectrometer in isolation procedure of ovatoxin-a

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Ovatoxins (OVTXs), produced by marine dinoflagellates like *Ostreopsis* cf. *ovata*, are potent marine neurotoxins structurally similar to Palytoxin (PLTX). In recent years, the global expansion of *Ostreopsis* spp correlated to a phenomenon called Harmful Algal Blooms (HABs)[1] has led to an increase of OVTXs, raising concerns about public health and environmental impact. Exposure to OVTX-contaminated seawater can lead to skin and eye irritation, respiratory issues, and muscular pain[2]. Despite their impact, the lack of well-characterized reference materials (RM) for OVTXs complicates their detection and risk assessment. Our research addresses this challenge by focusing on the optimization of the isolation protocol of OVTX-a from *Ostreopsis* cf. *ovata* cell pellets[3] in 4 steps: Extraction, Medium Pressure Liquid Chromatography (MPLC), Semi-preparative High Pressure Liquid Chromatography (HPLC-step 1) and Preparative HPLC (HPLC-step 2). Through meticulous optimization of each step, we achieved a doubling of total recovery yields from 12.5% to 25%. Moreover, refining the latter two steps enabled the chromatographic separation of all OVTXs present in the initial cell pellet, including OVTX-a, OVTX-d/e, and Isobaric PLTX, resulting in a final OVTX-a fraction with a purity exceeding 94%. This accomplishment marks a significant advancement in preparing reference materials for analytical and toxicological purposes, thereby aiding regulatory efforts to safeguard public health.

References:

[1] P.A. Tester, R.W. Litaker, E. Berdalet, 2020, Harmful Algae, 91, 101655
[2] E. Berdalet, A.S. Pavaux, R. Abós-Herràndiz, M. Travers, G. Appéré, M. Vila, J. Thomas, L. de Haro, M. Estrada, N.I. Medina-Pérez, L. Viure, B. Karlson, R. Lemée, 2022, Harmful Algae, 119, 102320.
[3] P. Ciminiello, C. Dell'Aversano, E. Dello Iacono, E. Fattorusso, M. Forino, L. Grauso, L. Tartaglione, F. Guerrini, L. Pezzolesi, R. Pistocchi, S. Vanucci, 2012, Journal of the American Chemical Society. 134, 3, 1869–1875.

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ANA-OR-076

Development of analytical platforms based on FFF coupled with On-chip sample detection for extracellular vesicles-based liquid biopsy

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Precision and personalized medicine advancements allow to tailor clinical approaches, depending on the makeup of patients' DNA and expression issues. Liquid biopsy and the chance to use selected biomarkers from biological fluids, could strongly contribute to the improvement of an increasingly patient-oriented method, avoiding invasive assays and tissue biopsies. Among the most important effectors of cellular interplay, Extracellular Vesicles (EVs), are on the rise for the possibility to be considered as powerful biomarkers, although the severe limitations of standard tools hinder their complete understanding and use. In fact, isolation, enrichment and sorting techniques available are often instrument- and time-heavy, and require a high amount of sample. Moreover, EV characterization needs various steps of sample pre-processing, involving e.g. centrifugation, which can influence stability, size and cargo release. The technological gap in handling this kind of sample, in its complexity and heterogeneity, limits the exploitation of such an information-rich pool, both for diagnostic and medical research applications. We aim to move forward in disentangling EVs heterogeneity going beyond limitations imposed by standard methods of analysis. In particular, using Flow-Field Flow-Fractionation (4F) and on-chip detection for their full characterization, our purpose is to build a benchtop-ready device able to identify arrays of biomarkers associated to the size and to different functions of EVs subclasses, customizable according to clinical needs. A key point is the effort in removing all the highly impacting processing procedures to operate in the most native conditions possible, reducing time and cost, and preserving EV morphology and properties. We present here the first results on combining dynamic cell culturing and on-chip detection of conditioned media[1] with in-flow sorting and selection of EV-rich fractions[2] to reduce processing steps, shorten analysis time, and enhance sensor lifetime by reducing interferences, in a streamlining process towards realistic liquid biopsy.

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References:

[1] Chiriacò MS, Bianco M, Nigro A, Primiceri E, Ferrara F, Romano A, Quattrini A, Furlan R, Arima V, Maruccio G. Sensors (Basel). 2018 Sep 20;18(10):3175.

[2] Marassi, V.; Giordani, S.; Placci, A.; Punzo, A.; Caliceti, C.; Zattoni, A.; Reschiglian, P.; Roda, B.; Roda, A., *Sensors* **2023,** *23* (23), 9432.

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ANA-OR-077

Mechanistic insights into the antimicrobial effect of copper-chitosan composites on *Escherichia coli* by scanning probe microscopy.

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Copper-chitosan (Cu-CS) films, composed of encapsulated bioactive nanophases within a thin polymer coating[1], are promising antimicrobial films for food packaging applications with excellent bioactivity. In this contribution, we report on Cu-CS thin films obtained by a simple solvent evaporation method accurately tuning the inorganic loading of nano-toxicologically safe Cu sub-microparticles. The procedure is green and straightforward, and exploits water-based solutions and mild conditions. The Cu-CS films were characterized by spectroscopic and scanning probe microscopy techniques with respect to composition and physicochemical properties. Electrothermal atomic absorption spectroscopy (ETAAS) studies were conducted to predict the antimicrobial properties of these composites via the quantification of Cu^{2+} ionic release over time.

Besides, atomic force microscopy (AFM) to image *E. coli* incubated on antimicrobial thin films between 2 and 20 h was used to visualize morphological alterations of bacterial cells when in contact with multicomponent antimicrobial surfaces like Cu-CS. Different antimicrobial mechanisms of action were identified based on the thin film composition and the incubation time. Signs of bacterial stress, like "blebbing", fimbria and flagella growth, clustering and the development of extracellular polymer matrix (EPS) were clearly evident[2]; massive cell lysis for long-time exposure to the antimicrobial surfaces was also observed. As response to harsh external conditions such as nutrients starvation and the presence of antimicrobials, the morphology of bacteria was altered from a rod-like to a smaller and coccoid shape associated with the reduced energy requirements to overcome hostile conditions[3]. These findings indicate a synergistic antimicrobial action exerted by CS and Cu particles when combined into composite thin films. This study investigates bacterial behavior when in contact with antimicrobial surfaces to better understand the mechanisms of action of these materials and the potential development of antimicrobial resistance phenomena.

References:

[1] D. d'Agostino, M.C. Sportelli et al., 2024, submitted.
[2] X. Juan-Hu, Z.X. Liu et al., Nuclear Science and Techniques, 2016, 27-56.
[3] G. Caniglia, M.C. Sportelli et al., Analytica Chimica Acta, 2022, art. n° 339892.

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ANA-OR-078

Analytical Characterization of Electrochemically Prepared Zn-based (Nano)materials

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Zn-based materials, such as zinc oxide or zinc phosphate, have different applications including antimicrobial treatments[1,2]. In the last years we have devoted part of our research activity to the development of green electrochemical approaches[3-5] for the synthesis of nano- and microstructures demonstrating its easiness, high yield and ability in controlling size and quality of the produced materials. In particular, the sacrificial anode electrolysis in alkaline media allowed preparing ZnO in several shapes and sizes by adding suitable stabilizers applying low current density. More recently, Calcium zincate was also synthesized and applied as antibacterial agent[5].

In this contribution, some successful examples of Zn-based (nano)material development will be illustrated emphasizing the advantages of electrochemical sol-gel routes. The versatility of this strategy will be further demonstrated, and cases of study will be discussed, including the development of advanced, or multi-component antimicrobials such as zinc phosphate particles and AgCl-nanoparticles @ ZnO-nanorods. The morphological and spectroscopic characterization of the proposed materials will be presented, highlighting the importance of structure, surface composition, and metal ion release. High-resolution TEM analysis, coupled with EDX elemental mapping, was performed to investigate morphology and composition. Moreover, spectroscopic characterization by FTIR and XPS techniques demonstrated that nanostructures composed of zinc phosphate tetrahydrate were obtained. Comparison with zinc phosphate produced by precipitation methods was also carried out, suggesting superior results of the electrochemical method.

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References:

[1] M. Izzi, M.C. Sportelli, L. Torsi, R.A. Picca, Nicola Cioffi, ACS Applied Nano Materials 2023, 6, 10881–10902.
[2] L. Zhu, X. Tong, Z. Ye, Z. Lin, T. Zhou, S. Huang, Y. Li, J. Lin, C. Wen, J. Ma, Chemical Engineering Journal 2022, 450, 137946.
[3] R.A. Picca, M.C. Sportelli, D. Hötger, K. Manoli, C. Kranz, B. Mizaikoff, L. Torsi, N. Cioffi, Electrochimica Acta 2015, 178, 45-54.
[4] M.C. Sportelli, R.A. Picca, M. Izzi, G. Palazzo, R. Gristina, M. Innocenti, L. Torsi, N. Cioffi, Nanomaterials 2020, 10, 473.
[5] M Izzi, M C. Sportelli, R.A. Picca, N Cioffi, ChemElectroChem 2023, 10, e202201132.

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ANA-OR-079

Quantitative XPS analysis: the case of NiP alloys.

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X-ray photoelectron spectroscopy (XPS) is an acknowledged surface-sensitive technique suitable for qualitative and semi-quantitative analysis.[1] The results obtained on a series of NiP coatings deposited on a copper substrate, previously characterized by EDX, XPS, and by AAS and UV-Vis (for determining Ni and P content respectively)[2], are presented in this investigation, which is focussed on the factors that might influence the quantitative analysis by XPS. A Theta Probe spectrometer (Thermo Fisher, UK) equipped with a monochromatic Alkα source (hν = 1486.6 eV) was used for the XPS analyses of NiP alloys. Prior to introducing the samples in the XP-spectrometer, they were cleaned for 16 h in isopropyl alcohol; then they were ion-etched using Ar^+ at 3kV x 3 μA, 3*3mm^2, for 3 minutes to remove any surface contamination. The high-resolution spectra were processed using CASAXPS software and applying the Shirley-Sherwood background. Peak intensities were corrected by using the calculated relative sensitivity factors[1]. The best linear relationship between the peak areas corrected for the relative sensitivity factors were obtained by considering the Ni 3s to P 2p corrected intensity ratio vs the chemical composition of the alloys, despite the fact that the Ni 2p is the most used signal in XPS quantitative analysis. These results can be explained by considering the influence of the kinetic energy differences within the Ni 2p and the Ni 3s signals that affects the inelastic mean free path (IMFP). The data quality parameters as accuracy, precision, range of linearity will be discussed by considering various concentrations of the NiP alloys together with the effect on the peak areas (peak intensities) of the background subtraction functions; of the correction for the instrumental parameters (asymmetry parameter and intensity energy response function) and of the method used for the calculation of the peak areas.

References:

[1] D. Briggs, J.T. Grant., IM Publications LLP 2003, ISBN: 978-1-901019-04-9.
[2] B. Elsener, D. Atzei, A. Krolikowski, V. Rossi Albertini, C. Sadun, R. Caminiti, A. Rossi, Chem. Mater. 2004, 16(22), 4216 – 4225.

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ANA-OR-080

NIR-Hyperspectral Imaging as an analytical tool to identify adulterations in dried oregano leaves

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Dried oregano leaves are commonly subjected to economically motivated adulterations, which consist in adding lower cost plant materials of different botanical origin. Frequent adulterants found in oregano samples include olive, sumac, strawberry tree, and myrtle leaves. To face this issue, the European Spice Association suggests the use of non-targeted fingerprinting techniques coupled with chemometric methods to monitor product authenticity[1].

In the present study, we evaluated Near Infrared Hyperspectral Imaging (NIR-HSI) as a rapid and non-destructive analytical tool to detect adulterated oregano samples. By proper chemometric elaboration of hyperspectral data, NIR-HSI enables a comprehensive chemical characterization of heterogeneous samples like dried oregano leaves thanks to the possibility of acquiring both spatial and spectral information from a sample.

Hyperspectral images of authentic oregano, pure adulterants (i.e., olive, strawberry tree, myrtle, and sumac leaves) and oregano with different percentages of adulterants were acquired in the 980 – 1660 nm spectral range using a line scanning spectral imaging system.

Multivariate classification models were calculated to differentiate authentic oregano from pure adulterants by using two classification strategies: class modelling with Soft Independent Modelling of Class Analogies (SIMCA)[2] and soft discriminant approach with Soft Partial Least Squares Discriminant Analysis (Soft PLS-DA)[3]. Soft PLS-DA achieved the best classification results, since this algorithm combines the advantages of class modelling and discriminant analysis methods.

Finally, based on Soft PLS-DA results the corresponding percentage of pixels predicted as oregano was calculated from each image. This allowed to establish a threshold value of 10% adulteration, serving as a detection limit of NIR-HSI to distinguish authentic oregano from adulterated samples.

References:

[1] European Spice Association, Adulteration Awareness Document.
[2] S. Wold, Pattern Recognition, 1976, 8, 127–139.
[3] R. Calvini, G. Orlandi, G. Foca, A. Ulrici, Journal of Spectral Imaging, 2018, 7, a13.

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ANA-OR-081

TD-NMR spectroscopy and chemometrics for determining cross-linking density in compounds for the tyre industry.

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The chemistry of tyre materials is complex due the presence of several compounds, that are mixture of elastomers and other chemicals, such as curing agents, fillers etc… In more detail, the curing agent is one of the most important constituents, as it promotes the vulcanization process. This process is a chemical reaction in which cross-linking bonds are formed between the polymer chains of the elastomers. The final product properties are strictly dependent on the cross-linking density and, therefore, it is of crucial importance to determine this value. Up to date, one of the most common analytical methods to determine such parameter is the equilibrium-swelling method[1], which requires some days to be performed and a huge amount of solvents.

The development of an analytical method fast and solvent-free can therefore be a huge advantage for the tyre industry. To the aim, Time-Domain Nuclear Magnetic Resonance (TD-NMR) spectroscopy is worthy of being studied, as its decay profile is highly correlated with the chain mobility in rubber-based materials.[2]

In the present study, performed in collaboration with Pirelli Tyre S.p.A., TD-NMR decays (^{1}H 18 MHz- obtained using the Carr-Purcell-Meiboom Gill (CPMG) sequence – developed in collaboration with Prof. Marco Geppi, University of Pisa) of 428 samples of compounds with a cross-linking density in the range 0.44-5.28 x 10^{-5} mol/g have been acquired. 285 of these samples, have been selected as training set (venetian-blind scheme) to build a regression model able to predict the cross-linking density value. The remaining 143 samples have been used to test the model.

Partial Least Square (PLS) regression models changing the signal pre-treatments (Discrete Exponential Fitting (DEF)[3] or Inverse Laplace Transform (ILT)[3]) have been built and compared in cross-validation. Applying the PLS model built on raw data on the test set a value of Root Mean Square Error in Prediction (RMSEP) of 0.65 has been obtained. The results obtained on DEF- and ILT-pretreated data ($RMSEP_{DEF}$ = 0.63; $RMSEP_{ILT}$ = 0.65) are comparable to the ones obtained with the raw data highlighting the robustness of the models.

Finally, an in-depth physico-chemical interpretation of the results allows to understand how variance in cross-linking density is correlated to variance in raw signals and pre-treated profiles.

References:

[1] B. A. Saville, A. A. Watson, Rubber Chemistry and Technology, 1967, 40(1), 100-148.
[2] G. Eidmann, R. Savelsberg, P. Blümer, B. Blümich, Journal of Magnetic Resonance, 1996, 122(1), 104-109.
[3] S. B. Engelsen, F. W. J. van den Berg, Modern Magnetic Resonance, 2018, 1669-1686.

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Enhancing Congenital Heart Disease Prediction: A Comparative Study of Machine Learning Approaches in Metabolomic and Lipidomic Data Analysis

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A previous study presented at the XXX Congresso della Divisione di Chimica Analitica (2023) in Vasto demonstrated the efficiency of Sequential and Orthogonalized Covariance Selection (SO-CovSel) Linear Discriminant Analysis (LDA)[a,b] in identifying biomarkers for Congenital Heart Disease (CHD) through metabolomic datasets. By integrating metabolomic and lipidomic profiles from *non-pregnant mothers* with CHD-affected offspring, the study achieved a test accuracy of 92% while reducing the variables to only 5 analytes. Furthermore, it reported a classification accuracy of 94.74% in structural CHD (sCHD), showcasing the power of targeted variable reduction in complex biological data analysis.

Building on this foundation, the current study extends the focus to metabolomic and lipidomic profiles from *pregnant mothers* with CHD-affected offspring. It aims to compare the efficacy of common data analysis approaches—including univariate analysis, Support Vector Machines (SVM), Random Forest, and Partial Least Squares Discriminant Analysis (PLS-DA)—with the previously mentioned SO-CovSel-LDA method. Additionally, this research investigates the impact of data augmentation techniques on enhancing the performance of these models across various analytical strategies.

The novelty of this work resides in its comprehensive approach to model comparison and a critical evaluation of data augmentation, a common strategy in data science, as a means to address challenges such as data scarcity and imbalance prevalent in medical research datasets.

Through this research, novel biomarkers may be identified that could initiate hypotheses to potentially uncover the sources of pathology. This offers promising avenues for early intervention and ultimately aims to improve maternal and fetal health outcomes in the face of this widespread congenital anomaly.

References:

[a] A. Biancolillo, I. Måge, T. Næs, Chemom. Intell. Lab. Syst. 2015, 141, 58–67.
[b] A. Biancolillo, F. Marini, J. M. Roger, J. Chemom.2020, 34, e3120 .

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Estimation of structural disorder degree from carbon materials' Raman spectra by Multivariate Curve Resolution and Partial Least Squares Regression

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Raman spectroscopy is the most frequently used technique to evaluate the disorder degree inside the chemical structure of carbon materials: whereas a perfect graphite sample shows only a narrow band at ca. 1580 cm^{-1} (*G* band), other components (*D* bands) become Raman-active in the presence of structural defects[1], the most prominent being at ca. 1350 cm^{-1} (D_1), thus broadening the global profile of the spectrum between 1000 and 1800 cm^{-1}. Usually, the spectra are treated via a curve-fitting process, using a pre-established set of mathematical functions (at least 5, with different shapes[2-3]), and then some specific disorder indices are derived from their properties (height, width, position, etc.). However, there is no general agreement on the number or shape(s) of those components; moreover, the fitting is usually done by hand or by non-automatic methods, thus resulting in a tedious and time-consuming process and leading to a high uncertainty of the results[4].

To overcome some of these problems, two different chemometric procedures based respectively on MCR and PLSR techniques, were applied in order to evaluate the disorder degree directly from the Raman spectra of many different carbon materials: petroleum coke, partially graphitized coke, synthetic and natural graphite (ca. 350 measures in total). The indices were calculated via a semi-automatic software[5] and consist of the ratio between the intensities of *D* and *G* (R_1), the sum of the areas of all the components divided by the intensity of *G* (*Standard Total Area*, *STA*), and the ratio between the average intensity value in 1575 – 1595 cm^{-1} and the average intensity value in 1610 – 1630 cm^{-1} (*G-shape-factor*, *GSF*)[5]. Monte Carlo cross-validation was used to estimate the prediction ability and in the case of PLSR to establish the optimal number of Latent Variables to retain, whereas for MCR a set of 3 pure components represent the best compromise between description completeness and model complexity: in any case, the models show good performances both in description and prediction, always leading to a coefficient of determination $R^2 > 0.99$ in fitting and > 0.98 in cross-validation.

References:

[1] A.C. Ferrari. Solid State Communications 2007, 143, 47–57.
[2] G. Rantitsch et al. International Journal of Coal Geology 2014, 130, 1-7.
[3] A. Croce et al. Research on Chemical Intermediates 2021, 47, 419–431.
[4] Z.E. Brubaker et al. Journal of Materials Science 2021, 56.27, 15087–15121.
[5] N.K. Lünsdorf et al. Geostandards and Geoanalytical Research 2017, 41.4, 593–612.

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Chemometric Treatment of UV-Visible Spectra of Acetonitrile Extracts: A Novel and Simple Approach for Detecting Plant-Derived Adulterants in Saffron (Crocus sativus L.)

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Saffron, derived from the stigmas of Crocus sativus L., is used worldwide as a food colorant and flavor agent and is increasingly employed as a medicinal formulation ingredient. However, its reputation and economic worth are constantly threatened by adulteration practices. The conventional ISO 3632 normative method[1], while effective in grading saffron quality, struggles to detect adulterants at low contamination levels, leaving room for fraudulent activities. We developed a novel UV-visible spectroscopic method inspired by ISO 3632 and specifically designed to identify common adulterants like Calendula officinalis L. petals (calendula), Carthamus tinctorius L. petals (safflower), and Curcuma longa L. powdered rhizomes (turmeric) in saffron. Our research underscores the limitations of traditional spectroscopy-based techniques in detecting plant-derived adulterants in saffron, which derived from their high solubility in water and strong absorption capabilities. After a preliminary screening of different solvents, we selected acetonitrile as the most suitable extraction medium, effectively enhancing detection sensitivity towards adulterants in saffron by amplifying their spectral signatures while minimizing interference from saffron constituents.We analyzed 163 saffron samples, including 40 genuine and 123 counterfeited samples with 5-10% w/w contamination levels, each contaminated with one of the aforementioned adulterants (41 for each kind of adulterant). The UV-visible spectra of these samples were processed using multivariate statistical methods to differentiate genuine saffron from adulterated ones. Initially, we employed Sequential Pre-processing through Orthogonalization (SPORT) algorithm[2], which successfully discriminated between genuine and adulterated saffron samples. The SPORT model, calibrated with 145 samples, exhibited remarkable accuracy in classifying external data samples, regardless of the contaminant type or level. Furthermore, a class model for genuine saffron was generated using Soft Independent Modelling of Class Analogies (SIMCA) on the same dataset, demonstrating excellent efficiency in authenticating genuine saffron (90% sensitivity, 100% specificity against safflower and turmeric and 90% against Calendula officinalis L. petals).

References:

[1] ISO 3632-1; Saffron (Crocus sativus L.), Part 1 (Specification). International Organization for Standardization: Geneva, Switzerland, 2011; ISO 3632-2; Saffron (Crocus sativus L.), Part 2 (Test Methods). International Organization for Standardization: Geneva, Switzerland, 2010.
[2] J.-M. Roger, A. Biancolillo, F. Marini, 2020, 199, 103975.

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Analysis of Parchments, inks, and lead seals of ancient PApal BuLLs from the hystorical archive of Santuario della Beata Vergine di Saronno (APPALLA project)

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The aim of the present research is to study different aspects of a selection of some of the Papal Bulls held by the Museum of Santuario della Beata Vergine di Saronno, in the north of Italy. The preservation of documents related to the life of the Sanctuary begins from its foundation (1498). The archive, notified by the "Soprintendenza archivistica e bibliografica della Lombardia" in 1997 as being of considerable historical interest, contains more than 30,000 documents, 385 account books, ledgers, registers of various kinds, and 106 papal bulls. These artifacts have never been studied with archaeometric methods, thus any information on the composition of inks and gathered on their general conservation status will be valuable. In particular, four papal bulls were selected and investigated through different methodologies: a bull of Pope Alexander Borgia dated 1502, a bull of Pope Paul III dated 1540, and two bulls of Pope Pius IV dated 1560 and 1561, respectively. The study of the elemental composition of the inks was conducted by means of Particle Induced X-ray Emission (PIXE) technique, which, due to its high sensitivity and spatial resolution, made it possible to study the parchments with very high detail. The analysis of the chemical composition of inks with PIXE has already been carried out on very precious documents such as Galileo's writings [1], providing information on the realization techniques. Moreover, PIXE mapping could be used to study the migration of some elements around the inscriptions, also allowing the analysis of the state of conservation of the artefact. A series of preliminary and non-invasive analyses were carried out at the archive, by means of Multispectral imaging (MSI) techniques. These included UV-induced fluorescence, UV reflectography, infrared reflectography, and UV and IR false-color imaging to identify possible interesting features and areas to be investigated by PIXE.

Fig.1-PIXE experimental set-up at AGLAE

The PIXE measurements were carried out at the Accélérateur Grand Louvre d'analyse élémentaire (AGLAE) of the C2RMF (Centre de recherche et de restauration des musées de France). The chemical nature of the iron gallic inks used in the different documents was studied in detail by also comparing areas where erasures were identified through MSI analysis. The large amount of data acquired will also allow reconstruction of the history of both these important documents and the sanctuary.

[1] F. Lucarelli & P. A. Mandó (1996) Studying the Chronology of Galileo's Writings with PIXE, Nuclear Physics News, 6:2, 24-31

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The dark side of optoelectronic and photovoltaic devices: preliminary results of the ROBERTA project

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Organic/inorganic systems are attracting attention in academic and industrial research as highly efficient p-type materials1. For example, several compounds have been coupled with semi-transparent perovskite solar cells, which are used for building-integrated photovoltaics due to their aesthetic advantages as light-harvesting windows2.

Unfortunately, the environmental fate of these systems in the event of uncorrected disposal represents a major environmental challenge that is still poorly understood.

The ROBERTA project aims to fill this knowledge gap by investigating the main variables responsible for the photo-transformation processes of these compounds under different environmental conditions.

The objective of the ROBERTA project is to develop an innovative Green Total Index (GTI) and label to classify different substances used in hybrid organic/inorganic photovoltaic and optoelectronic devices in order to improve the ecological transition.

In this context, elution and stress tests were carried out on different organic/inorganic devices and chemical characterisation was performed.

From the obtained results, the toxicity was evaluated, a Green Total Index was calculated by a specific algorithm and a classification was assigned considering low, middle and high eco-sustainability.

References:

[1] H. Zheng, D. Li, C. Ran, Q. Zhong, L. Song, Y. Chen, W. Huang, Solar RRL, 2021, 5.7, 1-17
[2] J. Wu, J., Cha, H., Du, T., Dong, Y., Xu, W., Lin, C. T., & Durrant, J. R. (2022). N. Surname, N. Surname, Journal Year, Volume, initial page – last page.

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ANA-OR-087

PVDC sorting challenge: A spectroscopy study and on field application

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Environmental challenges are increasing worldwide in the field of polymer recycling, circular economy and in general waste treatment. One of the main step to face the plastic recycling process is to set up an efficient and affordable sorting capability. Spectroscopy techniques are already in the field to support sorting; most of the polymer matrix have been tested and automated devices are available in the market. Among all polymer matrixes, halogenated and chlorinated needed to be identified[1]. In this study we present the results obtained in the Vibrational spectroscopy field (IR-Raman and NIR) related to polymeric materials containing PVDC (Polyvinylidene Chloride) film layers. The scope was to analyse, locate fundamental normal modes, combination and overtones bands useful to identify and sort PVDC containing films. We recorded data relative to multilayer films, standard PVDC and PE polymers: both frequency data and intensity parameters have been considered and discussed[2]. The spectroscopic findings revealed that the presence of Chlorine atoms nearby $-CH_2$ moieties clearly influence stretching frequencies and intensities in IR and Raman spectra; comparison with PE spectral data are given[3]. These specific features in the Vibrational spectra generate a correspondence in the NIR region (Figure 1). Moreover, to test in a real situation the sorting capabilities of a NIR commercial setup once the right information are stored and used in the sorting system, a Tomra sorting machine[4] has been used in the analysis of a plastic mixed stream. The results of the sorting test give excellent results with the sorting yield > 80%. This first test shed light to the possibility to put in place in the industrial sector advanced and trained sensors for selecting halogens and in particular PVDC containing materials.

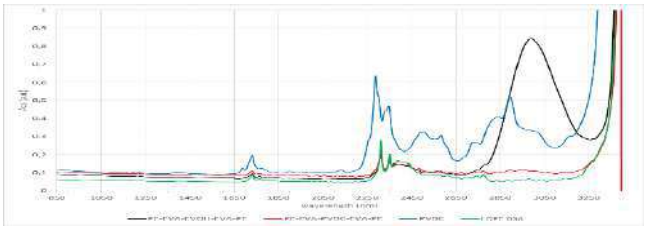

Figure 1: NIR spectra of PE and PVDC based film samples

References:

[1] Magali Laasonen et al. **:** *Analyst*, 2001, **126**, 1122–1128.
[2] M.Gussoni : Journal of Molecular Structure, 1986, 141 pag.63-92 .
[3] P.C.Painter, M.M.Coleman, J.L.Koenig: The Theory of Vibrational Spectroscopy and its application to Polymeric Materials, John Wiley & Sons 1982.
[4] https://www.tomra.com/

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High-precision Cd isotopic analysis using MC-ICP-MS equipped with 10^{13} Ohm faraday cup amplifiers and application to biological samples from Terra Nova Bay (Antarctica)

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Cadmium (Cd) is a "heavy metal" of significant concern due to its high toxicity and carcinogenic properties, posing risks to both the environment and human health.[1] Like other toxic elements such as Hg and Pb, Cd can be transported with fine atmospheric particulate matter over long distances, eventually reaching the Antarctic continent.[2] Antarctica serves as a crucial natural laboratory for studying the impacts of human activities on the environment and elucidating biogeochemical processes involving toxic elements such as Cd.

Isotopic analysis of Cd in various Antarctic matrices is a powerful tool to investigate its biogeochemical cycle and trace the sources of anthropogenic Cd pollution. Cd, like other elements with more than 2 isotopes, demonstrates natural variations in its isotopic composition due to mass-dependent fractionation, reflecting the slight difference in behaviour that its isotopes display in physicochemical and biogeochemical reactions.[3]

However, obtaining high-precision Cd isotope ratio data, particularly for samples with low Cd concentrations and complex matrices, remains challenging. Multi-collector inductively coupled plasma mass spectrometry (MC-ICPMS) emerges as the preferred technique for Cd isotopic analysis, providing precise isotope ratio measurements through simultaneous monitoring of the signals for all isotopes.

In this work, a single-stage chromatographic purification method was optimised combined with the use of a vacuum box technology for fast and quantitative isolation of Cd from matrix elements. High-precision Cd isotope ratio measurements at low concentrations were achieved using a high-transmission 'jet' interface and innovative 10^{13} Ω amplifier technology for monitoring ^{110}Cd, ^{111}Cd, ^{112}Cd, and ^{114}Cd isotopes, a novel approach in Cd isotope ratio measurement. External correction for the instrumental mass discrimination was combined with the use of Ag as an internal standard, obtaining good accuracy and precision. An external precision of 0.08‰ (2SD for $\delta^{114/110}$Cd) was obtained at Cd concentrations as low as 10 ng mL^{-1}. This research also introduced $\delta^{114/110}$Cd ratios for specific biological reference materials with low Cd content. Furthermore, various biological and sediment samples from Antarctica were characterized to preliminarily investigate the biogeochemical cycling of Cd isotopes.

References:

[1] P. Tanhuanpää, R. Kalendar, A. Schulman and E. Kiviharju, Genome Natl. Res. Counc. Can. Génome Cons. Natl. Rech. Can., 2007, 50, 588–94.
[2] F. Vagnoni, S. Illuminati, A. Annibaldi, F. Memmola, G. Giglione, A. M. Falgiani, F. Girolametti, M. Fanelli, G. Scarponi and C. Truzzi, Atmosphere, 2021, 12, 1030.
[3] F. Vanhaecke and P. Degryse, Isotopic Analysis: Fundamentals and Applications Using ICP-MS, John Wiley & Sons, 2012.

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Optimization of a GeLC-MS/MS approach for analysis of ancient proteins from medieval "Pietra Ollare" vessels

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Paleoproteomics, the study of ancient proteins, is a dynamic, rapidly growing field at the intersection of molecular biology, palaeontology, archaeology, paleoecology, and history. The analysis of protein residues absorbed in ancient ceramic vessels is used to identify the foodstuff processed, but detailed methodological investigations in this field remain rare[1,2].

The present work aimed at optimizing a protocol for extracting and identifying proteins preserved within food encrustations adhering to archaeological remains (sherds of "pietra ollare" vessels) found inside and around two houses of the medieval settlement of Nogara (Veneto Region), dating to its 9th- 10th centuries. For this purpose, we scraped the encrustations from the inner vessel wall (n=10) with a metal spatula. Protein extraction from ceramic vessels was performed using three different extraction protocols based on (1) 6M guanidine hydrochloride (GuHCl)[1], (2) 7M urea[3] and (3) 4% sodium dodecyl sulphate (SDS)[3]. The GuHCl protocol was adopted and modified by adding ultrasonication (20 kHz) and ultrafiltration (30 kDa cut-off) steps; additionally, extracted proteins were separated on a 12% SDS-PAGE gel and visualized by silver staining. Bands were excised and digested, and peptide mixtures were separated using an Ultimate 3000 nano-UHPLC system connected to an Orbitrap Fusion Lumos Tribrid MS instrument (Thermo Fisher Scientific). Protein identification was done using the Proteome Discoverer software through the Sequest HT search engine. The optimization of the employed protocol, based on the modified GuHCl method, resulted in a more effective extraction of proteins adsorbed to the inner vessel wall, allowing the removal of any potential deposit contamination. The GeLC-MS/MS analysis identified in each sample around 40 proteins (from animal species such as *Bos taurus, Sus scrofa, Gallus gallus,* and *Ovis aries*), with diagenetic modifications typical of ancient proteins, such as backbone cleavages, deamidation of asparagine and glutamine, formation of N-terminus pyroglutamic acid.

Our preliminary results allowed us to identify proteins in archaeological deposits of the Nogara dwelling accurately. This is particularly relevant for contributing to an in-depth study of the dietary practices during the Early Middle Ages in Northern Italy.

References:

[1] M.P. Chowdhury, S. Campbell, M. Buckley, Journal of Archaeological Science 2021, 132, 105414.
[2] J. Hendy, A.C. Colonese, I. Franz, *et al.* Nature Communication 2018, 9, 4064.
[3] D. Tanasi, A. Cucina, V. Cunsolo, *et al*. Amino Acids 2021, 53, 295–312.

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Ultra-high performance liquid chromatography-ion mobility-high-resolution mass spectrometry for untargeted metabolomics of raw milk using multivariate data analysis

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In the last 20 years, omics technologies have emerged as multi-disciplinary approaches aimed at comprehensively assessing different classes of biomolecules and genes in complex systems, combining chemical and genetic information[1]. Metabolomics is based on cutting-edge analytical techniques providing a snapshot of all small molecules present in biological samples. Ultra-high-performance liquid chromatography-high-resolution mass spectrometry (UHPLC-HRMS) has emerged as a powerful tool to tackle challenges related to the complexity of the metabolome. In addition to the sensitivity and specificity achieved by HRMS, the coupling with ion mobility spectrometry (IMS) offers an extra-dimension for the separation of co-eluting compounds, increasing confidence in metabolite annotation based on cross collisional section (CCS)[2]. Since thousands of features are generated, chemometrics is required for extracting valuable information.

In this study, the capabilities of UHPLC-IMS-HRMS were exploited for the untargeted metabolomic analysis of cow milk used for the production of DOP cheese. Analyses were carried out in positive and negative electrospray ionization modes by operating in data independent HDMS acquisition. After data filtering, both unsupervised and supervised approaches were applied. Being the dataset affected by high individual variability and presence of multiple factors (i.e. type of production, breeding systems, nutrition, animal conditions, etc…), only supervised approaches based on Partial Least Squares- Discriminant Analysis (PLS-DA) allowed sample clustering with sensitivity, specificity, and non-error rates close to 1. Less than 150 features were required for sample classification according to specific factors, including farm origin, diary production, lactation period. To avoid overfitting, model validation was performed on external test sets and biomarkers were annotated by a multi-dimensional match considering *m/z*, CCS values, isotope similarity and MS/MS spectra.

References:

[1] A. Valdés, G. Alvarez-Rivera, B. Socas-Rodríguez, M. Herrero, E. Ibáñez, A. Cifuentes, Analytical Chemistry 2022, 94, 366–381.
[2] N. Riboni, F. Bianchi, M. Mattarozzi, M. Caldara, M. Gullì, S. Graziano, E. Maestri, N. Marmiroli, M. Careri, Journal of Agricultural and Food Chemistry 2023, 71, 15407–15416.

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Hair analysis as an epidemiological indicator to assess the drug situation in Europe

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Novel Psychoactive Substances (NPS) are accumulating in the illicit market and are (un)consciously used in combination with common drugs of abuse, alcohol, and medicinal drugs thus complexing their detection in biological samples. The aim of this pioneer study was to provide effective tools for monitoring the consumption of traditional and new substances of abuse, in particular NPS and synthetic opioids, in different at-risk populations. To assess what type of psychoactive substances are used in Europe and whether people are aware of the intake of NPS or synthetic opioids, two different tools were combined: 1) the laboratory analysis of hair samples to detect the actual molecule taken by the sample donor, and ii) a sociological questionnaire to obtain information on which substances were thought to be consumed. The research took place in 2022 and early 2023 in four different countries: Italy, France, Portugal and Lithuania. In total, 332 samples were collected. When the hair was longer than 6 cm, it was divided in two segments up to 12 cm. From 332 samples, a total of 494 segments was obtained. The analyses were performed with targeted UHPLC-MS/MS for more than 150 substances.

Based on the analysis of keratin matrix samples, in the Italian territory, cocaine (68%), cannabis (50%), MDMA and ketamine (32% each) and heroin (26%) were the most prevalent substances, while synthetic cathinones and synthetic opioids were less frequently identified. Mephedrone, buphedrone and eutylone were detected in people who declared recent use (n=3) and past use (n=9) of MDMA and amphetamines; two people tested positive for recent use of mephedrone even though they did not declare it. Ketamine, MDMA and tramadol were often identified in samples collected from individuals who did not report any exposure to these substances. In Lithuania, the same pattern is repeated with cocaine (27%), MDMA (26%) and cannabis (22%) being the most used while ketamine (12%) and amphetamine (8%) follow. Mephedrone (n=6) was detected mainly in combination with cocaine. 2-FDCK (n=4) was detected in three cases together with cocaine. No heroin use was detected. An interesting aspect is noticed in Portugal: MDMA (60%) is by far the most prevalent substance followed by ketamine (47%) while cocaine and cannabis were detected to a 31% each. Amphetamine (18%) and mephedrone (2%) complete the detection window. Tramadol (n=1), mescaline (n=2) and harmine (n=3) were mainly detected in combination with other drugs.

The identification of substances in biological matrices in diverse populations is essential to obtain an overview of the diffusion of the substances around Europe, to understand the drug prevalence and trade patterns as well as their effects on humans health. While not being representative of the general population, this innovative approach based on two complementary methods provide valuable additional information about variations in use among different groups of people who use drugs.

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HPLC method for extracellular Guanosine 5′-triphosphate and tetrahydrobiopterin pathway products analysis from cadaveric samples and human biofluids

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To gain a deep insight and to obtain a superior understanding about guanosine-based pathway, this paper reports an innovative approach to study this critical subject. Firstly, after an exhaustive analysis of literature with a focus in legal medicine and extracellular vesicles, it was understood that a new method is inevitable to follow, determine, and quantify these analytes (Guanosine monophosphate - GMP, guanosine diphosphate - GDP, guanosine triphosphate - GTP, Guanosine, Neopterin, and tetrahydrobiopterin - BH4.

Starting from a previously method [1], we implemented and validated a new HPLC-DAD method in gradient elution mode with these six target analytes fully resolved in 18 min. The HPLC-DAD method uses a stationary phase XTIMATE C18 and mobile phase's phosphate buffer and Acetonitrile. Good correlation goes from 0.05 to 10 µg/mL with a limit of detection equal to 0.02 µg/mL and a limit of quantification equal to 0.05 µg/mL ($R^2 \geq 0.9824$).

Method was tested on human extracellular vesicles, isolated from different human parts, like urine, saliva and muscle, giving interesting results as different quantification of analytes depending on the sample matrix used. Interesting to underline is that saliva was the poorest source of these analytes, if compared with growth medium and urine.

References:

[1] M. Perrucci, C. Santangelo, D. Bondi, T. Pietrangelo, F. Savini, A.M. Catena, M. Bonelli, M. Locatelli, C. D'Ovidio, Journal of Chromatography Open, 2024, 5, article 100110

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Determination of F2-Isoprostanes in oral fluid employing PALME followed by UHPLC-MS/MS analysis.

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A dangerous imbalance between antioxidant defense systems and ROS can occur due to the overproduction of reactive oxygen species (ROS) or their missing degradation; in this scenario ROS exert their toxic action, leading to a condition called oxidative stress (OS). OS has been implicated in a variety of pathological condition. Since the lipid oxidative stress biomarkers, isoprostanes (IsoPs), are more chemically stable than other analytes, their study is more advantageous for analytical purposes. They are formed in situ from the oxidation of arachidonic acid esterified to phospholipids by the direct action of ROS in the cellular membrane [1]. Due to the low concentrations in biological fluids, a need to develop highly sensitive methods of analysis, and the use of instrumental analysis such as liquid chromatography coupled to tandem mass spectrometry (HPLC-MS/MS) started to be mandatory [2]. Oral fluid (OF) was used in this work as an alternative matrix being a fast patient-friendly approach and having a simpler composition than blood and urine to develop a new rapid, reproducible, and sensitive method for the quantification of F2-IsoPs in OF by UHPLC-MS/MS. The procedure involved an extraction step which was developed to reduce the volume of organic solvent, using the novel approach based on parallel artificial liquid membrane extraction (PALME). In the PALME setup, target analytes were extracted through a three phases system, exploiting a pH gradient to facilitate the mass transfer of uncharged analytes to an aqueous extracting phase, across an organic solvent immobilized within the pores of a membrane, which led to the low consumption of organic solvents for extraction. Moreover, this technique allows a high enrichment factor (40 fold) without an increasing matrix effect (below 20%). Noteworthy, for the first time, a microextraction technique in the 96-well format was developed for the extraction of IsoPs, to obtain satisfactory extraction levels in the PALME step, it was necessary to pay attention to different parameters: the nature of organic solvent, volumes of biological sample, composition and volume of donator and acceptor solution, pH, ionic strength of donator solution and agitation time.

References:

[1] Kaviarasan, S., Muniandy, S., Qvist, R. & Ismail, I. S. Journal of Clinical Biochemistry and Nutrition 2009, 45 1–8. 10.3164/jcbn.08-266.
[2] Fanti F, Vincenti F, Montesano C, Serafini M, Compagnone D, Sergi M. Journal of Pharmaceutical and Biomedical Analysis 2020, 186:113302; 10.1016/j.jpba.2020.113302.

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ANA-OR-094

Dried blood spot long-chain polyunsaturated fatty acids and Heart Failure disease

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Heart failure (HF) is a complex clinical syndrome that results from any structural or functional impairment of ventricular filling or ejection of blood. Patients are generally stratified with respect to ventricular ejection fraction (LVEF), which could be reduced (<40%, HFrEF) or preserved (>50%, HFpEF). Cardiopulmonary exercise testing (CPET) coupled to exercise stress echocardiography (ESE) is a valuable tool to evaluate metabolic derangements during effort. Additionally, a chemical characterization of metabolites from human biofluids may allow to gain deep insights into disease severity and pathophysiology.

Dysfunction of cardiac mitochondria is a hallmark of HF and a leading cause of oxidative stress, which in turn causes myocardial tissue damage and inflammation thus contributing to HF progression. Oxylipins are important bioactive signalling molecules, which derive from both the enzymatic and non-enzymatic oxidation of polyunsaturated fatty acids (PUFAs), and considerably increase upon inflammatory insult. The analysis of these metabolites in minimally invasive biological specimens, e.g. oral fluid and dried blood spots (DBSs), can be extremely useful in elucidating their biological activity as well as their potential role as biomarkers in the clinical setting.

Here, a very powerful analytical platform, based on micro-extraction by packed sorbent (MEPS) coupled to liquid chromatography-tandem mass spectrometry (UHPLC-ESI-MS/MS), was fully developed and validated for the targeted profiling of fifty-two oxylipins (i.e., isoprostanoids, prostaglandins, epoxy- and hydroxy-fatty acids, specialized pro-resolving mediators) and four PUFAs in DBSs. The protocol was successfully employed in a pilot study on a cohort of HF and control subjects (n=100) during the CPET-ESE.

Using this approach, we identified key changes in PUFA levels characterizing HF population both at rest and during exercise. HF patients showed generally lower levels of antioxidant omega-3 fatty acids than controls, in line with the “malnutrition-inflammation complex syndrome”. Arachidonic acid (AA) significantly ($p < 0.05$) differed between HFpEF and HFrEF at rest, highlighting a different bioavailability of this circulating omega-6 PUFA. AA levels significantly ($p<0.01$) decreased during the CPET-ESE protocol only in HFpEF population, thus suggesting distinctive changes in myocardial uptake and utilization of energy substrates.

These results pave the way for an in-depth molecular understanding of the biological functions of energy substrates and their signalling role, which will be fundamental in the development of novel therapeutic approaches to HF syndrome.

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Quantifying N-Acylethanolamines: Unveiling Their Role in Pain and Metabolism with Isotope-Labelled Probes

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N-acylethanolamines (NAEs) play a crucial role as lipid mediators affecting pain modulation, inflammation, and metabolism[1]. Precise quantification of NAE levels in mammals, especially utilizing advanced techniques like HPLC-MS/MS[2,3], offers significant insights into their physiological functions. Mouse models are extensively utilized in studies to elucidate the intricate balance and regulation of essential pathways, including the involvement of the endocannabinoid system in pain processing. This quantification primarily serves as a tool to investigate the influence of diets, drugs, and genetic factors on lipid metabolism. Understanding the dynamics of NAEs is instrumental in the development of targeted therapies for conditions such as chronic pain. Using an isotope-labeled PEA (N-palmitoylethanolamine) and/or its derivatives is a valuable method to study the balance of NAEs (N-acylethanolamines) in the body. Additionally, the isotope-labeled drug helps detect changes in endogenous NAE levels, offering crucial information on the regulation of NAEs in response to treatments or specific conditions.

Here, we present a study that assesses the impact of administering PeaOxa (a prodrug of PEA) and PEA itself on NAE metabolism. The study involved administering both molecules, along with their labelled isotopes (Figure 1), to mice. This allowed for the separate investigation of endogenous changes and the exogenous contributions to NAE metabolism. The analytical method, developed using HPLC-MS/MS, unveiled intriguing fluctuations in the metabolic equilibrium of NAEs subsequent to prodrug administration.

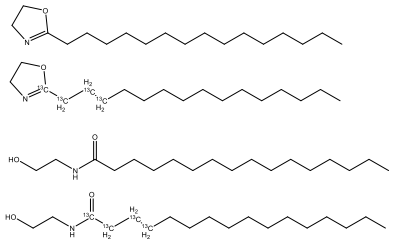

Figure 1: PeaOxa (A), Pea (B) and relate isotope label (C and D) structures.

References:

[1] Mock ED, Gagestein B, van der Stelt M., Prog Lipid Res. 2023; 89, 101194.
[2] Fanti F, Vincenti F, Imparato G, Montesano C, Scipioni L, Ciaramellano F, Tortolani D, Oddi S, Maccarrone M, Compagnone D, Sergi M., Talanta. 2023, 15, 257, 124392.
[3] Gurke R, Thomas D, Schreiber Y, Schäfer SMG, Fleck SC, Geisslinger G, Ferreirós N., Talanta. 2019 1,204, 386-94.

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Green method for triacylglycerol analysis by subcritical fluid chromatography

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Supercritical fluid chromatography (SFC) has witnessed a resurge of interest in the last decade, motivated by substantial progress in hardware capabilities and the availability of specifically tailored separation materials. To extend the range of SFC-amenable analytes, an organic co-solvent is often added to carbon dioxide under subcritical conditions (subFC). The mobile phase modifier will also affect the selectivity, as demonstrated by several applications, and TAG separation is achieved based on the partition number and the unsaturation degree.

In the present work, a subFC method was developed for the separation of triacylglycerols (TAGs) in complex lipid matrices, by using photodiode array detection. The TAGs were separated on four columns serially coupled, attaining improved chromatographic performance, in terms of peak capacity and resolution. The method presented in this work is cheaper, faster, and more environmentally friendly than conventional methods used for TAGs analysis, consisting of non-aqueous reversed-phase liquid chromatography (NARP-HPLC), in terms of use of bio-based co-solvent (ethanol from corn), reduced analysis time (30 vs. 110 min), reduced organic solvent consumption and waste (1.5 mL per analysis).

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Deep Eutectic Solvents: innovative green strategies to analyze tomato pesticides

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Deep Eutectic Solvents (DESs) are new green generation solvents, easily obtained starting from two or more components that through hydrogen bonds generate an eutectic mixture, liquid at room temperature[1].
Their low vapour pressure makes them difficult to apply for the determination of trace analytes such as contaminants. In recent years, green strategies involving the use of DESs as extraction solvent or extraction aid for pesticide determination have been presented.
Two innovative DES-based analytical methods for tomato pesticides determination through high performance liquid chromatography coupled with mass spectrometry analysis were developed, optimized and validated.
In the first work a DES was used as extraction solvent in a matrix solid phase dispersion extraction (MSPD) for five triazoles determination in tomato samples. MSPD extraction is based on homogenization phase between a solid sample and a solid dispersant that has the function to break sample improving extraction yield. The developed procedure involved fungicides extraction using a DES composed by ChCl and ethylene glycol (molar ratio 1:2), followed by analytes back-extraction using ethyl acetate. The analytical method optimization was performed through One-Factor-At-Time (OFAT) experiments. The optimized extraction procedure involved the use of Aluminum oxide as dispersant, in a matrix-to-dispersant ratio of 1:5 (w/w), 4.5 mL of DES as extraction solvent and 2 mL of ethyl acetate to perform the back-extraction.
In the second work, a DES composed of ChCl and sesamol, molar ratio 1:3, was tested as possible adjuvant during the homogenization phase of a MSPD extraction for the determination of fourteen tomato pesticides. Aluminum oxide and ethanol were selected through OFAT experiments as dispersant and extraction solvent respectively. The optimized extraction conditions, obtained through a Box Behnken statistical design were: 1:4 matrix-to-dispersant ratio (w/w), 900 µL of EtOH as extraction solvent and 50 µL of ChCl-sesamol.
Both analytical methods were validated and optimal results in terms of accuracy, precision and limit of determination were obtained, comparable with those of previously traditional published work.

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References:

[1] J. Werner, A. Zgoła-Grześkowiak, J. Płatkiewicz, J. Płotka-Wasylka, N. Jatkowska, A. Kalyniukova, S. Zaruba, V. Andruch, Microchemical Journal, 2023, 191, 108898.

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Development and application of two LC-MS methods for the determination of several pharmaceutical substances in wastewater and assessment of their sustainability

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Introduction: In the last few years, the interest in pharmaceutical drugs and their metabolites as environmental pollutants is gaining growing importance and regular monitoring and timely actions are decisive to implement appropriate water resource management strategies. This study aims to present two methods developed for the simultaneous determination of a group of about hundreds of pharmaceuticals from different classes in wastewater. These two procedures are compared, highlighting their advantages and disadvantages and their performance. The two methods will be presented as a procedural evolution and evaluated according to the principles of green chemistry[2] through the use of specific indicators (AGREE, BAGI, etc). The methods were applied to real samples to demonstrate the effective detection of the compounds.

Methods: Wastewater samples (50 mL) were centrifuged at 4000 rpm for 5 min and vacuum-filtered through 0.22 µm filter device. Then, an aliquot of filtered wastewater was added with the mixture of internal standards and, depending on the method, either extracted by SPE[3] or added with a mixture of ammonium formate (2 mmol/L) and formic acid (0.02%). Finally, the samples were vortexed, centrifuged and 7 µL of the supernatant was injected into either UHPLC-HRMS or UHPLC-MS/MS systems. The real samples were collected as 24 h composite samples of the inlet and outlet wastewater from 3 wastewater treatment plants (WWTPs) located in the NW Italy.

Results: Both developed methods proved adequate for the individual detection of the target analytes at concentrations equal or lower than 10 ng/L. Although no universal method is available to detect all drugs reaching the aquatic ecosystem from WWTPs, several multi-analyte detection methods can be found in the literature and the most use solid phase extraction (SPE). However, although well performing, SPE is time-consuming and involves the use of expensive and environmentally-affecting consumables and additional solvents (AGREE score 0.44). In this context, we have developed another analytical procedure using 10 mL sample volume followed by direct-injection (AGREE score 0.61) which was considered more environmentally friendly. Finally, a total of 42 pharmaceutical products out of the one hundred targeted pharmaceutical drugs were detected in almost all sites.

Conclusion: Two sensitive analytical methods for the simultaneous quantitative determination of several pharmaceutical were presented and applied to wastewater samples from 3 WWTPs. The method evolution allowed the creation of a simple, fast and more sustainable procedure. Thanks to these features, the developed procedure can be applied in future in high-performance wastewater monitoring campaigns, thus enabling social and environmental protection actions.

References:

[1] M. de la Guardia, S. Garrigues, The Concept of Green Analytical Chemistry, in: Handb. Green Anal. Chem., John Wiley & Sons, Ltd, 2012: pp. 1–16. https://doi.org/10.1002/9781119940722.ch1.

[2] M. Massano, A. Salomone, E. Gerace, E. Alladio, M. Vincenti, M. Minella, Wastewater surveillance of 105 pharmaceutical drugs and metabolites by means of ultra-high-performance liquid-chromatography-tandem high resolution mass spectrometry, J. Chromatogr. A 1693 (2023) 463896. https://doi.org/10.1016/j.chroma.2023.463896.

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A multi-block approach for discriminating spray paints for forensic purposes

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In the field of forensics, paint analysis is highly significant and encompasses a wide range of areas, from automotive to artistic. The use of non-invasive and/or non-destructive techniques, such as spectroscopy, in the forensic field has always been of paramount importance. Technological advancements in recent years have enabled the development of increasingly smaller, more precise, and faster instruments.

The aim of the present study is to assess the possibility of discriminating spray paints with the same colour code (RAL) but produced by different brands, utilizing various spectroscopic techniques including micro-FTIR spectroscopy, micro-Raman spectroscopy and Vis spectrophotometry.

Each technique has been employed for a specific purpose: the first one focuses on identifying the type of binding medium composing the paint; the second is utilized to study the main organic and inorganic pigments responsible for the characteristic colour tones, while the third enables obtaining a measure of colour in diffuse reflectance.

To exploit the complementary information present in the three spectroscopies, the collected data (33 samples from 3 different brands) were analyzed using multivariate strategies based on PCA (Principal Component Analysis), classification model like PLS-DA (Partial Least Square – Discriminant Analysis) and through a multi-block regression algorithm known as ROSA[1] (Response Oriented Sequential Alternation).

The use of ROSA, and thus the multiblock approach, has proven to be extremely effective in discriminating between paint brands with the same colour, significantly enhancing discrimination capability compared to using algorithms on individual data blocks or in low-level data fusion.

References:

[1] KH Liland, T Næs, UG Indahl, Journal of Chemometrics, 2016, Vol. 30, 651 - 662.

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ANA-PO-001

3D-Printed Biosensor for Nerve Agent Detection in Drinking Water Using Carbon Black/Thermoplastic Polyurethane: A Cost-Effective and Portable Solution

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Nerve agents, highly toxic substances with severe consequences for human health, are commonly associated with chemical warfare or terrorist activities, posing significant risks to public safety and environmental integrity. Detecting these hazardous compounds, especially in water sources, is paramount to safeguarding human health and mitigating environmental contamination[1]. Utilizing 3D printing technology, which offers cost-effective and portable solutions, presents a promising approach to developing biosensors capable of detecting nerve agents across various applications[2]. This study focuses on the creation of an amperometric biosensor for identifying paraoxon, a nerve agent simulant in water, by inhibiting the butyrylcholinesterase enzyme (BChE).

In constructing electrodes suitable for electroanalytical tasks, thermoplastic polyurethane (TPU) electrodes were 3D printed, with carbon black incorporated as a filler to enhance electrode conductivity. Additionally, the combination of carbon black with Prussian blue nanoparticles (CB-PBNPs) was employed to exploit their electrocatalytic properties, particularly in the oxidation of thiol-containing compounds at low applied potentials[3]. The electrodes' surface characteristics were assessed through electrochemical impedance spectroscopy and cyclic voltammetry, revealing reduced charge transfer resistance, and heightened peak current intensity, attributed to the presence of CB-PBNPs.

The developed biosensor demonstrated a linear response to paraoxon concentrations up to 20 ppb, with a limit of detection (LOD) of 2 ppb. The LOD was determined as the quantity of paraoxon inducing 10% inhibition of the enzyme in drinking water. Such a biosensor holds promise for detecting and addressing the harmful effects of nerve agents in both crisis scenarios and as a preventive measure.

References:

[1] A.W. Abu-Qare, M.B. Abou-Donia, Food and Chemical Toxicology, 2002, 40, 1327–1333.
[2] B. Gross, S.Y. Lockwood, D.M. Spence, Analytical chemistry, 2017, 89, 57-70.
[3] S. Cinti, C. Minotti, D. Moscone, G. Palleschi, F. Arduini, Biosensors and Bioelectronics, 2017, 93, 46-51.

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ANA-PO-002

Novel electro-analytical approach for the detection and discrimination of cannabinoids in cannabis extracts

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We have developed screen printed electrodes modified with carbon black (SPE-CBs) for qualitative and quantitative analysis of the main cannabinoids produced by Cannabis sativa L. The electrochemical procedure proposed, together with the good detection performances of SPE-CBs, allow discrimination between different cannabis samples based on their cannabinoid content. Cannabinoids are electroactive, due to the irreversible oxidation of the phenolic group so electrochemical sensors can be used for their fast in situ detection, representing an alternative to other more expensive techniques[1]. Among phytocannabinoids the best known are Δ^9-tetrahydrocannabinol (THC) and cannabidiol (CBD), even if the acidic precursors THCA and CBDA are mainly present in *Cannabis sativa* L. plants. Marijuana, referred to as recreational cannabis, is illegal due to its high THC, which is psychoactive, and THCA content. On the other hand, cannabis plants that contain less than a defined concentration of the psychotropic compound have recently become legal in many countries. These plants, referred as fiber cannabis, and their associated products mostly contain CBD and CBDA, which are not psychoactive. According to the European regulation, vegetal material can be commercialized only when containing a very limited amount of THC, namely <0.3 % w/w[2]. Therefore, accurate controls of the THC and THCA levels to meet specific regulations are fundamental. In this work, we analysed extracts of different types of cannabis characterized by different cannabinoids contents. We verified the possibility to quantify the THCA content in the different extracts using a calibration curve[3]. On the other hand, we investigated the sensor ability to recognize illegal and legal samples by a multivariate approach. Moreover, a prototype of a portable device, capable of performing a rapid in-situ analysis of cannabis samples, has been developed. This device uses micro-pumps and flow sensors to prepare all the solutions, starting from the extraction step, and finishing with the electrochemical analysis performed with a SPE-CB inside a flow cell.

References:

[1] B. Zanfrognini, L. Pigani, C. Zanardi. Journal of Solid State Electrochem, 2020, 24, 2603–2616.
[2] Cannabis legislation in Europe: an overview. EMCDDA, Lisbon, March (2017). http://www.emcdda.europa.eu/publications/adhoc/cannabis-legislation-europe_en
[3] A. Monari, S. Cantalù, B. Zanfrognini, V. Brighenti, P. Verri, C. Zanardi, F. Pellati, L. Pigani. Analyst, 2023,148, 4688-4697

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ANA-PO-003

Photolytic and photocatalytic degradation of diclofenac: identification of the transformation products by non-target LC/MS-MS approach

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The intensive use of non-steroid anti-inflammatory drugs worldwide leads to environmental problems especially related to the contamination of surface waters by emerging micropollutants (MPs). Therefore, studies focused on mitigating and controlling the occurrence of these MPs in water bodies, among which diclofenac[1], are becoming essential to address derived toxicity issues. Studies carried out in our laboratories have shown that diclofenac in aqueous solution does not degrade when irradiated with visible light alone, whereas it degrades completely in 120 min when subjected to UV-vis irradiation (diclofenac removal of 99%). However, in this case, the UV-vis spectrum of the pale-yellow resulting solution shows the presence of photolysis products that have absorptions in the same wavelength range as diclofenac, probably carbazoles, whose toxicity is greater than their precursor[2]. Therefore, it is planned to try to degrade diclofenac by photocatalysis to test whether the transformation products could be less toxic than the precursor molecule.
This study aims the identification of photolysis and photocatalytic degradation products of diclofenac mediated by kesterite nanoparticles (CZTS). Kesterite is a semiconducting inorganic compound (Cu_2ZnSnS_4) with a band gap of 1.4-1.6 eV and a high absorption coefficient of light radiation. These characteristics make it a potential photocatalyst in the presence of sunlight. Furthermore, this material is insoluble in water and capable of homogeneously dispersing in it, it is non-toxic, and consists of elements that are available in large quantities and at low cost.
An ultra-high-performance liquid chromatography coupled with a high-resolution quadrupole time-of-flight mass spectrometry (UHPLC-QTOF MS/MS) method was developed and fully validated. Following a non-targeted approach, several transformation products, among which 16 already reported in the literature were identified and their formation mechanisms proposed based on the high-resolution MS/MS data. Some common degradation reactions give to carbazole formation via cyclization, radical hydroxylation and oxidation followed by C-N bond scission. In addition, a toxicity and environmental persistence assessment of all the elucidated degradation products was carried out by *in-silico* methods. The results stated that the use of CZTS nanoparticles leads to the elimination of diclofenac (removal of 99% with UV-vis irradiation and 91% with only vis irradiation), and the formation of TP with less toxicity.

References:

[1] Directive 2013/39/UE of the European Parliament and the Council, 12 August 2013.
[2] M. E. Becerril, J. J. Ramírez-García, N. Cavazos, A. R. Serrano, Water Air Soil Pollut 2019, 230, 219-229

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ANA-PO-004

Integration of Electrochemical and Photoelectrochemical Modes for Enhanced Nitrate Ion Sensing: A Bimodal Sensor Approach

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Bimodal sensors can provide built-in self-calibration by eliminating interferences and normalizing environmental errors with dual-signal readout mode. This approach piqued the interest of researchers in analytical sensing with the potential to achieve more accurate analyses[1]. In recent years, researchers have succeeded in developing a variety of sensors that incorporate various transduction modes, such as electrochemical-photoelectrochemical (EC-PEC), electrochemical-electrochemiluminescence, electrochemical-colorimetry, electrochemical-fluorescence[2]. Clearly, combining the EC and PEC modes to build a dual mode detecting platform is a promising strategy for accurate, rapid, and sensitive detection, especially when using the same instrumentation. Thus, developing nanomaterials with high electrical conductivity and photoactivity plays a vital role.

Herein, we propose copper doped graphitic carbon nitride (Cu/g-C_3N_4), where nominal copper is dispersed on the nanosheets. In fact, pristine g-C_3N_4 demonstrates poor conductivity and a high electron hole recombination rate, restricting the electron transportation and electro-catalytic activity along with low quantum efficiency which reduces the photocatalytic efficiency[3]. Therefore, nanostructuring and doping g-C_3N_4 with copper assisted in overcoming these flaws and improving its catalytic performance due to the synergetic effect of both Cu and g-C_3N_4. Cu/g-C_3N_4 nanomaterial proved to be an effective photo-electrocatalyst. The sensor was developed by depositing the nano-catalyst on a fluorine-doped tin oxide coated glass and served as an active electrode for the electro/photoelectroreduction of nitrate ions at neutral pH.

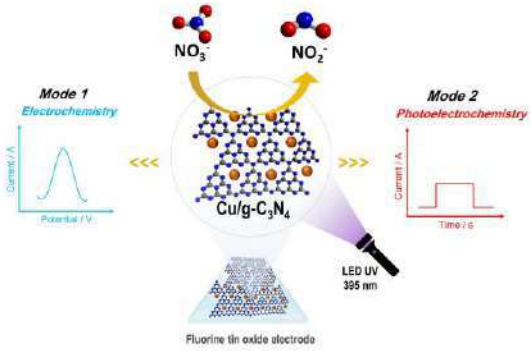

Figure 1: Schematic illustration of bimodal EC-PEC sensor based on Copper modified g-C_3N_4 for Nitrate Detection.

References:

[1] Y. Huang, J. Ge, H. Chen, Z. Wang, J. Han, G. Xie, S. Chen, *Sensors Actuators B Chem.* **2021**, *327*, 128871.
[2] J. Xu, B. Zhang, Y. Zhang, L. Mai, W. Hu, C.-J. Chen, J.-T. Liu, G. Zhu, *Talanta* **2023**, *253*, 124037.
[3] H. Wang, Y. Wang, Y. Zhang, Q. Wang, X. Ren, D. Wu, Q. Wei, *Sci. Reports 2016 61* **2016**, *6*, 1–7.

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ANA-PO-005

Sustainable Cannabinoids Purification Through Twin-Column Recycling Chromatography and Green Solvents

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Cannabidiol (CBD), a non-psychoactive cannabinoid, has become a focus of research due to its beneficial effect in many areas, i. e. medicine, cosmetic and food industry. The depletion of tetrahydrocannabinol (THC) or purification of other cannabinoids from CBD rich samples is a challenging task due to their similar chemical structure and physical properties. The separation of two substances characterized by close retention times, like several cannabinoids, is one of the largest challenges in HPLC. There are many strategies to overcome the coelution issue, for example changing the flowrate, the solvent gradient and/or the column bed length. When decreasing the flowrate and changing the gradient do not result in separation of the target peaks, a longer column bed length might be the solution. Recycling chromatography could be an interesting alternative strategy to increase the column bed length. This process enables an equivalent separation capacity of a long column using one or two identical short columns and a valve. In the one column system (close loop recycling), the eluted target peaks are re-injected in the same column through the pump. In a twin-column system (alternate pumping recycling), a 2-position valve is placed between the two columns and, by the switch, the eluted target peak from one column is re-injected into the second column without passing through the pump. In both cases a recycling circuit is formed, which can be repeated several times until desired separation is achieved[1,2].

In this work, twin-column recycling chromatography has been employed for the purification of a real Cannabis extract by using a green solvent, ethanol, as the mobile phase. The performance of the method, in terms of purity, recovery, productivity and solvent consumption, was compared to that of traditional batch operations showing the potential of the twin-column recycling approach. The employment of a theoretical model to predict the band profiles of the two compounds during the recycling process has facilitated method development, thus further contributing to process sustainability by avoiding trials and errors or suppressing their numbers significantly.

References:

[1] A. Seidel-Morgenstern, G. Guiochon, AIChE Journal, 1993, 39, 809 - 819.
[2] G. Compagnin, Y. Krauke, S. Felletti, G. Greco, KNAUER App. Note VTN0028.

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ANA-PO-006

Self-Powered Flexible and Sustainable Electrochemical Sensor for Oxygen Detection

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Food packaging is a well-known practice to primarily safeguard and encase food items. However, with the advancement and increasing complexity of society, there has been a rising demand from various finally users, including food producers, retailers, and consumers, for ensuring food safety and quality within the packaging. This growing emphasis on food safety and quality has led to the emergence of intelligent food packaging as an innovative packaging solution [1].

Intelligent food packaging refers to a packaging system equipped with smart sensors to monitor the condition of packaged food by the detection of several physical and chemical parameters, such as temperature, humidity, and gas concentration.

In this regard, oxygen has the potential to cause food spoilage via the i) oxidation of food components, ii) enzymatic reactions that accelerate ripening and browning, and iii) proliferation of aerobic microorganisms. In this context, it is crucial to monitor oxygen levels within the food packaging to ensure food quality and safety.

In this overall scenario, we are under development of a flexible miniaturized self-powered electrochemical sensor for oxygen monitoring in intelligent food packaging. In detail, the device encompasses i) a cathode layer based on silver ink screen-printed on oriented polypropylene substrate, acting as oxygen diffusion layer, ii) a sustainable deep eutectic solvent gel electrolyte[2] characterized by high ionic conductivity, low-cost, and biodegradability, and iii) an anode based on pure metal. The three layers were pressed giving rise to a solid-state self-powered electrochemical sensor. The whole detection system is based on the oxidation of anodic metal ions by oxygen, allowing it to diffuse through a gas diffusion layer from the air at the cathode. The final quantification of oxygen is carried out by means of open circuit voltage (OCV).

For the development of the self-powered sensor, optimization studies were first conducted on the cathode silver layer deposition, the anodic material layer, and finally on the DES composition. The electrochemical sensor will be applied for oxygen monitoring in simulated packaging for real-time oxygen measurement.

References:

[1] S. Won, K. Won, 2021, 29, 1-6.

[2] R. Puttaswamy, C. Mondal, D. Mondal, D. Ghosh, 2022, 33, 1-26.

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ANA-PO-007

GC-MS as a tool for the analysis of cannabinoid-containing gummy sweets: identification of HHC and the synthetic process used for its preparation.

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In recent years, the market for foodstuffs and dietary supplements containing cannabinoids has grown steadily.[1] Among the cannabinoids available on the market, the most commons are non-psychotropic cannabidiol (CBD, **1**) and psychotropic Δ^9-tetrahydrocannabinol (Δ^9-THC, **2**), whose effects have been thoroughly investigated over the years and whose sale is legal in some countries, depending on current legislation.[2,3] Recently, hexahydrocannabinol (HHC, **3**), a tricyclic compound that is formerly the hydrogenated counterpart of Δ^9-THC, has emerged, having been neglected by some regulatory authorities. HHC is semi-synthetic Δ^9-THC derivative, prepared via acid catalyzed cyclization of CBD followed by catalytic hydrogenation. There are only few reports on the effects of HHC in humans, although it is supposed to have much the same biological activity of Δ^9-THC. Nevertheless, it has been classified in the Table I of the substances of abuse in Italy in 2023.[4] In order to limit the spread of HHC and its analogues, there is a growing interest in improving the routinely available GC-MS and LC-MS methods for the identification and quantification of newly synthesized cannabinoids.[5] In this work we have developed a liquid extraction method for the analysis of seized HHC-containing gummy sweets. The main cannabinoids present in the samples analyzed were identified and quantified via GC-MS analysis, indicating that along with HHC, significant amounts of unreacted starting materials (i.e., CBD and THCs) were present. The data obtained allowed us to identify the synthetic procedure used to prepare the active principle present in the sample.

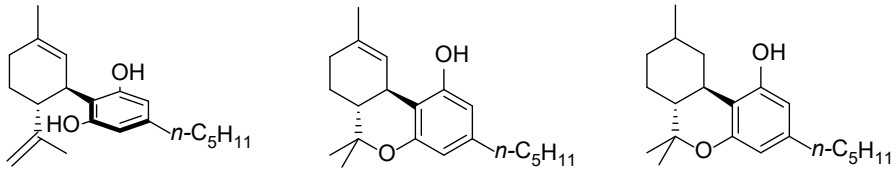

Figure 1: structure of cannabidiol (CBD, **1**), Δ^9-tetrahydrocannabinol (Δ^9-THC, **2**) and hexahydrocannabinol (HHC, **3**).

References:

[1] H. Peng, F. Shahidi, *J. Agric. Food Chem.* **2021**, *69*, 1751–1774.
[2] T. Wang, J. Collet, S. Shapiro, M. A. Ware, *CMAJ* **2008**, *178*, 1669-1678
[3] F. Baratta, I. Pignata, L. Ravetto Enri, P. Brusa, *Front. Pharmacol* **2022**, *13*, 1-17.
[4] https://www.gazzettaufficiale.it/eli/id/2023/07/25/23A04164/sg, last visited: 14/03/2024.
[5] S. Gjoshe, I. Cvetkovikj Karanfilova, V. Stoilkovska Gjorgievska, A. Trajkovska, N. Geskovski, M. Karapandzova, S. Kulevanova, *Mol.* **2022**, *27*, article number 975.

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ANA-PO-008

Quantification of microplastics and polymer additives in airborne particulate and settled dust collected in indoor environments

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The widespread use of synthetic polymers has led to a significant environmental crisis caused by plastic pollution, with microplastics being found in various environments and posing risks to both human health and the ecosystems. Moreover, microplastics in the environment undergo continuous mechanical fragmentation due to chemical weathering, photo-oxidation, biological decomposition, and mechanical forces, leading to the formation of smaller plastic debris, more prone to be transported and dispersed by atmospheric agents. The potential for plastic fragments to disperse in the air as particulate and to be accidentally inhaled by humans potentially causes harm to the respiratory and other systems[1]. Therefore, there is a particular necessity to study microplastics as air pollutants. In this study, we tested a combination of analytical pyrolysis, gas chromatography, and mass spectrometry, as well as gas and liquid chromatography-mass spectrometry, to identify and quantify both microplastics and their additives in airborne particulate matter and settled dust from two indoor work environments. By using this combined approach, we were able to accurately quantify ten distinct synthetic polymers (polyethylene, polypropylene, polystyrene, acrylonitrile butadiene styrene copolymer, polymethyl methacrylate, polycarbonate, polyethylene terephthalate, Nylon-6, Nylon-6,6, and polyvinyl chloride) as well as eight classes of polymer additives. The determined additives include phthalate esters, adipates, citrates, sebacates, trimellitates, benzoates, organophosphates, and newly developed brominated flame retardants.

This study received funding from the European Union - Next-Generation EU - National Recovery and Resilience Plan (NRRP) – MISSION 4 COMPONENT 2, INVESTMENT N. 1.1, CALL PRIN 2022 D.D. 104 02-02-2022 – DIORAMA (A deep dive into the study of microplastics in aqueous matrices).

References:

[1] U. Vattanasit, J. Kongpran, A. Ikeda, Science of The Toal Environment 2023, 904, 166745

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ANA-PO-009

CRISPR-Cas12a Amplification of Transcription Factor DNA-Binding Activity by Using Dynamic DNA Translators

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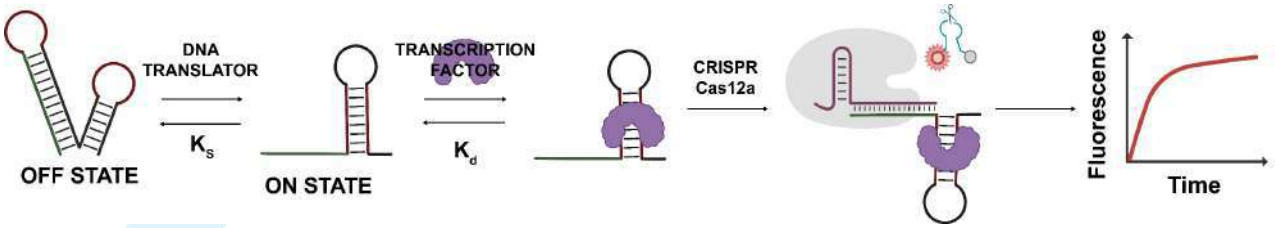
The field of nucleic acid diagnostics has undergone a transformation with the application of CRISPR-Cas12a-based biosensing technologies, which enhance signals by causing collateral target-induced cleavage of tagged DNA reporters. However, interfacing the CRISPR-Cas machinery with non-nucleic acid targets has been limited due to the intrinsic difficulty of converting non-nucleic acid targets, such as proteins and small molecules, into nucleic acid inputs for CRISPR-Cas activation. Our main goal was to tackle this challenge and look at new ways to integrate CRISPR-Cas12a signal amplification into protein sensing. We specifically focused on transcription factors (TFs), a class of DNA-binding protein that play a central role in biological processes and are significant targets in diagnostic, therapeutic and bioengineering strategies. We leveraged the inherent DNA-binding activity of target TFs to integrate an activity-based approach with DNA nanotechnology, demonstrating that CRISPR-Cas12a nuclease activity can be triggered by a range of different transcription factors in a programmable manner. We have engineered libraries of conformation-switching DNA structures that act as dynamic translators. These rationally designed translators undergo a controllable conformational change when they bind to their cognate transcription factor [1,2], exposing a CRISPR-Cas12a target sequence only upon TF binding. This allowed for converting the DNA-binding activity of transcription factors such as TATA-binding protein (TBP), Myc-Max, EGR1 and EGR4 into a trigger input for the activation of CRISPR-Cas12a, generating an amplified optical signal proportional to the protein concentration. This study paves the way for new modalities of protein-controlled CRISPR-Cas molecular computation and exemplifies how CRISPR-Cas12a signal amplification may be successfully incorporated into protein sensing.



References:

[1] Bertucci, A.; Porchetta, A.; Del Grosso, E.; Patiño, T.; Idili, A.; Ricci, F. Angew. Chem. Int. Ed 2020, 59, 20577–20581.
[2] Fortunati, S.; Pedrini, F.; Del Grosso, E.; Baranda Pellejero, L.; Bertucci, A. Anal. Sens. 2022, 2, e202200037.

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ANA-PO-010

Implementation of rapid diagnostics: nanoMIPs transform the LFA paradigm

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In the realm of immunodiagnostics, antibodies have long been regarded as the gold standard for molecular recognition, playing a pivotal role in various applications[1]. However, the challenges associated with antibody production, high cost, batch-to-batch variability, and ethical concerns, have spurred exploration into alternative molecular recognition systems. Among these alternatives, molecularly imprinted nano polymers (nMIPs) have emerged as promising biomimetic materials. They are synthetic, highly cross-linked materials designed with cavities that exhibit selective molecular recognition[2]. Although the current state-of-the-art applications predominantly employ nMIPs for tasks such as molecular separation, sensing, and controlled release, their adoption as primary recognition elements in diagnostics remains limited. While LFA has become a widespread and user-friendly tool for rapid diagnostics, traditional antibodies continue to dominate as the recognition element. The potential of nMIPs in LFA, with their advantages of stability, reproducibility, and cost-effectiveness, is an area ripe for exploration[3]. This study presents a novel approach to lateral flow immunoassay (LFIA) diagnostics, aiming to reshape point-of-care testing (POCT) by minimizing reliance on biomolecules. The innovation centres around integrating nMIPs with core-shell gold silica nanoparticles (Au@SiO_2), a strategically chosen marker widely utilized in colorimetric LFIA[4]. nMIPs were synthesized to selectively target IgG bovine, establishing a molecularly imprinted framework. Functionality and binding properties of the composite nanomaterial were investigated through batch rebinding to estimate affinity and binding capacity. Characterization studies, including transmission electron microscopy (TEM) and dynamic light scattering (DLS), validated the structural integrity of the material. To enhance their functionality, the nMIPs were conjugated with Au@SiO_2, ensuring a synergistic integration of their selective recognition properties with the optical advantages of gold nanoparticles. Experiments were meticulously designed to evaluate the applicability of the new hybrid material in the LFA. Key objectives included establishing the visual limit of detection, unravelling the dynamic interaction between nMIP and IgG, and conducting selectivity studies were crucial to defining the potential of this innovative detection system. This proof-of-concept challenges conventional LFIA paradigms, showcasing the power of nMIP for the advancement of synthetic receptors in rapid bioanalytical tests. This approach paves the way for a future where LFA becomes more accessible, robust, biomolecule-free, and user-friendly, signalling a significant advancement in rapid screening tests.

References:

[1] Y. Gao, X. Huang, Y. Zhu, Z. Lv, J. Immunoass. Immunochem 2018, 39, 351–364, 2018.
[2] O.I. Parisi, F. Francomano, M. Dattilo, F. Patitucci, J Funct Biomater 2022, 13,1-12.
[3] J.W. Lowdon, H. Dili¨en, P. Singla, M. Peeters, T.J. Cleij, B. Van Grinsven, Sensor. Actuator. B Chem 2020, 325.
[4] F. Di Nardo, M. Chiarello, S. Cavalera, C. Baggiani, L. Anfossi, Sensors 2021, 21.

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ANA-PO-011

Innovative On-line Pressurized Hot Water Extraction with Solvent Recirculation Coupled with Liquid Chromatographic-Tandem Mass Spectrometric Analysis of Pharmaceuticals in Soil

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In this study, a new self-assembled apparatus for the extraction of solid samples was built, using suitably modified standard chromatographic equipment, in order to develop a recirculated pressurized hot water extraction directly coupled to liquid chromatography-tandem mass spectrometry. In order to investigate the potential of this new extraction apparatus, the proposed system was applied to the analysis of 34 target pharmaceuticals compounds characterized by heterogeneous physicochemical properties (e.g., -0.05 ≤ log D ≤ 4.31) in three soils with different textural characteristics (i.e., loam, silt-loam and silty-clay-loam). A multivariate strategy based on the design of experiments[1] (DoE) was used to identify the best extraction conditions for the target analytes by studying temperature, pressure and number of extraction cycles. The optimization procedure successfully demonstrated that the number of cycles, in combination with the high temperature, had a favourable impact on the recovery of target analytes. The application of DoE set point to the three reference soils provided average semi-quantitative recoveries (≥ 60% for most target analytes in all soils) and good precision (< 25% in almost all cases), regardless of the textural differences among samples.

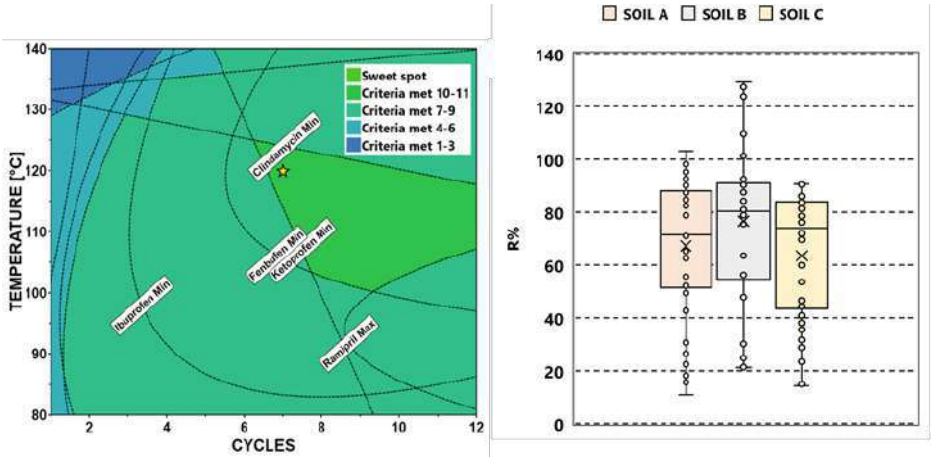

Figure 1: Sweet spot plot for the 12 significant CMAs; the star point refers to the best compromise in terms of R% values and extraction time (120 °C, 110 bar, 7 cycles), (B) box plot of recoveries for the three soils under the optimized conditions.

References:

[1] L. Marzullo, O. Ochkur, S. Orlandini, L. Renai, R. Gotti, O. Koshovyi, S. Furlanetto, M. Del Bubba, Journal of Chromatography A 2022, 1677, 463329.

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ANA-PO-012

Photochemical-driven dissipative metal-coordinated gels for transient controlled release and autonomous mechanical actuation

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Transition-metals, such as Fe^{3+}, can strongly coordinate carboxymethyl cellulose (CMC),[1] leading to the formation of stimuli-responsive Fe^{3+}-CMC hydrogels for a variety of applications.[2] However, the lack of mechanical robustness is a major issue for the implementation of these polymer networks in advanced applications, such as soft robotic. Here we report an innovative strategy to fabricate redox responsive Fe^{3+}-CMC gels, which can retain the high loading capacity of the porous network, while accessing enhanced mechanical properties, for photochemical-driven, transient controlled release and mechanical actuation under aerobic conditions (Figure 1). Cryogels of Fe^{3+}-CMC are obtained by multiple cycles of freezing and defreezing, which induce the formation of a Fe^{3+}-crosslinked cryogel matrix, displaying enhanced stiffness properties.[3] The cryogel matrix is redox responsive and the photosensitized reduction of Fe^{3+}-CMC, mediated by Ru(II)-*tris*-(bipyridine) complex, leads to the lower stiffness $Fe^{3+/2+}$-CMC gel. In the presence of oxygen, the aerobic re-oxidation of Fe^{2+} in the matrix restores the initial high-stiffness Fe^{3+}-CMC gel, leading to the development of a dissipative functional matrix with transient stiffness properties.

The light-induced transient release of a model payload from the cryogel matrix is reported. In addition, the light-triggered, transient mechanical bending of a bilayer construct, made of poly-N-isopropylacrylamide (p-NIPAM)/Fe^{3+}-CMC, is demonstrated (Figure 1), providing the potential use of dissipative metal-coordinated gels for developing the next-generation self-regulative, autonomous materials.

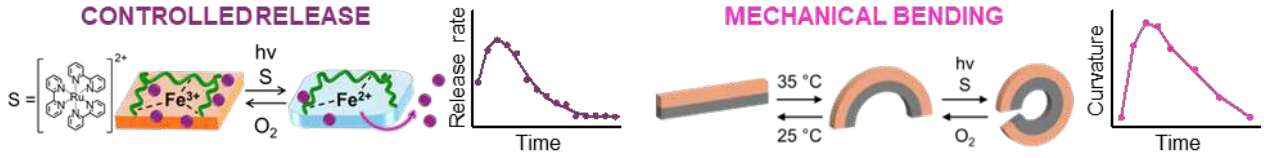

Figure 1: Schematic representations of photochemical-driven, transient controlled release (left) and autonomous mechanical bending (right) of the Fe^{3+}-CMC cryogel matrix.

References:

[1] V. Gabrielli, R. Baretta, R. Pilot, A. Ferrarini, M. Frasconi, Macromolecules 2022, 55, 450–461.
[2] R. Baretta, A. Raucci, S. Cinti, M. Frasconi, Sens. Actuators B Chem. 2023, 376, 132985.
[3] R. Baretta, G. Davidson-Rozenfeld, V. Gutkin, M. Frasconi, I. Willner, J. Am. Chem. Soc. 2024, in press, https://doi.org/10.1021/jacs.4c00625.

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ANA-PO-013

Selective extraction of patulin in apple juice samples using a hydrophilic molecularly imprinted polymer as dispersive solid phase extraction sorbent

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Patulin (PAT) is an α,β-unsaturated γ-lactone mycotoxin generated as a secondary metabolite by at least 60 different species of fungi[1]. *Penicillium expansum* species is the most threatening one for people's health and market security[2]. This species is often associated with a post-harvest disease affecting apples[3], although other fruits can be contaminated, including pears[4], citrus[5], and grapes[6]. A PAT-specific molecularly imprinted polymer was successfully synthesized, utilizing dopamine and melamine as functional monomers, along with formaldehyde as the cross-linker. This resulting material displayed numerous hydrophilic groups, including hydroxyls, imino groups, and ether linkages. For the first time, uric acid was used as a dummy template for its structural similarity to PAT. Comprehensive characterization and analysis of the adsorption process were conducted through adsorption isotherms and kinetics studies. Separation, identification, and quantification of PAT were achieved using ultra-high performance liquid chromatography coupled with both photodiode array detection and tandem mass spectrometry, which was crucial for confirming PAT presence in real samples. The methodology was validated with 20 apple juice samples, demonstrating the polymer's high selectivity and specific adsorption capabilities, with mean recoveries ranging from 85 to 90% and a relative standard deviation below 15%. The developed molecularly imprinted polymer exhibited good linearity within the concentration range of 1–100 ng mL^{-1}, with a coefficient of determination (R^2) > 0.99. Furthermore, the method displayed a low limit of detection (0.5 ng mL^{-1}) and quantification (1 ng g^{-1}). The hydrophilic nature of the developed polymer facilitated efficient purification of apple juices, owing to the polar interactions established with the target analyte.

References:

[1] S. Wang, X. Wang, L. Penttinen, H. Luo, Y. Zhang, B. Liu, B. Yao, N. Hakulinen, W. Zhang, X. Su, Toxins, 2022, 14:440.
[2] J.L. McCallum, R. Tsao, T. Zhou, Journal of Food Protection, 2002, 65, 1937–1942.
[3] L. Palou, Postharvest Decay, 2014, 45-102.
[4] D. Wei, X.U. Jun, F. Dong, X. Liu, X. Wu, Y. Zheng, Journal of integrative agriculture, 2017, 16, 1645–1651.
[5] K. Aslam, S.Z. Iqbal, A.F.A. Razis, S. Usman, N.B. Ali, International Journal of Environmental Research and Public Health, 2021, 18, 2270.
[6] V. Ostry, F. Malir, M. Cumova, V. Kyrova, J. Toman, Y. Grosse, M. Pospichalova, J. Ruprich, Food and Chemical Toxicology, 2018, 805-811.

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ANA-PO-014

Comprehensive structural characterization of seaweeds polar lipidome by coupling single-phase extraction and aza-Paternò-Büchi derivatization

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The valorization of seaweeds has generated unprecedented interest in recent years due to their unique chemical characteristics. The taxonomic differentiation between Chlorophyta, Rhodophyta, and Ochrophyta is often supported by their contrasting chemical characteristics. The lipid contents of seaweeds are generally low and quite variable between and within phylum. Seaweeds are known for their rich content of biologically active polyunsaturated fatty acids (PUFA), such as eicosapentaenoic acid, which are crucial in various physiological processes, including brain development, cardiovascular health, and inflammation regulation. The polar lipidome of seaweeds has gained significant interest in the scientific community since they are the primary deliverers of PUFA. However, despite their importance in determining their biological properties of lipids, little is known on the regiochemistry, i.e., the geometry and position of carbon-carbon double bonds, of free and conjugated fatty acids in seaweeds [1]. In the present work, an analytical platform was developed for the extraction, untargeted HRMS-based analysis, and detailed annotation of the lipid species. First, four one- and two-phase solid-liquid extraction protocols were tested and compared on a seaweed pool sample to select the method that allowed the overall highest efficiency as well as easy coupling with lipid derivatization by photochemical [2 + 2] cycloaddition with 6-azauracil. Underivatized lipids were annotated, employing a data processing workflow on Compound Discoverer software designed explicitly for polar lipidomics. Subsequently, inspection of the MS/MS spectra of the derivatized lipids following the aza-Paternò-Büchi reaction allowed pinpointing the regiochemistry of carbon-carbon double bonds. Once the platform was set up, the lipid extracts from eight seaweed samples from different seaweed species were characterized, with information on the regiochemistry of free and conjugated fatty acids. The overall analytical approach helped to fill a gap in the knowledge of the nutritional composition of seaweeds.

The work was supported by the PRIN2022 PNRR project Prot. P2022PTYWP, entitled “Design of high-pRofit fostEring bioActive coMpounds through integral valorization of seaWEEDs infesting the MEditerranean sea (DreamWEEDme),” provided by the Italian Ministry of Education, Universities, and Research.

References:

[1] A. Cerrato, A. L. Capriotti, C. Cavaliere, C. M. Montone, S. Piovesana, A. Laganà, Anal. Chem. 94 (2022) 13117-13125.

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A Multidimensional Approach on Preparative Scale for Oligonucleotides Purification

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Therapeutic oligonucleotides represent a recent breakthrough in the pharmaceutical industry since they are emerging due to their ability to regulate gene expression with great specificity [1].
They are short nucleic acid chains and, nowadays, the most established technology to produce them is solid phase synthesis. This technic is a cyclic approach where the progressive addition of nucleotides monomers results in a polymeric chain. However, this leads not only to the main target but also in many structurally similar impurities such as a deletion or addition nucleotide resulting in the so called shortmers (n-1) or longmers (n+1) impurities [2,3].
Therapeutic oligonucleotides require extensive chromatographic purification to ensure that a high-quality Active Pharmaceutical Ingredient (API) is manufactured, and to fulfill the strict purity requirements imposed by the regulatory agencies. In the biopharma industries the purification of oligonucleotides usually is carried out through single column preparative liquid chromatography, in particular the main technique used for this purpose are Anion Exchange Chromatography (AEX) and Ion Pair- Reversed Phase Chromatography (IP-RP) [3].
AEX takes advantage of the negative charge on phosphate linkage on the oligonucleotide, the elution is generally performed with a sodium salt gradient and at the end of the process the product is already in its sodium form. On the other hand, IP-RP purification ensures not only charged based residues but also discriminated neutral lipophilic impurities. However, because of the use of counterion, an additional salt-exchange step is required to yield the oligos in its sodium form [3]. Nevertheless, single column purification techniques suffer from a purity-yield trade off, for this reason the batches are run sequentially to overcome this problem. Therefore, this results in higher production and analysis costs since intermediate analysis steps are necessary between the different purifications [1,2,3].
In this work a multidimensional technique on a preparative scale, the Integrated Batch process, has been applied on a preparative scale for the purification of a single-stranded DNA oligonucleotide. This process can combine two chromatographic steps, where the eluted product from the first column can be diluted in-line and loaded directly in the second column to maximize the throughput of the purification process.

References:

[1] R. Weldon, Journal of Chromatography A 1663, 2022, 462734.
[2] M. Catani, Biotechnology Journal, 2020, 15, 1900226.
[3] Y. S. Sanghvi, in RSC Drug Discovery Series, vol. 2019-January, Royal Society of Chemistry, 2019, pp. 453– 473.

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ANA-PO-016

Chemometric-assisted electrochemical SPE measurements: towards quality control platform for drug delivery

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Lipid nanocarriers (LNCs) are powerful and versatile tools in the field of drug delivery for a wide range of medical purposes, from cancer treatment to vaccines[1]. Despite efforts to optimize the efficiency of drug encapsulation and minimize drug loss during the encapsulation process, challenges persist, so during formulation development, techniques such as chromatography, mass spectrometry, and UV-Vis absorption are employed to evaluate the effectiveness of encapsulation[2]. In this paper, we present an innovative and "portable," easy-to-use and inexpensive strategy to rapidly assess LNC quality. This work involves the use of an electrochemical strip using a screen-printed electrode to detect methylene blue (MB) as a representative cargo encapsulated in various liposomes (used as model LNCs), including distearoylphosphatidylcholine, dipalmitoylphosphatidylcholine, and hydrogenated soybean phosphatidylcholine. The experimental setup, including the release of MB content and its electrochemical detection, was fine-tuned through a multivariate design of experiments (DoE), a d-optimal design, which allowed optimization of the 4 variables with only 19 experiments. In addition, using principal component analysis and linear discriminant analysis (PCA-LDA), the lipid bilayer compositions of liposomes were distinguished by analyzing their voltammetric profiles. n this work, therefore, we highlight the synergy between portable electroanalysis and multivariate analysis as a powerful tool for enhancing quality control in the context of pharmaceutical technologies. In addition, this approach also shows promise in the field of diagnostics, especially in its application to naturally occurring lipid nanoparticles, such as exosomes.

References:

(1) Dhiman, N.; Awasthi, R.; Sharma, B.; Kharkwal, H.; Kulkarni, G. T. Lipid Nanoparticles as Carriers for Bioactive Delivery. *Front. Chem.* **2021**, *9*. https://doi.org/10.3389/fchem.2021.580118.
(2) Lim, S. B.; Banerjee, A.; Önyüksel, H. Improvement of Drug Safety by the Use of Lipid-Based Nanocarriers. *J Control Release* **2012**, *163* (1), 34–45. https://doi.org/10.1016/j.jconrel.2012.06.002.

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Exploring Cannabis chemovars' floral profiles by two-stage thermal desorption coupled to comprehensive two-dimensional gas chromatography

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The floral scent is an important phenotypic characteristic of flowering plants. It plays a critical role in various areas such as attracting pollinators to enable reproduction success, defence and protection from predators or pathogens and species differentiation to reduce competition for pollinators and increase their chances of reproduction.

The floral fragrancy derives from the presence of volatile secondary metabolites, which contains various low molecular weight compounds with a low boiling point. They are mainly synthesized via the terpenoid, benzenoid, and fatty acid biosynthetic pathways[1]. These volatile compounds have been widely used in cosmetics, medicinal products, perfumes, and food flavorings.

Terpenoids are the main responsible for the aroma of many flowering plants, including those belonging to the Cannabaceae family. Furthermore, the synergistic relationship between different chemical compounds in cannabis, including terpenes, appears to enhance biological activity, and this result is commonly referred as the 'Entourage Effects', i.e. the ability of two or more active compounds to work together to produce a greater effect than they could achieve separately[2]. In this regard a more comprehensive chemical characterization is necessary to a better understanding of cannabis volatile composition and variability.

The present contribution aims at exploring, in a detailed manner, the volatile composition of different Cannabis chemovars, using state of the art comprehensive two-dimensional gas chromatography coupled to mass spectrometry (GC×GC-MS) technology[3]. The head-space extraction was dynamic and sorbent-based, specifically using trap tubes, packed with solid sorbent material which were properly selected for their selectivity to terpenoids. After the extraction, they were thermally desorbed online with the GC×GC-MS system using single-stage and dual-stage desorption system to understand pros and cons. Identification of the volatile compounds was carried out using mass spectral similarity and retention indices.

References:

[1] Natalia Dudareva, New Phytologist (2013), 198, 16-32.
[2] Ethan B Russo, British Journal of Pharmacology (2011), 163, 1344-1364.
[3] Delphine Zanella, Jean-François Focant, Flavio A Franchina, Analytical Science Advances (2021) 2, 213-224.

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Design and development of a wearable sensing device for monitoring Dopamine in sweat

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Dopamine is a neurotransmitter belonging to the catecholamine family that plays a crucial role in neurotransmission processes, in particular in motor coordination, motivation behavior and regulation of cognitive processes. Impaired dopamine levels in brain lead to the onset of symptoms related to the onset of various and heterogeneous neurological disorders, such as Parkinson and Alzheimer diseases, increasing motorial impairments such as bradykinesia or tremor. Nowadays, the only way to bring relief to patients suffering of Neurological Disorders is the pharmacological administration of drugs with the aim of restoring the adequate levels of neurotransmitter in brain's pathways. Regrettably, the fine-tuning of such pharmacological strategies is strictly dependent on the levels of neurotransmitters in cerebrospinal or blood fluids, therefore a painful and continuous monitoring is strictly required. Taking into account these considerations, several peripheral biofluids, such as saliva, urine and sweat, promote the development of wearable sensitive devices capable to detect neurotransmitters in a painless, continuous, and non-invasive manner. For this purpose, electrochemical-based sensors offer amazing potential for the development of point-of-care-analysis devices. Indeed, due to the miniaturization, sensor can be integrated into comfortable ordinary tools such bracelets or smartwatches. This study introduces a new analytical wearable platform for screening and monitoring dopamine in peripheral biofluids, with the aim of develop a sensitive and painless wearable device. Specifically, graphite screen-printed working electrodes were enhanced with a biocompatible polymeric conductive layer. To this end, different amino acids were studied as biocompatible and biodegradable functional monomers. Then, the polymeric layer was further modified by the enzyme covalent immobilization and by electrodepositing gold nanoparticles for the direct detection of electroactive. The modified platforms were characterized using cyclic voltammetry and electrochemical impedance spectroscopy. The analytical performances were evaluated in both standard solutions and in artificial biological fluids.

Acknowledgements

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Differential proteomics from blood cells of long-lived individuals: identification of molecular determinants related to aging and related diseases.

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In recent years the growing interest on human aging and longevity has promoted the establishment of an international scientific pole for research on aging. The main objective of this research network is to prolong human life and preserve its quality in term also of biological state. Understanding the molecular mechanisms of aging is crucial for developing new therapeutic approaches to improve health and quality of life. Changes associated with aging may involve alterations in protein structure and function, accumulation of harmful or altered proteins, post-translational modifications, and changes in the composition and activity of protein complexes. These alterations can impact various essential biological processes, such as metabolism, cellular homeostasis, stress responses, inflammation, and immune system function.[1]

This study aims to identify such potential blood cell biomarkers conduct a differential proteomic analysis of erythrocytes from cohorts of individuals of different ages. The goal is to characterize the differences and similarities of each group qualitatively and quantitatively at the molecular level.

Extraction protocols and analysis were first carried out on *Mus musculus* as animal model system. Whole blood cells from the blood samples of young (6 months), middle-aged (12 months), and aged (30 months) mice were collected, and the proteinaceous content of membrane was extracted and fractionated. Identification of potential biomarkers related to membrane proteins was performed using untargeted LC-MS/MS Proteomics Analysis. Raw data were processed by using MaxQuant software and output files were subsequently processed using STRING to integrate all known and predicted associations between up- or down-regulated proteins.

Several of the identified proteins differentially expressed play a key role in physio-pathological processes, such as PSMD3 that is involved in maintenance of protein homeostasis by removing misfolded or damaged proteins. Finally, a similar strategy was set up on human blood samples to confirm the accuracy of the model.

Overall, this study reveals potential blood cell-protein biomarkers of aging and explains the possible correlation between the biomarkers and some processes related to immune system or metabolic pathways. The reported data provide a piece to unravel the complex puzzle related to aging processes and to assist basic research that requires multiple, interdisciplinary approaches on the study of human longevity.

References:

[1] R. Moaddel, C. Ubaida-Mohien, T. Tanaka, A. Lyashkov, N. Basisty, B. Schilling, R. D. Semba, C. Franceschi, M. Gorospe, L. Ferrucci, 2021, 20 (4),1 – 14.

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ANA-PO-020

The effect of environmental conditions and deposition substrate on bloodstains ageing: a spectroscopic approach to target a forensic analytical problem

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Determining time since deposition of bloodstains can be a potent tool for the forensic chemist in resolving legal cases. This topic has been investigated through several analytical techniques, mainly spectroscopies, such as ultraviolet-visible (UV-Vis), Raman, mid and near infrared (MIR and NIR). In this context, the contribution of chemometrics proved to be essential to gain understanding of the subtle spectral changes ongoing during the ageing of this complex biological fluid.

Until now, reduced attention has been devoted to the contribution of environmental conditions and deposition substrate which may have a significant influence on speed and kinetics of blood degradation. Therefore, understanding which factors influence this process (and to what extent) is crucial to avoid over/under estimations of bloodstain age.

To study in depth the impact of such factors, bloodstains were subjected to ageing under controlled temperature (T) and humidity (RH%) in a constant climate chamber (KMF115 – BINDER GmbH, Tuttlingen, Germany), mimicking two environmental conditions with a proper day-night alternance: condition CW – day: T = 25°C, RH% = 75%; night: T = 10°C, RH% = 90%; condition HD – day: T = 35°C, RH% = 60%; night: T = 20°C, RH% = 75%. The effect of direct light exposure was investigated as well, performing the ageing sessions either with or without a window that filters the light going from the lamp to the samples.

Six 20-µl bloodstains (from two different donors) were deposited on each of four different substrates, namely hydrophilic fabric (cotton), hydrophobic fabric (polyblend), metal (knife) and glass, making a total of 96 samples. Their ageing was followed for 12 days with two different analytical techniques: a handheld NIR device (MicroNIR® – Viavi Solutions Inc., Santa Rosa, California, USA), working in the spectral range 900-1700 nm; a confocal Raman microscope (InVia™ – Renishaw plc, Wotton-under-Edge, Gloucestershire, UK), acquiring in the Raman shift range 150-1900 cm^{-1}.

The obtained spectra were pre-processed for minimizing the unwanted systematic effects and subjected to chemometric analysis. Exploratory data analysis by means of principal component analysis (PCA) showed that NIR spectra are more subjected to the effect of the substrate, when compared with Raman spectra. It was observed that absorbing substrates (cotton, polyblend) yield a more efficient time trend model when analysed with NIR spectroscopy, while non-absorbing substrates (glass, metal) gave more consistent results with Raman spectroscopy. PCA also evidenced shifts between sessions carried out at different temperature and humidity, suggesting that environmental conditions may determine not only a faster/slower ageing, but also a different ageing kinetics. Then, ANOVA simultaneous component analysis (ASCA) was applied to quantify the effect of each factor (temperature, humidity, substrate, light exposure) on the ageing of bloodstains, to understand which conditions are most important to be controlled in real case scenarios.

The present study confirmed that determination of time since deposition of bloodstains is strongly related to environmental conditions and deposition substrate and, therefore, that tailoring models to take into account these factors is preferable.

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Multiplexed biosensing with smartphone-based bioluminescent tissue on-a-chip

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Living cells used as sensing systems have proved to be valuable tools for prediction of the physiological response to drugs, chemicals, and samples in complex matrices, which toxic effects and specific biological activities can be evaluated in a straightforward manner. Thanks to their predictivity, 3D cell models (i.e. spheroids, organoids and microtissues) are replacing conventional 2D cell cultures, enabling to recapitulate the extracellular matrix and cell cell interactions, creating an architecture that reflects native morphology of organs and tumors. Bioluminescent reporter assays represent the gold standard for high throughput screening assays employed in drug discovery and BL proteins showed a formidable tool for elucidating the biological mechanisms underlying morphogenetic and pathogenetic processes and for unravelling molecular pathways involved in the etiopathogenesis of several diseases.

According to the three key pillars of the organ on a chip technology, we developed a bioluminescent tissue on a chip with different cell lines (i.e., human embryonic kidney (HEK293T), human cervical cancer (HeLA)) genetically engineered with newly developed luciferase mutants emitting at different wavelengths and characterized by high stability,[1,2] implemented in a microfluidic system for multiplexed biosensing. Thanks to 3D printing technology a cell cartridge and an adaptor were developed to provide a mini dark box interfaced with portable light detectors for BL signal acquisition.

The proposed biosensing platform could become a useful tool for multiple bioactivity analysis, for on-site screening of toxic substances, prioritizing samples for more accurate chemical analyses.

References:

[1] M.M. Calabretta, D. Gregucci, H. Martínez-Pérez-Cejuela, E. Michelini, Biosensors, 2022, 12(9), 742.
[2] M.M. Calabretta, D. Gregucci, E. Michelini, Analyst, 2023,148, 5642-5649.

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ANA-PO-022

Multiway data fusion approach for the determination of synthetic caramel in Balsamic Vinegar of Modena

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Synthetic caramel is one of the most widely used colourants in the food industry. The use of caramel in Balsamic Vinegar of Modena PGI is regulated by the protocol of the Consortium of Balsamic Vinegar of Modena[1]. However, recent years have witnessed an alarming increase in food fraud, with synthetic caramel being a significant contributor to adulteration in Balsamic Vinegar of Modena. The challenge has therefore arisen to develop an analytical approach capable of determining synthetic caramel in balsamic vinegar. An approach based on two analytical techniques was thus investigated: fluorescence spectroscopy and solid-phase headspace microextraction coupled with gas chromatography-mass spectrometry (SPME-GC-MS). With both techniques, not only vinegar samples were analysed, but also the raw materials from which balsamic vinegar is produced (wine vinegar, cooked must and concentrated must) to study their effect on the instrumental response. Both techniques result in three-dimensional datasets (i.e. samples x emission wavelengths x excitation wavelengths for fluorescence spectroscopy; samples x retention time x mass spectra for GC-MS) that require the application of appropriate data analysis techniques. In the case of fluorescence, PARAFAC[2] was applied to resolve and quantify fluorophores related to the presence of caramel. For the GC-MS analysis, PARADISe software[3] was used for the resolution, integration and identification of analytes characterising the aroma of vinegar samples. A model was then built to determine the presence of synthetic caramel in balsamic vinegar samples from Modena.

References:

[1] https://www.consorziobalsamico.it/
[2] R., Bro, Chemometrics and Intelligent Laboratory Systems 1997, 38, 149-171.
[3] L. G., Johnsen, P. B., Skou, B., Khakimov, R., Bro, Journal of Chromatography A 2017, 1503, 57-64.

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ANA-PO-023

Rice husk ash precursor of a new sorbent material for the preconcentration of perfluoroalkyl substances in environmental waters

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Per- and poly- fluoroalkyl substances (PFAS) are a class of anthropogenic chemicals that have been in use since the 1950s and have received increased public attention in recent years. These environmental contaminants contain an aliphatic fluorinated carbon chain of variable length and a hydrophilic end group which, together with the extremely strong C–F bond, confer unique properties such as thermal and chemical stability, resistance to hydrolysis and microbial degradation but also make them non-degradable resulting in their accumulation in the environment.[1]

Rice husk (RH) is a non-food waste biomass containing approximately 40% cellulose, 30% lignin, 20% silica in amorphous form, pigments, pectins and proteins.[2] The main byproduct from RH combustion is RH Ash (RHA), with highly porous structure that can be used, opportunely treated, as Solid-Phase Extraction (SPE) sorbent for many emerging organic pollutants[3], and in this work for the preconcentration of 12 PFAS in environmental waters. In the framework of Green Chemistry and Green Sample Preparation, the original synthesis[3] of this sorbent, which involved 8-hour ultrasound-assisted oxidation in sulfonitric mixture followed by 10-hour heating at 200° C, has been greatly improved moving on a very short microwave-assisted oxidation (10 min) with a few millilitres HNO_3. The final thermal treatment was optimized by an experimental design evaluating two temperatures (150° C and 250° C) and two times (2 hours and 10 hours). Each one of the four materials obtained was tested for the sorption capacity in SPE cartridges (250 mg) in tap water samples (50 mL, native pH) enriched with 1 µg L^{-1} of each fluorinated analyte. The most performing material (250° C, 2h) showed quantitative adsorption and elution (by 2 mL MeOH 0.1% v/v NH_3) of the 12 PFAS examined (recovery from 82% to 115%, RSD% < 10%, $n = 3$), analysed by UPLC-ESI-MS/MS with marked internal standards quantification.

The procedure was then successfully tested in tap water samples fortified at lower environmentally significant concentration (100, 50 and 10 ng L^{-1}) with recoveries between 70 and 111% (RSD% < 15%, n = 3). Tests in river waters and wastewater treatment plants effluents at the same concentration levels are ongoing.

References:

[1] K. Miserli, V. Athanasiou, V. Boti, D. Hela, I. Konstantinou, Case Studies in Chemical and Environmental Engineering 2023, 8, 100505
[2] P. Stroeven, D. Bui, E. Sabuni, Fuel 1999, 78, 153–159
[3] P. Bianchini, F. Merlo, F. Maraschi, R. Brescia, M. Prato, A. Profumo, A. Speltini, Molecules 2023, 28, 745

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ANA-PO-024

Biochars of dead *Posidonia oceanica* leaves as adsorbents of rare-earth elements

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The widespread use of Rare earth elements (**REE**) in cutting-edge technologies has led to a surge in their consumption and the urgency of finding sustainable solutions for their recovery.[1] The European Community included REE in the list of critical raw materials, i.e. the list of materials whose recovery is considered of strategic interest.[2] Among the different REE recovery methods, adsorption is one of the most attracting, in particular when the employed adsorbents come from waste platforms.[3] This contribution presents the results achieved using three biochars coming from the pyrolysis of dead *Posidonia oceanica*, a marine plant whose leaves accumulate in abundance on the sicilian cost, as adsorbents of REE from aqueous solutions. To this end, thermodynamic and kinetic experiments were carried out to study the recovery of La, Nd and Dy ions onto the biochar of *Posidonia oceanica* as it was (**BC**) and after two types of chemical activations, i.e., an acid activation with phosphoric acid (**BCA**) and a basic activation with potassium hydroxide (**BCB**) in aqueous solution at pH = 5 and t = 25°C. The adsorption of REE ions onto BCA, the best adsorbent among those investigated, was also studied, at the same pH, in $NaNO_3$ 0.1 mol L^{-1} to evaluate the effect of ionic strength. Single batch adsorption experiments were also carried out at pH = 3 and 6 to evaluate the effect of pH. Chemical and morphological characterization of adsorbents were carried out by SEM-EDX, FT-IR, elemental analysis, nitrogen adsorption/desorption and pH of point zero charge measurements. The REE adsorption were well described by Langmuir isotherm and, among the adsorbents investigated, the BCA showed the highest q_m value. The q_m of BCA decreases with the decreasing of pH and in presence of $NaNO_3$. The adsorption equilibrium was reached within 8 hours and the kinetic of adsorption was well described by the double exponential equation. Recycling experiments were also carried out to test the reusability of the BCA.

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References:

[1] T.B. da Costa, M.G.C. da Silva, M.G.A. Vieira, J Rare Earths, 38(4), 339-355.

[2] European Commission, https://www.consilium.europa.eu/it/infographics/critical-raw-materials/ (accessed 14 March 2024), 2024.

[3] S. Cataldo, N. Muratore, F. Giannici, D. Bongiorno, V. Chiodo, S. Maisano, A. Pettignano, Environ. Sci. Pollut. Res., 2022, 29, 90231-90247.

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ANA-PO-025

Evaluation of the relative response factor among different gas chromatographic systems

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When it comes to gas chromatographic analysis, we usually tend to consider MS as the reference detector to identify the analytes, while FID for their quantification. This is because the molecules do not respond in the same way to different detectors, and due to the analogue response of FID, the analytical signal is more linear to the concentration and the dynamic range maintains the linearity over a range of higher concentration.

If the analysis goal is the chemical elucidation of a given sample, the response normalization of the single analytes on the total detected signal (area %), is an effective and common way to express the chemical distribution of within a given sample.

This is reasonable and accurate with a detector as FID, whose response is fairly consistent between different compounds or at least predictable through the calculation of relative response factors (RRFs). Different approaches have been developed for their calculations, among which the effective carbon number (ECN)[1].

Applying total response normalization when using an MS detector is generating an error, especially if different chemical classes are considered: this is due to the different responses of molecules in relation to their different structure. In addition, predicting the RRFs is not yet demonstrated.

In this contribution the relative response factors of 35 compounds with different chemical structure (*n*-paraffins, *i*-paraffins, olefins, naphthenes, aromatics, and N/O-containing compounds) were calculated for GC coupled to different detectors: FID, qMS, TOFMS, and VUV. Using on-column injection, it was possible to understand the different responses of the various detectors for each class of compounds.

In addition, it was studied the inlet splitting influence on RRFs, through the comparison of on-column and split injection analyses.

References:

[1] J.T. Scalon, D.E. Willis, Journal of Chromatographic Science, 1985, 23, 333-340.

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ANA-PO-026

Electrodeposition and Characterization of Nanostructured Metal on Silicon

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The electrodeposition of nanostructured materials on silicon substrates provides a means to combine the desirable properties of metals with the exceptional electronic properties of silicon, enabling the development of integrated circuits, electrodes in batteries, supercapacitors, fuel cells, sensors, and photovoltaic cells[1]. This deposition technique was chosen because is an inexpensive, easily scalable, and quick synthesis route, is carried out at room temperature and atmospheric pressure, in aqueous solution, and with adjustable properties.

In this work, the possibility of obtaining electrodeposited nanoparticles, ultra-thin films, and Under Potential Deposition (UPD) on n-doped silicon was evaluated[2]. The first selection of metals to be electroplated was made through the evaluation of Density Functional Theory (DFT) calculations, considering the Schottky barrier, the metal-silicon, and the metal-metal formation energy. Voltammetric studies were then carried out using solutions containing Ni, Ru, Pd, Rh, Pt, Ag, Mn, and Co. Charge-controlled depositions were performed, and tests on electroless deposition were made. Ideal deposition conditions were sought for the most promising metals. The deposits thus obtained were characterized morphologically and compositionally using Secondary Electrons (SE), Backscattered Electrons (BSE) Scanning Electron Microscope (SEM) techniques, and extensively by analytical spectroscopy point of view, by the means of Energy Dispersive X-ray Spectroscopy Analysis (EDS) and X-ray Photoelectron Spectroscopy (XPS) technique. The focus of the study was the electrochemical deposition of rhodium on silicon which is surprisingly not much covered in the literature. For this reason, multi-step charge-controlled deposition studies were carried out, and the surface coverage, the average thickness, and the variation in deposited particle size distribution were then evaluated accordingly. The knowledge gained was used to obtain ultrathin silicon nanowires (NWs) by a wet etching process assisted by an electrochemically deposited metal thin film, a procedure not widely used in the literature at the state of the art. These results could create new opportunities for smaller-sized and better-performing sensors[3].

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References:

[1] G.D. Sulka, molecules, 2023, 28, 4040-4052.
[2] X. Zeng, Y. Zhao; et al., small structures, 2021, 2, 2000138-2000163
[3] D. Morganti.; A. Leonardi; et al., nanomaterials 2021, 1767-1778.

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ANA-PO-027

Label-free and single-molecule detection of Sars-CoV 2 subgenomic mRNAs

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The ongoing COVID-19 pandemic is undeniably one of the most significant global threats in modern history, which has resulted in severe social and economic consequences.[1] Several detection approaches and genome sequencing methods have been utilized for SARS-CoV-2, as indicated by the extensive number of available data [2]. Currently, the SARS-CoV-2 diagnosis is based on Reverse Transcription-quantitative Polymerase Chain Reaction (RT-qPCR) method, which is considered the gold standard [3]. However, the RT-qPCR major limitation is the non-specificity in the detection of genomic, subgenomic, or degradation product of the viral RNA. Indeed, different studies prove that subgenomic mRNAs (sgmRNAs) could be used as a significant epidemiological marker for detecting different SARS-CoV-2 strains [4,5]. Furthermore, these mRNAs are related with the active replication of the virus[5]. In this study, we evaluated the application of the Single Molecule with a Large Transistor (SiMoT) technology [6] to perform a proof of concept for the early detection of nucleocapsid protein coding SARS-CoV-2 sgmRNAs. The core of the SiMoT device, based on an electrolyte-gated field-effect transistor, is a gold gate electrode biofunctionalized with a self-assembled monolayer [7], densely packed of the sgmRNAs . The proposed label-free, fast electronic assay paves the way to ultra-high performing immunometric point-of-care devices for large-scale screening of the active replication of the virus.

References:

[1] M. Nicola, Z. Alsafi, C. Sohrabi, A. Kerwan, A. Al-Jabir, C. Iosifidis, M. Agha, R. Agha, Int. J. Surg. 2020 Jun:78:185-193.
[2] N. Goodacre, A. Aljanahi, S. Nandakumar, M. Mikailov, A. S. Khan, mSphere 2018 Mar 14;3(2):e00069-18.
[3] B. A. Oliveira, L. C. de Oliveira, E. C. Sabino, T. S. Okay, Rev. Inst. Med. Trop. Sao Paulo 2020 Jun 29:62:e44..
[4] M. Chiara, A. M. D'Erchia, C. Gissi, C. Manzari, A. Parisi, N. Resta, F. Zambelli, E. Picardi, G. Pavesi, D. S. Horner, G. Pesole, Brief. Bioinform. 2021 Mar 22;22(2):616-630.
[5] A. Oranger, C. Manzari, M. Chiara, E. Notario, B. Fosso, A. Parisi, A. Bianco, M. Iacobellis, M. d'Avenia, A. M. D'Erchia, G. Pesole, Commun. Biol. 2021, 4(1):1215.
[6] E. Macchia, K. Manoli, B. Holzer, C. Di Franco, M. Ghittorelli, F. Torricelli, D. Alberga, G. F. Mangiatordi, G. Palazzo, G. Scamarcio, L. Torsi, Nat. Commun. (2018), 3223.
[7] E. Macchia, A. Tiwari, K. Manoli, B. Holzer, N. Ditaranto, N. Picca, Rosaria Anna Cioffi, C. Di Franco, G. Scamarcio, G. Palazzo, L. Torsi, Chem. Mater. 2019, 31, 6476.

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ANA-PO-028

PAM-Engineered Toehold Switches as Input-Responsive Activators of CRISPR-Cas12a for Sensing Applications

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The RNA-programmed CRISPR effector protein Cas12a has emerged as a powerful tool for gene editing and molecular diagnostics. Nonetheless, additional bio-engineering strategies are required to achieve precise control over Cas12a activity.[1] Here, we introduce a novel class of Cas12a regulators termed PAM-engineered Toehold Switch DNA, featuring re-engineered locked protospacer adjacent motif (PAM) within the loop.[2] This design enables precise control of Cas12a activities in response to specific molecular targets via structure switching and PAM complementation. Reconfiguring the Toehold Switch DNA from a hairpin to a duplex conformation through a strand displacement reaction provides an effective means to modulate the accessibility of the PAM, thereby controlling the binding and cleavage activities of Cas12a. This approach demonstrates the potential to initiate downstream Cas12a activity by exploiting proximity-based strand displacement reactions upon target binding (Figure 1). By utilizing Cas12a *trans*-cleavage activity as a signal transduction mechanism, our approach shows versatility in sensing applications. Our system facilitates rapid, one-pot detection of IgG antibodies and small molecules with high sensitivity and specificity, even within complex matrices. Beyond its bioanalytical utility, the switchable PAM-engineered Toehold Switches serve as programmable tools, allowing precise regulation of Cas12a-based targeting and DNA processing in response to molecular inputs, thus holding promise for diverse biotechnological applications.

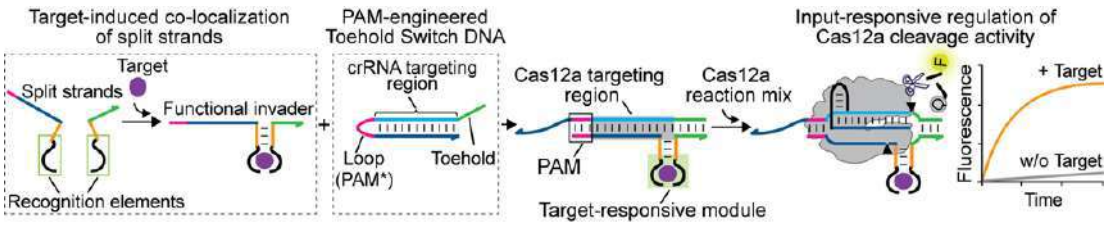

Figure 1: PAM-engineered Toehold Switch DNA reconfiguration enables precise control of Cas12a activities in response to specific molecular targets via structure switching and PAM complementation within a proximity-based reaction network.[2]

References:

[1] S. Del Giovane, N. Bagheri, A. C. Di Pede, A. Chamorro, D. Migliorelli, L. Burr, S. Paoletti, H. Altug, A. Porchetta, TrAC, Trends Anal. Chem. 2024, 172, 117594.
[2] N. Bagheri, A. Chamorro, A. Idili, A. Porchetta, Angew. Chem. Int. Ed. 2024, e202319677.

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ANA-PO-029

Early detection of Xylella fastidiosa in olive sap of infected plants using wide-field electronic biosensor

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The early detection of pathogens is essential for timely diagnosis and implementing preventive measures and treatments. One particularly concerning pathogen is the bacterium Xylella fastidiosa, known for its detrimental effects on various crops and plants crucial for both ecosystems and agriculture. Responsible for diseases such as Pierce's disease of grapevine, phony peach disease, plum leaf scald, citrus variegated chlorosis disease, and olive scorch disease, *X. fastidiosa* is among the most harmful plant bacteria globally. In this study, we employed the Single Molecule with a Large Transistor (SiMoT) technology, utilizing an Electrolyte gated Organic Field-effect transistor (EG-OFET), to detect *Xylella fastidiosa* with high sensitivity. Achieving a limit-of-quantification (LOQ) of 2±1 bacteria in 0.1 mL (20 colony-forming units/mL), the assay utilized a bio-functionalized millimeter-wide gate with Xylella-capturing antibodies. Importantly, this detection was performed directly on saps obtained from naturally infected plants. Furthermore, we demonstrated the selectivity of the SiMoT system against a non-target bacterium, *Paraburkholderia phytofirmans*. To assess the biofunctionalization protocol and antibody capture efficiency, Surface Plasmon Resonance (SPR) technique was employed. SPR offers label-free detection and real-time monitoring of bio-affinity reactions, providing valuable insights into the assay's performance. Additionally, we compared our bio-electronic platform with the established qPCR gold-standard method. Remarkably, our label-free electronic assay proved to be faster (30 minutes) and more precise (with false-negatives and false-positives below 1%) than state-of-the-art technologies, obtaining a limit of quantification two orders of magnitude lower than rt-PCR. This suggests the potential of our platform for large-scale screening of asymptomatic plants, paving the way for efficient plant pathogen detection at the point of care.

References:

[1]. Bonnassieux Y, et al. Flexible and Printed Electronics, 6(2021) DOI 10.1088/2058-8585/abf986.
[2]. Torricelli F, et al.,. Nature reviews | methods primers, 1 (2021). DOI: 10.1038/s43586-021-00065-8
[3]. Harper S J, et al., Phytopathology, 100 (2010), 1282–1288. DOI: 10.1094/PHYTO-06-10-0168
[4]. M. J. Linman, et al.,, Analyst, 135 (2010), 2759. DOI: 10.1039/C0AN00466A

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ANA-PO-030

Improving the reliability of Single-Molecule-with-a-large-Transistor (SiMoT) platform with a multivariate quality control based on principal component analysis.

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Biosensors performance can be affected by many factors, such as stability, temperature, or fluid matrix interferences. The validation of the biosensor performance is the process of verifying and demonstrating that the biosensor meets the predefined specifications and requirements for its intended use. This is essential for ensuring the reliability, reproducibility, and quality of the biosensor results. In this study, we developed a multivariate *Quality Control* (QC) based on *Principal Component Analysis* (PCA) method[1,2] to improve the reliability of SiMoT platform[3]. Due to the complexity of the device and the use of different human fluids, the biosensor performances can be affected by nonspecific interactions due to matrix effects, characteristic of complex biological samples. To this end, it was necessary to define a statistical model to identify and evaluate all experiments that exhibit abnormal biosensor performance and therefore cannot be considered acceptable. Current changes registered with reference gates and with 7 negative control experiments, have been used as variables for QC. Initially, a dataset called '*Normal Operating Conditions'* was defined, including samples in which all sensors operate according to the electronic specifications established. The reliability of the NOC dataset as a reference dataset was evaluated by performing the PCA and verifying the absence of outliers. All other samples were used as test datasets. The latter were compared with the NOC dataset to assess the possible presence of *faulty* samples. Q residuals and Hotelling's T^2 statistics have been analyzed to spot the presence of outliers. To demonstrate the reliability of this QC model, an automatic classification model was built with the same training and test datasets. It emerged that all samples with abnormal biosensor behaviors identified in the test dataset of the QC analysis, were misclassified by the classification model. This underlines the importance of using real-time process monitoring when using biosensors to improve the reliability of such devices.

References:

[1] Li Vigni M., Durante C., Cocchi M., Data Handling in Science and Technology 2013,28, 55-126;
[2] Bro R., Smilde A. K., Anal. Methods, 2014,6, 2812-283;
[3] Macchia E., Manoli K., Holzer B., Nature Comm. 2018,9, 3223;
[4] Genco E., Modena F., Sarcina L., Adv. Mater. 2023, 35, 2370303.

ANA-PO-031

Enhanced Urea Detection in Wastewater using Catalytic and Biocatalytic Approaches

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As urea is a common fertilizer and additive for cow feed, it pollutes the environment by causing soil runoff, which in turn leads to eutrophication and algal blooms[1]. This makes it crucial to keep an eye on wastewater's urea levels. Because wastewater often contains significant quantities of urea, quantifying urea is helpful in determining when it might be worthwhile to try recovering it or converting it in a valuable material for many applications, including for energy issues. This will give a contribution in achieving circular economy and to valorize materials that would otherwise be treated merely as waste[2]. Catalytic and biocatalytic methods can be employed in wastewater treatment plants to monitor, treat, and recover urea. In fact, the urea oxidation process (UOR) is now thought to be a promising alternative energy source. Catalytic and biocatalytic technologies can be used to monitor, treat, and recycle urea in wastewater treatment facilities. Indeed, because of its low cost, ecologically favourable features, and green processing, urea oxidation reaction (UOR) is currently considered an attractive alternative energy conversion, environmental remediation, and electroanalysis topic. In contrast, the high selectivity that may be achieved is the driving force behind biocatalytic-based methods[3].

In this work, we developed a novel combination of flow injection analysis (FIA) and bio-cartridges for a real-time urea monitoring process. For continuous monitoring and automated sample processing, FIA-based bio-cartridges are very helpful. Enzymes were immobilized onto spherical particles inside the cartridge, to improve the surface to volume ratio and mimic homogeneous reactions. For the electrochemical readout, the bio-cartridges are then connected to small solid-state ammonium sensors. To generate the greatest signal in the shortest length of time, various parameters were tuned, including the amount of immobilized enzyme, flow rate, and reagent concentrations. After that, the bio-cartridge results were compared with an electrochemical method based on UOR. In order to do this, many Ni-based electrode surfaces for the amperometric detection of urea were examined and characterized. For online detection, various analytical parameters were tuned.

Preliminary results on wastewater samples were reported.

References:

[1] P. M. Glibert, J. Harrison, C. Heil, S. Seitzinger, Biogeochemistry, 2006, 77, 441-463.
[2] P. Simha, A. Zabaniotou, M. Ganesapillai, Journal of cleaner production, 2018, 172, 4152-4161.
[3] L. Quadrini, S. Laschi, C. Ciccone, F. Catelani, I. Palchetti, Trends in Analytical Chemistry,2023, 168, 117345.

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First-row transition metal ions speciation studies with quinolinic and coumaric ligands

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The coordination in solution of first-row transition metal ions naturally occurs in the body or can be induced to enhance the transportation, increase the activity, or reduce the toxicity of the ions[1]. The speciation of metal-ligand systems in solution is useful to investigate the behaviour and the implications of the components in physiological conditions. Quinoline and coumarin derived ligands were studied in combination with some bio-relevant first-row transition metal ions. In particular, 8-hydroxyquinolines (8-HQs) and n-hydroxycoumarins (HCs) represent two families of naturally occurring compounds showing interesting biological properties, including the ability to chelate metal ions[2,3].

Metal ions as $V^{IV/V}$, Cr^{III}, Mn^{II}, Fe^{II}, Co^{II}, Ni^{II}, Cu^{II} and Zn^{II} were considered and studied in combination with 8-HQs and HCs derived ligands. These ions are naturally involved in biological mechanisms and their chelation can dramatically change their activity and distribution in the body. The combination of these metals with biologically interesting ligands nowadays represents a strategy in drugs discovery[4]. The considered metal ions and ligands were combined and their interaction was investigated aqueous solution. Several metal-ligands systems were studied adopting a multi-technique approach. Potentiometric, spectrophotometric and NMR titrations were performed, in $KCl_{(aq)}$ 0.2 mol·L^{-1} and T = 298.15 K. The characterization of the systems was further expanded exploiting other electrochemical and spectroscopic techniques as voltammetry, fluorimetry, and EPR spectroscopy. Combining the information obtained from different techniques, it was possible to achieve a good grade of knowledge about the chemistry of the investigated systems. Stoichiometry of the formed metal complexes were identified, and coordination modes were hypothesized. The stability constants of the complexes were estimated, and the speciation diagrams were obtained defining the main species formed in solution over the biologically relevant pH range.

References:

[1] C. Van Cleave, D. C. Crans, *Inorganics (Basel)* 2019, 7, 111
[2] V. Oliveri, G. Vecchio, Eur J Med Chem 2016, 120, 252–274
[3] T. Filipsky, M. Riha, K. Macakova, E. Anzenbacherova et al., *Curr Top Med Chem* 2015, 15, 415–431
[4] E. J. Anthony, E. M. Bolitho, H. E. Bridgewater, O. W. L. Carter et al., Chem Sci 2020, 11, 12888–12917

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Study of phenol compounds as functionalized agent for active packaging

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The processing of agricultural products inevitably leads to large amounts of waste, which is a serious disposal problem. In particular, the fruit and vegetable supply chain results in approximately 90 million tonnes of residues per year in Europe, a volume that is expected to increase in the coming years[1]. For example, a large part of the total berry production is processed for juice production, of which approximately 20–30% ends up as waste[2]. Additionally, a large amount of fruit is wasted in the field due to unforeseen weather conditions exacerbated by climate change.

In a circular economy approach, also considering the high value due to the presence of active compounds, it is crucial to recover fruit wastes, rich in phenols and active substances[3]. Taking into account the principles of "green chemistry," the development of a polyphenol valorization process requires the identification of environmentally friendly solvents[4]. From this perspective, polyphenolic extracts obtained by green approach can be used as active agents (antimicrobial and antioxidant) in cosmetics and packaging.

Polyphenols known for their antimicrobial and antioxidant properties can be used as functionalizing agents in active packaging: ‘materials and articles designed to deliberately incorporate components that release substances into or absorb them from the packaged foodstuff or its environment' (EC Regulation 450/2009).

Small fruit sector (e.g. raspberries, blueberries) is one of the Italian markets with high product losses caused by the early onset of senescence phenomena related to microbial contamination. Reason why the active packaging systems currently used for the marketing of fresh fruit and vegetables are based on the control of microbiological contamination.

The aim of this work is to recover bioactive compounds from food waste using green extraction solvents and techniques. The extracted polyphenol will be used as functionalized agent in active packaging produced from bio-based and/or biodegradable polymer. The interaction of phenol compounds and different polymers matrices and the mechanical properties of final products will be evaluated. Finally, the release of bioactive compounds using food simulant will be verified and the antimicrobial properties of active packaging will be tested on fruit samples (i.e. raspberries).

References:

[1] S. Plazzotta, L. Manzocco, M.C. Nicoli, *Trends in Food Science & Technology* **2017**, *63*, 51–59
[2] H. Liu, S. Qin, R. Sirohi, et. al., *Bioresource Technology* **2021**, *332*, 125181
[3] I. Ignat, I. Volf, V.I. Popa, *Food Chemistry* **2011**, *126* (4), 1821–1835
[4] F. Alchera, M. Ginepro, G. Giacalone, *Foods* **2022**, *11* (18), 2727

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ANA-PO-034

Detection of abusing drugs achieved by using a multienzyme filter layers on amperometric biosensors

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Propofol is widely recognized as the preferred intravenous anaesthetic for short-term sedation due to its rapid onset and elimination, gentle recovery from anaesthesia, and minimal side effects.[1] Improper administration, either excessive or insufficient, may result in propofol infusion syndrome (PRIS) or intraoperative awareness, leading to physiological and psychological harm to patients. Notably, there is considerable variability in individual responses to propofol anaesthesia. Additionally, there is a growing global concern about addiction and fatalities associated with propofol abuse in recent years. Therefore, the assessment of plasma propofol levels is crucial in drug metabolism and pharmacokinetics (DMPK) as well as forensic toxicology research.[2,3]
In this work, an innovative enzyme-based amperometric biosensor was developed by using horseradish peroxidase (HRP) immobilized onto graphene based screen-printed electrodes. In particular, HRP was operated in mediated electron transfer (MET) using $[Os(4,4'\text{-dimethyl-}2,2'\text{-bipyridine})_2(\text{poly-vinylimidazole})_{10}Cl]^{2+/+}$ as immobilized mediator, monitoring the inhibition of H_2O_2 catalytic activity of HRP induced by propofol.[4] Moreover, enzymatic layers applied on the electrode surface have been used to eliminated or decrease the signal of interference molecules that may be present in actual blood samples.
The modified electrodes were characterized by using cyclic voltammetry and amperometry to extract the biosensor analytical figures of merit (e.g., dynamic linear range, limit of detection (LOD), sensitivity and stability). The electrodes were finally tested in blood samples using a smartphone-integrated system in order to develop a blood-prick propofol screening test.

References:

[1] McKeage, K., & Perry, C. M. (2003). Propofol: a review of its use in intensive care sedation of adults. CNS drugs, 17, 235-272.
[2] George, A. A., Hargrove, V. M., & Molina, D. K. (2016). Postmortem propofol levels: a case of residual detection long after administration. The American Journal of Forensic Medicine and Pathology, 37(1), 4-6.
[3] Sahinovic, M. M., Struys, M. M., & Absalom, A. R. (2018). Clinical pharmacokinetics and pharmacodynamics of propofol. Clinical pharmacokinetics, 57(12), 1539-1558.
[4] Bollella, P., & Gorton, L. (2018). Enzyme based amperometric biosensors. Current opinion in Electrochemistry, 10, 157-173.

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Edible Enzymatic Biosensors for Amperometric Monitoring of Glucose concentration

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As per the World Health Organization, approximately 422 million individuals, around 5% of the global population, have diabetes, making it a significant health concern.[1,2] Predicted to become the seventh leading cause of death, diabetes is a serious threat due to its associated complications, including cardiovascular disease, blindness, amputation risk, and kidney failure. Managing blood glucose levels is crucial for delaying these complications, but it's a challenge due to significant variability, especially in severe cases. This need for precise monitoring has led to a thriving market for glucose biosensors valued at over 15 billion EUR annually. However, challenges persist, primarily in scaling up biosensor production with multiple costly biological elements. To address this challenge, the scientific community is working on developing reusable biosensing platforms with long-term stability.[3]

Although implantable and minimally invasive sensors offer the advantage of continuous monitoring, their chemical compositions pose significant regulatory challenges for routine usage. As a result, there is a growing emphasis on developing diagnostic devices that are biodegradable, bioresorbable, or ingestible to overcome this limitation. In this regard, we have addressed the very important challenge of tailoring and designing novel conductive smart carbon-based inks completely biocompatible and edible to develop biocatalytic biosensors able to monitor the intestinal absorption of glucose in type 2 diabetic (T2D) patients. We employed a Design of Experiments (DoE) approach like Face Centered Design to optimize processing variables and enhance ink performance, providing a unique model for formulating edible carbon-based inks.[4]

References

[1] P. Bollella, 2022, Anal. Chim. Acta, 340517
[2] J.R. Camargo, T.A. Silva, G.A. Rivas, B.C. Janegitz, Electrochim. Acta, 2022, 409, 139968
[3] A. Tricase, A. Imbriano, M. Valentino, N. Ditaranto, E. Macchia, C. Di Franco, R. Kidayaveettil, D. Leech, M. Piscitelli, G. Scamarcio, G. Perchiazzi, L. Torsi, P. Bollella, 2023, Adv. Sensor Res., 2300036
[4] V. Marchianò, A. Tricase, M. Caputo, E. Farinini, R. Leardi, A. Imbriano, D. Leech, R. Kidayaveettil, L. Gentile, L., Torsi, E. Macchia, P. Bollella, 2024, Chem. Mat, 36, 1, 358–370

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ANA-PO-036

DNA-based dynamic combinatorial library as a multi-analyte sensing tool

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Complex intracellular networks that dynamically respond to different biological and chemical cues play a fundamental role in regulating signalling transduction pathways. Researchers have recently explored the possibility of developing artificial systems that, mimicking such dynamic networks, allow to build synthetic systems that respond to different targets with high sensitivity and specificity.

Dynamic combinatorial libraries can be promising tools to engineer artificial networks. In these systems, a set (Pool) of building blocks forms reversible bond and are allowed to reach thermodynamic equilibrium in the presence of external inputs, resulting in a variety of output libraries.[1]

Synthetic DNA has emerged as a versatile biomaterial to engineer nanodevices with potential applications in different fields, like sensing, imaging, and drug-delivery. Taking advantage of the high programmability and predictability of DNA-DNA interactions, several strategies used to design synthetic receptors for a wide range of different targets (Antibody, protein and small molecule) have been reported.[2]

Motivated by the above considerations, here we propose to develop a DNA-based dynamic combinatorial library (DNA-DCL) as a sensing tool able to respond to the presence of multiple targets. To achieve this, we have designed a DCL composed of short reactive DNA strands (Pool) that can interact with each other leading to the generation of a library of products (Output). The presence of specific external inputs (Target) can sequester reactive DNA strands from the pool, inducing the upregulated formation of only a specific product.

To prove the versatility of our approach, we have also designed a DNA-DCL to orthogonally control the assembly and disassembly process of DNA-based nanostructures.

References:

[1] J. Li, P. Nowak, S. Otto, Journal of the American Chemical Society 2013, 135, 9222-9239.
[2] N. C. Seeman, H.F. Sleiman, Nature Reviews materials 2018, 3, 17068.

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ANA-PO-037

Paper-sensors based on freestanding conductive films of nanofibrillar biochar from industry waste for food by-product valorization

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The circular economy model promotes the use of sustainable materials and wastes/by-products. In the analytical field, this led to new approaches in which 'recycled materials' are employed as building blocks for analytical devices manufacturing; these sustainable 'materials' often are also sources of compounds with economic/biological added value that deserve to be analyzed, closing the circularity of the process.

In this work, paper-based electrochemical sensors based on films composed exclusively of nanofibrillar biochar (BH) were manufactured and used for the determination of bioactive compounds in food by-products and derivates; the BH was produced from paper-industry waste, while paper from 100% recycled fibers was used as substrate for the sensors. Nanofibrillar BH was dispersed in water via ultrasound-assisted liquid phase exfoliation, conductive BH films were formed onto paper and defined using a laser plotter; eventually, the complete paper sensors were assembled via stencil printing. The biochar-based paper sensors (BH-PS) were employed for the analysis of phenolic compounds (i.e., caffeic acid, catechin, chlorogenic acid, and oleuropein) in exhausted coffee, coffee and cocoa bean husk, and artichoke and olive leaf based supplements. Linear dose-response curves ($R^2 \geq 0.995$) and micromolar limits of detection enclosed between 0.03 and 0.6 µM were obtained. Moreover, analysis of samples returned quantitative and reproducible recoveries (97-114%, RSD≤13%, n=3), allowing sorting samples in agreement with conventional more complex, and time-spending methods. Eventually, White Analytical Chemistry principles were used to evaluate the sustainability of the BH-PS-based approach toward traditional analytical methods[1] highlighting economic and environmental advantages; on the other hand, the analytical performance obtained ensures an efficient analysis of phenols in food by-products and derivatives, allowing to valorize the residual bioactive components.

Figure 1: Representation of the circularity of the biochar-based paper sensors

References:

[1] P.M. Nowak, R. Wietecha-Posłuszny, J. Pawliszyn Trends in Analytical Chemistry 2021, 138, 116223.

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ANA-PO-038

Paper-based sensors on algae-derived substrate functionalized with nanobiochar for bisphenol A determination in Zebrafish embryo ecotoxicological model

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Bisphenol A (BPA) has become a pervasive environmental contaminant, posing a significant threat to aqueous ecosystems and human health. In this work, for the first time, paper derived from seaweed biomasses (Algae) has been used for manufacturing lab-made electrochemical sensors, that were employed as monitoring tools during eco-toxicological studies performed with Zebrafish embryos (Z-EBs, *Dario rerio*) exposed to different BPA levels. Firstly, the potentiality of Algae paper to assist the stencil-printing was investigated, employing different graphitic inks as conductive elements; Algae-paper sensors were compared with transducers fabricated onto other types of paper (recycled and office-grade) and polyethylene terephthalate (PET), showing superior performances for BPA electro-sensing. The electrochemical properties of the sensors have been improved by employing two kinds of biochars (BH) with fibrillar (F) and amorphous (A) morphology, both deriving from industrial by-products and nano-dispersed through an aqueous-based and solvent-free sonochemical method. The most performing Algae-paper sensor has been challenged towards the direct BPA sensing in Z-EBs culture medium, achieving robust analytical performance devoid of any matrix effects, returning satisfactory limit of detection (LOD = 48 nM) and linear range (0.25 – 6 µM), together with quantitative recoveries (95-113%, RSD≤9.1% n=3). Afterward, the BPA bioaccumulation in Z-EBs during ecotoxicological studies was determined using the Algae-paper sensor; despite the inherent complexity of embryos, in matrix calibrations returned useful linearity (0.25 – 8 µM) and a LOD of 57 nM, allowing the estimation of the BPA bioaccumulated within Z-EBs (recoveries: 98-114%, RSD≤5.4% n=3).
Herein, the marriage between Algae-paper and BH gave rise to an effective analytical tool for monitoring BPA in Z-EBs, employed as an environmental (culture medium) and toxicological (embryos) model. This study proves how by-products can become active and functional parts of analytical devices, creating a virtuous circle able to offer sustainable solutions for environmental monitoring.

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Silver Nanoparticle/Zein Composites as Green Antimicrobial Self-standing Films

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To reduce waste and reduce costs, the current trend is to find alternative solutions aimed at combating environmental pollution, e.g. by replacing classic plastics with biodegradable and sustainable materials. Therefore, the use of plant biopolymers could be a valid alternative. In this communication, self-standing zein films, of potential application as food packaging layers, were prepared by co-dispersion with sodium caseinate to improve the mechanical and barrier properties[1]. Zein is a highly hydrophobic corn protein with excellent film-forming properties, which could be extracted by corn gluten meal (byproduct of corn milling process)[2]. Moreover, the embedding of silver nanoparticles (AgNPs) was considered to confer antimicrobial properties[3] to the proposed materials. AgNPs were first prepared according to a green reduction process limiting the amount of silver precursor ($AgNO_3$) and using low-toxic chemicals (ascorbic acid as a reducing agent and zein as a stabilizer). NPs were then added to the zein/caseinate dispersion to obtain antimicrobial films. AgNPs and composite films were characterized by a multi-analytical approach in terms of NP morphology and size (DLS, TEM) and chemical composition (UV-Vis, XPS, FTIR). AgNPs have typically a spheroidal shape with a mean diameter of about 20 nm. FTIR analysis, as reported in the literature[1], confirmed the high compatibility and strong interactions between casein and zein. Mechanical and water absorption tests were performed showing good results. Moreover, preliminary antifungal *in vitro* tests and silver ion release (ETAAS) are presently under study to evaluate film properties.

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References:

[1] S. Wang, H. Chen, Y. Tong, Y. Li, J. Zhang, C. Chen, F. Ren, C. Hou, P. Wang, Food Hydrocolloids 2023, 134, 108017.
[2] X. Lan, X. Zhang, L. Wang, H. Wang, Z. Hu, X. Ju, Y. Yuan, Food Chemistry 2023, 424, 136403.
[3] L. Mei, Z. Teng, G. Zhu, Y. Liu, F. Zhang, J. Zhang, Y. Li, Y. Guan, Y. Luo, X. Chen, Q. Wang, ACS Appl. Mater. Interfaces 2017, 9, 35297–35304.

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ANA-PO-040

Exploring tensor-based decomposition methods for hyperspectral image analysis: a comparative study with spectral unmixing techniques

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Tensor-based decomposition methods have long been established as robust methodologies in chemometrics, providing effective tools to analyse complex data structures[1]. In the context of hyperspectral images, where simultaneous exploration of spatial and spectral domains is crucial, Canonical Polyadic Decomposition (CPD) and Tucker decomposition[2] are useful techniques. However, CPD's imposition of rank 1 on each factor can be overly restrictive, while Tucker decomposition offers greater flexibility but suffers from rotational ambiguity. An intermediate method, Block Term Decomposition (BTD)[3], facilitate a compromise. By imposing rank = 1 on one factor and allowing rank ≠ 1 for the other two factors (LL1-BTD), it preserves the uniqueness property of CPD while accommodating more complex spatial structures related to a single spectral signature. Therefore, BTD is well-suited for analysing hyperspectral images where the spatial structures of various spectral components require distinct factorization. This includes scenarios such as the presence of minor components or components with similar spatial distributions but different spectral signatures, and vice versa. In this study, we explore the adoption of LL1-BTD for analysing benchmark hyperspectral imaging datasets of chemical mixtures, biological fluids, leaves, a mineral sample, and remote sensing images. These datasets were acquired using different spectroscopic techniques such as UV-Vis, NIR, Raman, LIBS. LL1-BTD performances are compared with CPD and spectral unmixing methods applied to unfolded hyperspectral data cubes. Results indicate that LL1-BTD shows promise for hyperspectral image analysis, offering insights into the efficacy of tensor-based decomposition methods for addressing the challenges posed by such data.

References:

[1] E. Acar, Y. Bülent, IEEE transactions on knowledge and data engineering, 2008, 21, 6-20.
[2] T.G. Kolda, W.B. Bader, SIAM review, 2009, 51, 455-500.
[3] L. De Lathauwer, SIAM Journal on Matrix Analysis and Applications, 2008, 30, 1033-1066.

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ANA-PO-041

Adsorption isotherms and kinetics of rare earth metals on multifunctional materials from various waste pomaces

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This contribution presents the preliminary results obtained using waste biomasses from the industrial food chain for the preparation of multifunctional materials possibly able to detect, bind and extract, efficiently and selectively, rare earth metal ions from aqueous solutions simulating real matrices. These metals belong to the list of "Critical Raw Materials", *i.e*. the group of materials whose recovery is considered strategic by the European Community[1]. The use of food-processing industry wastes as secondary raw materials offers a sustainable and environmentally friendly approach, that could also be useful for the rare earth metals recovery. In particular, the adsorption of neodymium and dysprosium ions in aqueous solution was studied at pH ~ 5 and t = 25°C using different waste biomasses, namely Bergamot Pomace (BP), Olive Pomace (OP) and Grape Pomace (GP), chemically pretreated at t = 30°C with H_2O and HNO_3 0.10 mol dm^{-3} [2,3]. The materials were characterized employing different analytical techniques; through the FT-IR ATR spectroscopy [2], it was possible to confirm the presence of functional groups capable of interacting with the above mentioned metals. To evaluate their adsorption capacity, batch experiments were carried out on different solutions containing the metal ions (M^{3+} = Nd^{3+}, Dy^{3+}). The concentration of each M^{3+} was determined by ICP-OES [4]. The results obtained from adsorption experiments show that Langmuir equation was the best isotherm fitting model for BP, OP and GP for the rare earth metals adsorption. The adsorption equilibrium was reached within 24 hours and the kinetic of adsorption was well described by the pseudo-second order model. Then the recovery of the metals adsorbed on the biomasses was carried out using HNO_3, but the reused materials show lower performance than the starting ones, exception done for BP, which showed great reutilization capacities [4].

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References:

[1] European Commission, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0160, 2024.
[2] A. Irto, S.G.M. Raccuia et al. Microchem. J. 2023, 193, 109183
[3] A. Satira et al. Appl. Sci. 2021, 11(22), 10983.
[4] S. Cataldo et al. Environ. Sci. Pollut. Res. 2022, 29,9023.

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Mapping of local hydrogen peroxide generation on bioactive surfaces by scanning electrochemical microscopy

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Due to the rise of antimicrobial resistance, new formulations and more efficient materials are being investigated for the control of the microbe spread and the fight against harmful pathogens. This is the case of inorganic antimicrobials, which have become popular in different applications. However, it is nowadays essential to estimate correctly and deeply the nature of bioactivity mechanisms and material surface properties with the ultimate goal of developing safer and greener (nano)antimicrobials. For example, we have recently demonstrated the importance of applying a thorough analytical characterization to predict possible toxicity mechanisms[1], thus suggesting specific dose-effect correlations in the case of Cu nanoparticles. In this communication, we present our recent results about ZnO-based materials. Zinc oxide is a widely used antimicrobial whose action mechanism involves multiple processes[2]. In fact, ZnO bioactivity can be ascribed both to the action of reactive oxygen species (ROS) formed by a photocatalytic process and to Zn^{2+} release from the material surface[3]. In this work, scanning electrochemical microscopy (SECM) is used *in situ,* to evaluate if the ROS generation is caused by the Zn^{2+} ions or by the intrinsic ZnO photoactivity[3]. Specifically, the real-time spatially resolved (photo)reactivity of ZnO-based coatings was investigated, monitoring the local oxidation current of hydrogen peroxide, which is the most stable ROS. First, the detailed analytical characterization of the sub-micrometric ZnO-based materials by microscopic (TEM) and spectroscopic (UV-Vis, ATR-FTIR, XPS) investigation will be presented, offering an overview of the material morphology, chemical composition and surface reactivity. Then, the SECM results will be discussed, allowing a point-to-point correlation between the mapping of H_2O_2 electrochemical evolution, and the antimicrobial surface features. Specifically, higher oxidation currents were produced in specific micrometric regions even at dark conditions, hence without the photoactivation of ZnO. The local release of Zn^{2+} ions occurs in proximity of the ZnO structures that are homogenously distributed into the polymeric coatings, and can be associated to the generation of a significant amount of ROS, even under dark, that could be enhanced under UV-illumination.

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References:

[1] M. Izzi, M. Oliver, H. Mateo, G. Palazzo, N. Cioffi, M. Mirò, Nanoscale Advances 2023,5, 6533-6541.
[2] X. Yang, Q. Yu, W. Gao, X. Tang, H. Yi and X. Tang, Ceramics International 2022, 48, 34148–34168.
[3] M. Izzi, M. C. Sportelli, L. Torsi, R. A. Picca and N. Cioffi, ACS Applied Nano Materials 2023, 6, 10881–10902.
[4] F. Conzuelo, A. Schulte, W. Schuhmann, Proceedings of the Royal Society A 2018, 474, 20180409.

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Study on Molecularly Imprinted Polymers obtained sonochemically for the determination of phytosterols from food matrices

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Phytosterols (PSs) are bioactive compounds structurally and functionally similar to cholesterol. They contain an extra methyl, ethyl group, or double bond, and most of their side chains contain 9-10 carbon atoms. PSs have been classified as 4-desmethyl sterols of the cholestan series, which all have double bonds at the C_5 position of the B-ring[1]. These molecules are particularly known for widely range of properties including reduced intestinal cholesterol absorption and potential contributions to the prevention of cardiovascular diseases[2]. PSs are generally classified into three groups based on the number of methyl groups on carbon-4, two (4-dimethyl), one (4-monomethyl), or none (4-desmethyl). Moreover, 4-dimethyl esters and 4-monomethylsterols are metabolic intermediates in the biosynthetic pathway leading to the final product, 4-desmethyl phytosterols, but are usually present at low levels in most plant tissues. These compounds are present in plants, such as seeds, grains and legumes, both in free and conjugated form and they can be found in the form of fatty acyl esters, glycosides and fatty acyl glycosides. The selectivity issue in plant matrices is a challenging task, and classic approach such as solvent or solid phase extraction (SPE) are expensive and not always give the needed selectivity. In this scenario a low cost molecularly imprinted polymers (MIPs) approach for the selective of extraction these compounds was not fully explored. In this work, a fast chemical MIPs synthesis approach for selective extraction of PSs was performed, using cholesterol as a dummy template. The MIPs were used as an adsorbent phase for SPE and combined with a targeted approach using liquid chromatography coupled to tandem mass spectrometry (LC-MS/MS) with atmospheric pressure chemical ionization (APCI). The results showed high selectivity with significant extraction performances and low matrix effect, a principal goal in complex plant matrices. The proposed strategy can be consider as fast and effective method to produced MIPs as extraction tool for the determination of these target compounds.

References:

[1] R.A. Moreau, L. Nystrom, B.D. Whitaker, J.K. Winkler-Moser, D.J. Baer, S.K. Gebauer, K.B. Hicks, 2018, 70, 35–61.
[2] R.A. Othman, M.H. Moghadasian, 2011, 69, 371–382.

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ANA-PO-044

Single Particle Inductively Coupled Plasma Mass Spectrometry (SP-ICP-MS): an innovative approach for inorganic nanoparticles analysis

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During the last two decades, the use of engineered nanoparticles (ENPs) in a wide range of applications has been growing exponentially due to their unique chemical and physical properties. The increasing presence of these materials in consumer products has inevitably led to their release into the environment and, consequently, to their incorporation into the human body[1]. Together with their spread, the need for an in-depth risk assessment and the introduction of global regulations for a safe and sustainable employment of ENPs became evident.

In this context, single particle – inductively coupled plasma – mass spectrometry (SP-ICP-MS) represents a powerful and emerging technique for routine analyses of NPs. In SP mode, the conventional ICP-MS unit operates in time-resolved analysis mode by using higher data acquisition frequencies to detect every signal pulse corresponding to each individual NP reaching the ICP[2]. Through a single analysis, SP-ICP-MS can provide a wide range of information, such as chemical composition, size distribution and particle number and mass concentrations, overcoming many of the limitations specific to techniques traditionally used for nanomaterials characterization[3].

In this work, the development of analytical methods for the analysis of different kinds of inorganic NPs (e.g. Au, SiO_2, Ni) will be described. Besides illustrating all the fundamental aspects concerning the analysis, the main challenges in rendering SP-ICP-MS a routine approach, especially for environmental studies, will be underlined.

References:

[1] M. Resano, M. Aramendía, E. García-Ruiz, A. Bazo, E. Bolea-Fernandez, F. Vanhaecke, *Chem. Sci.* **2022**, *13* (16), 4436–4473.
[2] E. Bolea-Fernandez, D. Leite, A. Rua-Ibarz, L. Balcaen, M. Aramendía, M. Resano, F. Vanhaecke, *J. Anal. At. Spectrom.* **2017**, *32* (11), 2140–2152.
[3] A. Rua-Ibarz, E. Bolea-Fernandez, G. Pozo, X. Dominguez-Benetton, F. Vanhaecke, K. Tirez, *J. Anal. At. Spectrom.* **2020**, *35* (9), 2023–2032.

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Photoinduced oxidation of microplastics in aqueous media: a study of the degradation products

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The presence of plastic waste is recognized as a significant worldwide environmental hazard, with inadequate handling and disposal practices resulting in escalating levels in natural surroundings. Of recent interest is the breakdown of plastics into particles ranging from macroscopic to microscopic, and even to nano-sized particles measuring less than 1µm. At the nano level, plastics pose detection challenges and can be dispersed through air, soil, and water environments. Thus, studying the degradation patterns of plastics is necessary for accurate evaluation of their fate in the environment[1]. Among plastics, expandable plastics offer numerous advantages, including excellent energy absorption, impressive shock and fire resistance, exceptional thermal insulation properties, resistance to water and chemicals etc. These properties make them ideal for use in protective packaging solutions, where they help minimize damage during transportation and provide thermal insulation, among other benefits[2]. In this study, we have acquired engineered expandable acrylonitrile based microplastics to study its UV induced degradation and (photo)-oxidation, using mass spectrometry and microscopy (scanning acoustic microscope, SAM). We observed that microplastics release organic compounds in liquid phase upon degradation and most of them are byproducts of the polymerization process. SEM analysis has been carried out to acquire the morphological information of the polymers and it has been observed that these spherical microplastics ruptured when subjected to degradation. In this presentation we will discuss the degradation of these microplastics upon irradiation using UV light and H_2O_2, and we present the procedures used to study microplastic degradation under environmental-like conditions.

References:

[1] O. S. Alimi, J.F. Budarz, L. M. Hernandez, N. Tufenkji, **2018**, *52* (4), 1704–1724.
[2] J. Lu, D. Wang, P. Jiang, S. Zhang, Z. Chen, S. Bourbigot, G. Fontaine, M. Wei, **2021**, *305*, 124773.

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FFF multidetection for direct, real-time, size-resolved measurements of drug release from conjugates of biocompatible gold nanoparticles

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The conjugates of gold nanoparticles (AuNPs) and protein are promising systems for drug delivery. Because of its bioaccumulation, targeting, biocompatibility, and surface properties, albumin can transport diverse therapeutic systems in a localized way, which is denoted "spatially controlled release". The interesting optical properties of AuNPs allow them to be monitored using imaging tools, and the photothermal effect can release adsorbed molecules on the AuNP surface, thereby temporally controlling drug release[1].

Curcumin (Cur) is a polyphenolic compound extracted from the rhizomes of Curcuma longa. It is particularly attractive for its antioxidant, antimicrobial, anti-inflammatory, and anticancer effects. This study presents the first application of Asymmetric flow field-flow fractionation (AF4) with on-line detectors like UV/vis and multi-angle light scattering to quantify release profiles of curcumin from Au-BSA conjugates nanoparticles. The main drug carrier, Au-BSA conjugates for improving the bioavailability of curcumin, have been studied in detail in previous work[2].

In contrast to conventional measurements requiring separation of the NPs and dissolved drugs (typically by dialysis) prior to quantification, AF4 provides in situ removal of unincorporated drugs, while the combination of online UV detection selectively provides the entrapped drug concentrations, and hence the drug release information. In the synthesis stage, with the 3D UV-vis spectrum, we can further detect the changes of different species in the incubation solution, especially the independent binding between the drug and excess BSA provides a further basis for the quantification of drug loading. Further coupling with online multi-angle light scattering (MALS) and offline dynamic light scattering (DLS) allows us to monitor the size changing of Au-BSA-Cur carrier at the drug burst release stage. In addition, The factor I 401 nm/ I 530 nm (signal intensity of nanocarriers at 401 nm and 530 nm) as an index to judge the drug loading and release greatly avoids errors caused by stability and environmental changes, while the factor at no-load is 0.54 ±0.01 (n>3).

Overall, with the support of the dialysis models and AF4 technique, we are able to evaluate the Au-BSA-Cur drug carrier from the synthesis to the release stage completely, and the assistance of multi-detectors enables us to accurately monitor the changes in each stage.

References:

[1] K. Bolaños, M. J. Kogan, E. Araya, 2019, 14, 6387-6406.
[2] J. Wang, S. Giordani, V. Marassi, B. Roda, P. Reschiglian, A, Zattoni, 2022, *3.*

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A RPLC-APCI-FTMS method to identify and quantify major free sterols in *Brassicaceae* innovative vegetable products

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Plant sterols (PSs) are secondary metabolites originating from isoprene, occurring in plants in various forms, including free sterols (FSs), esters of fatty acids, steryl glycosides and acyl steryl glycosides[1]. Particularly, PSs are principal components of raft-domains of plasma membrane, in which they exhibit self-association properties with sphingolipids; through these interactions, they can regulate membrane fluidity and permeability[2]. PSs are considered bioactive substances due to their ability to lower blood cholesterol levels and to exert anti-obesity, anti-diabetic and anti-inflammatory activities[3]. In the last decade, with the increasing attention to healthy eating and lifestyle, the interest in fresh, ready to eat innovative vegetables, such as microgreens and baby leaves, including compounds with a nutraceutical potential, like PSs, has been on the rise. The characterization of FSs using reversed-phase liquid chromatography coupled to high-resolution Fourier-transform mass spectrometry with atmospheric pressure chemical ionization (RPLC-APCI-FTMS) has thus been recently undertaken in our laboratories. The attention has been focused on microgreens and baby leaves of *Brassicaceae* species such as broccoli raab and kale, already known as sources of bioactive compounds[4], including PSs, recently identified in these products using GC-MS[5]. In the present work, the ability of RPLC to enhance the separation of PSs and of APCI to efficiently ionize these compounds will be demonstrated. The developed RPLC-APCI-FTMS method enabled the detection of major FS, such as campesterol, β-sitosterol and stigmasterol, its isomers isofucosterol and Δ7-avenasterol, brassicasterol and cholesterol, in the extracts of broccoli raab and kale microgreens and baby leaves. Moreover, the RPLC-APCI-FTMS method was validated to quantify FSs in these innovative vegetables and, for comparison, in corresponding adult forms. The obtained results show that β-sitosterol and campesterol are the most abundant FSs in the examined vegetables; other FSs are principally present in microgreens while their concentration levels are below the method detection limits in adult forms, thus corroborating the nutraceutical potential of innovative vegetable products.

References:

[1] J.N. Valitova *et al*., Biochemistry, 2016, 81, 819-834.
[2] S. Mongrand *et al*., Trends in Plant Science, 2010, 15, 656-663.
[3] P. Poudel *et al*., Natural Secondary Metabolities: From Nature, Through Science, to Industry, 2023, 285-319.
[4] D. Ramirez *et al*., International Journal of Molecular Sciences, 2020, 21, 1-21.
[5] A. Castellaneta *et al*., Journal of Steroid Biochemistry and Molecular Biology, 2023, 232, 1-10.

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Elemental characterization of PM2.5 from two alpine locations of Aosta Valley

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The interest on high mountain sites as observatory for the study of atmosphere composition is growing in the last years. In fact, the use of these sites has many advantages, among which to get insight about the background atmospheric composition, highlight the influences of surround anthropized regions on remote areas, to study the long-range transport of substances in the free troposphere (e.g., Saharan dust events)[1].

In this work we present the inorganic elemental composition of aerosol PM2.5 collected in 2022 at two different sites of Aosta Valley. The first site was near the village of La Thuile (1637 m a.s.l.) and can be classified as medium-mountain rural site; the sampling activity were performed in May and July. The second site was the CNR laboratory Testa Grigia on the Plateau Rosà (3480 m a.s.l.), that can be considered a glacier site of high mountain, and the sampling activity was performed in the month of August. In our knowledge this is the first attempt to study the elemental composition of PM at this site. The prospective of this work would be to extend the monitoring network of PM in high mountain supporting the other national observatories (e.g., Monte Cimone, Col Margherita, Monte Martano).

The sampling of PM2.5 was performed by a low volume aerosol sampler on quartz filters with a daily resolution. The filters have been mineralized according to UNI EN 14902:2005 by microwaves acid digestion. The elements (Ca, K, Mg, Al e Sc, Ti, V, Mn, Fe, Co, As, Sr, Ba, Cr, Ni, Zn, Mo, Cd, Pb, and rare Earth elements) were analysed by ICP-AES or SF-ICP-MS according to their concentration. Crustal enrichment factors have been calculated respect Al revealing that Cu, Ni, Mo, Cr, Pb, Cd, Zn, and Sc are affected by sources different from the crustal one, most probably linked to anthropogenic emission. Multivariate analysis (PCA, cluster analysis) has been performed to extract information from the whole dataset about correlation among the elements' behaviour and differences and similarities between the samples[2]. Events of incoming air masses with higher amounts of aerosol than background level have been recorded at both the sites. Back trajectory analysis will be performed to infer about the provenience of these air masses[3].

References:

[1] S. Okamoto, H. Tanimoto, Progress in Earth and Planetary Science 2016, 3, 1-52
[2] R. Bro, A.K. Smilde, Analytical Methods 2014, 6, 2812-2831
[3] B. Moroni, S. Crocchianti, C. Petroselli, R. Selvaggi, S. Beccagli, R. Traversi, D. Cappelletti, Rendiconti Lincei, 30, 337-349

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Transducer/Aptamer Interface optimization for the design of electrochemical biosensors for biomedical applications

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Keywords: Electroanalysis, Sensors-BioSensors, Spectroscopy, Aptamers, Polymers.

The biosensors field has become quite a hot topic, especially from an electrochemical point of view, with interests ranging from the biomedical and health-care to biological and engineering fields. In the recent years, a peculiar class of biological species, the aptamers, received high attentions: these bioreceptors which demonstrated pretty good characteristics as sensing platforms, such as high stability and reproducibility, easy chemical modification, enhanced target affinity and ease / cost-effectiveness[1]: these features grant good performances and a large amount of applications[2]. Different aptamers were tested, focusing on *Listeria monocytogenes* specific aptamers. In order to anchor the aptamers to the electrode surfaces, different polymer were used, such as polydopamine and its derivatives (i.e L-DOPA): such polymers were electrochemically deposited onto the electrode surface, with different concentrations. To fully studies the sensors surface functionalization, step-by-step, Cyclic Voltammetry, EIS, FT-IR, ATR, Raman and XPS techniques were used.

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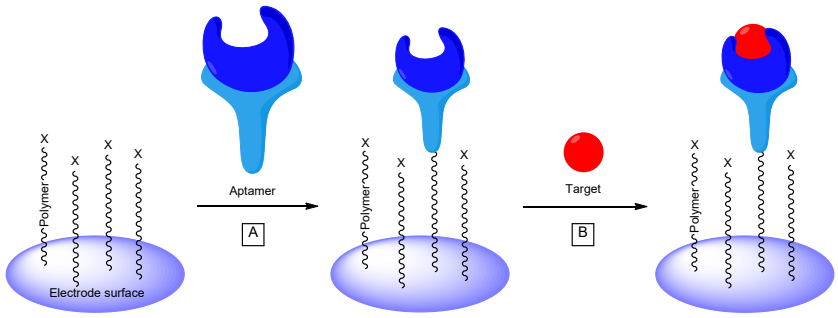

Figure 1: Scheme regarding the mechanism involved in the biosensing process; [A] Aptamer binding to the polymer surface; [B] Target molecule binding / detection.

References:

[1] L. Hosseinzadeh, M. Mazloum-Ardakani, Advances in aptasensor technology, *Advances in Clinical Chemistry*, 2020, 99, 237-279.

[2] F. Di Pietrantonio, D. Cannatà, M. Benetti, Biosensor technologies based on nanomaterials, *Func. Nano. Interfaces for Env. And Biom. Applications*, 2019, 181-242.

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Molecularly imprinted polymers as nanosensing tool for the detection of protein contaminants through time-resolved fluorescence spectroscopy

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Molecularly imprinted nanoparticles (nanoMIPs) are synthetic receptors with tailor-made recognition sites prepared by a template-assisted synthesis. NanoMIP-based optical sensors are currently attracting significant interest as they rely on combining the MIP's selective capability with optical techniques that offer exquisite sensitivity, low detection limit and real-time response.[1] In the present work, an optical nanosensor based on MIP was designed for the detection of human serum albumin (HSA) through time-resolved fluorescence spectroscopy (Fig. 1).[2] Fluo-nanoMIPs were physically characterized by dynamic light scattering, showing a hydrodynamic size of about 120 nm. Scanning electron microscopy and atomic force microscopy confirmed the size of the nanoparticles. Steady-state fluorescence spectroscopy was used as a classical method to study the ability of Fluo-nanoMIPs to bind HSA, showing an apparent dissociation constant (Kapp) of 30 pM. Moreover, the cross-reactivity of Fluo-nanoMIPs were tested against different proteins, demonstrating high selectivity for the analyte. Then, a Fluo-nanoMIP-based sensor, challenged with increasing concentrations of HSA, was tested in solution through time-resolved fluorescence spectroscopy. A decrease in fluorescence lifetime decay was detected, and characteristic saturation binding isotherm was observed with a Kapp of 18 pM, a linear dynamic range of 3.0 – 83.5 pM and a limit of detection of 1.26 pM. As a proof of concept, nanosensor was shown to detect HSA spiked in wine, presenting a new potential method for monitoring beverage allergens. Finally, with the idea of knowledge transfer, we attempted to immobilize Fluo-nanoMIP onto a surface to develop a portable, compact and easy-to-use device.

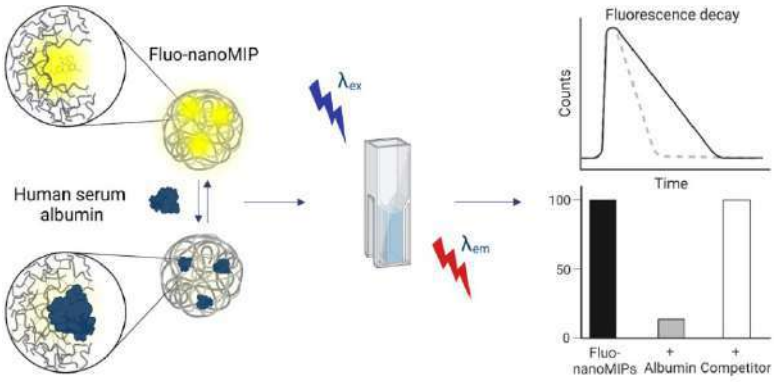

Figure 1: Fluo-nanoMIP-based sensor operation.

References:
[1] Y. Saylan, S. Akgönüllü, H. Yavuz, S. Ünal, A. Denizli, Sensors 2019, 19,1279.
[2] A.M. Bossi, A. Marinangeli, A. Quaranta, L. Pancheri, D. Maniglio, Biosensors 2023, 13, 745.

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ANA-PO-051

Facile and rapid ultrasound-assisted liquid-liquid extraction for the determination of pesticides in extra virgin olive oil followed by chromatography techniques hyphenated to tandem mass spectrometry

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According to the Food and Agriculture Organisation of the United Nations, the extra virgin olive oil world production reached 2.4 million tonnes per year in 2021. This high production is linked to its unique health claim, included in the European Union (EU) Regulation 432/2012. Pest and disease control through the application of pesticides helps to maintain the high production yields. To ensure compliance with maximum pesticide residue levels and to assess consumer exposure to pesticide residues in and on food, multi-annual pesticide residue monitoring programmes (MACPs) are in place within the EU.

The following research involved the development of an easy, rapid, and high sample throughput workflow based on an ultrasound assisted liquid-liquid extraction followed by low-pressure gas chromatography (LPGC) and high-performance liquid chromatography (HPLC) coupled to a triple quadrupole mass spectrometry detection (QqQ MS). 290 pesticide residues were determined in extra virgin olive oil. Separation was achieved in less than 10 min using the LPGC approach, while 15 minutes were necessary for the HPLC analysis. The use of QqQ MS detection guaranteed both the sensitivity and selectivity of the method.

The developed method was validated according to the SANTE/10704/2021 guidelines, showing good recovery, intra-day and inter-day precision, and accuracy results, proving to be a valid and rugged method for the analysis of pesticide residues in extra virgin olive oil. In this regard, the proposed method was applied for the analysis of 50 commercial extra virgin olive oil samples.

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A chemometric approach for the optimization of the synthesis of biomass-based Carbon Quantum Dots

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Since the discovery of Carbon Quantum Dots (CQDs) in 2004,[1] interest in these materials has increased over the last two decades. Moreover, the synthesis of CQDs from green sources offers a valuable alternative for waste management and has received great attention thanks to the biocompatibility and affordability of the starting materials.[2] Among the various preparation strategies, the most common is the green hydrothermal method. However, the literature varies widely on the chosen synthesis conditions. For the hydrothermal treatment using water as solvent, temperature, time, and initial concentration of precursors seem to be the main parameters affecting the properties of the obtained products in terms of particle size and surface functionalization, which in turn reflect on the photoluminescence properties and stability of the CQDs.[3]

This work exploits the chemometric tool of experimental design[4] to optimize the synthesis of biomass-based CQDs. Citrus waste lyophilized bergamot pomace was used as a precursor. An initial hydrothermal synthesis was performed using 250 mg of pomace in 25 mL of water, heated in an autoclave at 180 °C for 6 hours.[5] The experimental design was then conducted according to a 2^k full factorial design while varying the initial amount of precursor (200 and 300 mg of pomace), the temperature (150 and 210 °C), and the reaction time (3 and 6 hours). After purification, the quantum yield was evaluated using quinine sulfate as a reference, and the particle size was evaluated through Transmission Electron Microscopy. The results were used to construct the experimental surface, allowing to determine the optimal conditions for the synthesis of CQDs from bergamot pomace and to clarify which parameter mostly influences the properties of the obtained product.

Aknowledgement: We thank MUR: PNRR - Missione 4, Componente 2, Investimento 1.1 - Bando Prin 2022 - Decreto Direttoriale n. 104 del 02-02-2022. Project title: "Wastezilla: Recycled waste biomass for efficient recovery of critical elements". CUP: J53D23007540006 – project code: PRIN_2022HYH95P_001.

References:

[1] X. Xu, R. Ray, Y. Gu, H. J. Ploehn, L. Gearheart, K. Raker, W.A. Scrivens, J. Am. Chem. Soc. 2004, 40, 12736–12737.
[2] S. Mathew, B. Mathew, Inorg. Chem. Commun. 2023, 156, 111223.
[3] M. Palacio-Vergara, M. Álvarez-Gómez, J. Gallego, D. López, Talanta Open 2023, 8, 100244.
[4] R. Leardi, Anal. Chim. Acta 2009, 1, 161–172.
[5] Z. Wang, Y. Xie, Z. Lei, Y. Lu, G. Wei, S. Liu, C. Xu, Z. Zhang, X. Wang, L. Rao, Anal. Chem. 2019, 15, 9690–9697.

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The dependence on medium and ionic strength of Ga(III) hydrolysis: a critical literature overview

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Gallium is widely employed in plenty of fields, being crucial in many industrial and technological, as well as medical, applications[1,2]. This widespread use, together with its limited availability, concurred to include Ga(III) in the list of the Technologically Critical Elements (TCEs)[1]. As such, its recovery is important for the reutilization in all these applications. Many Ga properties and applications, as well as some recovery processes, take place in aqueous solutions, in which it is present as trivalent Ga species. Being Ga^{3+} a hard Lewis acid, it undergoes strong hydrolysis in aqueous solution, which deeply affects its chemico-physical parameters and reactivity. Consequently, its speciation is dominated by the formation of several hydrolytic species, both mononuclear and polynuclear, with different stability. The most common species in literature are the mononuclear $Ga(OH)^{2+}$, $Ga(OH)_2^+$, $Ga(OH)_{3(aq)}$ and $Ga(OH)_4^-$, while few other polynuclear species are reported by single authors. Collected literature values were critically analyzed in this work, evidencing that hydrolysis constants and solubility products are determined in a wide range of temperature, medium and ionic strength conditions. However, significant discrepancies were found concerning both the nature and the stability of hydrolytic species of Ga^{3+}. In addition, reported data at different temperatures are usually obtained in single media and ionic strengths, and *vice versa*, highlighting the necessity to perform further dedicated experiments, in order to define a correct speciation model as a function of different conditions[3-7]. However, considering the wide number of aqueous solution studies involving this cation, an attempt of rationalization of available data is necessary. For this reason, being most of literature hydrolysis constants of Ga^{3+} reported at T = 298.15 K in various media (e.g., ClO_4^-, NO_3^-, Cl^-, Br^-) and ionic strengths ($0 < I$ / mol dm^{-3} ≤ 1.5), these data were used for the modeling of the dependence on medium and ionic strength, and results are reported in this contribution.

References:

[1] K. Zheng, M.F. Benedetti, E.D. van Hullebusch; J. Environ. Manage., **2023**, 347, 119043.
[2] F. Kurtuldu, N. Mutlu, A.R. Boccaccini, D. Galusek; Bioact. Mater., **2022**, 17, 125-146.
[3] A.E. Martell, R.M. Smith, R.J. Motekaitis; NIST Standard Reference Database 46, vers.8. Gaithersburg, 2004.
[4] D. Pettit, K. Powell; IUPAC Stability Constants Database. Academic Software: Otley, UK, 2004.
[5] P.M. May, D. Rowland, K. Murray, E.F. May; JESS, Joint Expert Speciation System, http://jess.murdoch.edu.au/jess_home.htm, accessed March 2024.
[6] C.F. Baes, R.E. Mesmer; The Hydrolysis of Cations. John Wyley & Sons: New York, **1976**.
[7] P.L. Brown, C. Ekberg; Hydrolysis of metal ions, Wiley-VCH Verlag GmbH & Co. **2016**.

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Retention behavior of Porous Graphitic Carbon stationary phases under High Temperature Supercritical Fluid Chromatography conditions

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Porous Graphitic Carbon has been known as an HPLC stationary phase since the 1980s; the most significant benefits of PGC materials are their stability at very high temperatures (250 °C) and a wide pH range (1-14), as well as the absence of free silanol groups, which could influence analyte retention properties.

The planar graphite-like sheet functionality of PGC affords unique retention mechanism of polar compounds and separation of structurally related analytes, and extreme chemical stability. Chromatographic behaviour of PGCs may be summarised as follows: i) polar retention effect (PREG), whereby solutes of increasing polarity showed a high affinity towards the graphite surface compared to conventional alkyl-bonded silicas, ii) increased retention of non-polar compounds (based on dispersive interactions), iii) increased selectivity towards structurally related compounds due to the flat and highly adsorptive surface of the graphite. The strength of interaction further depends on both the molecular area of an analyte in contact with the graphite surface and upon the nature and type of functional groups at the point of interaction with the flat graphite surface.

Following a previous work in which PGC columns were explored under high temperature LC conditions [1], the present research focuses on the investigation of the same column under High Temperature Supercritical Fluid Chromatography.

A new instrument configuration has been developed in this study: an SFC system was used. This instrument was interfaced to a GC oven, to heat the PGC column up to 200° C. In this prototype instrumentation, in order to achieve a fast and efficient heating of the eluent coming from the autosampler prior to enter into the column, a pre-heating tube was interposed between the autosampler outlet and the column inlet.

Homologue series of parabens, nitroalkanes and pairs of cis-trans isomers were used as *probes*. The performance of the analytical method was evaluated in terms of retention factor, number of theoretical plates per meter, resolution, peak width, and tailing factor.

Moreover, the greenness was quantitatively estimated to demonstrate the further advantage arising from the use of SFC under high temperature conditions to enhance selectivity and method rapidity, minimizing the use of organic modifier.

[1] R. La Tella, F. Rigano, C.R. Corman, G.A. Odugbesi, P. Donato, P. Dugo, L. Mondello, LCGC Supplements, 36 (s5).

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Analytical characterization and synergic evaluation of volatile terpenes of selected *β*-caryophyllene containing spices for diabetes treatment

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Diabetes prevalence is steadily increasing worldwide, estimated to reach over 300 million cases by 2030. Despite the significant progress made using oral anti-diabetic agents, current treatments are far from perfect, requiring to find novel viable alternatives. In this regard, recent studies have shown that some spices and herbs are active in reducing high blood glucose, thanks to the biological activities of the volatile fraction[1]. In this respect, the anti-hyperglycemic effects of sesquiterpenes received attention, since they intervene on biochemical pathways deranged in diabetes mellitus[1]. Among this class of compounds, *β*-caryophyllene (BCP), a volatile sesquiterpene component, has gained interest because of its abundant occurrence, non-psychoactive nature, and dietary availability through consumption of edible plants, including spices.

In this study, an advanced analytical characterization was carried out to define the chemical composition of spices' essential oils, such as black pepper, prior to biological assays. While the quali-quantitative profiling was defined by means of gas chromatography coupled to mass spectrometry (GC-MS) and to flame ionization detection (GC-FID), a deeper investigation about the chiral components was carried out through multidimensional gas chromatography. Moreover, in order to clarify the presence of target components responsible for the therapeutic effect, a preparative GC method was developed. In order to collect the highest amount of target fractions per analysis, wide bore capillary columns were exploited, allowing a consistent reduction in terms of total time analysis. In a first step, this system allowed the efficient isolation of essential oils' sub-fractions, e.g monoterpenes and sesquiterpenes, to be tested with antidiabetic assays. Secondarily, according to the biological results, target components of each sub-fraction have been isolated by means of preparative multidimensional gas chromatography, in heart-cut mode, aiming to demonstrate synergic biological effects.

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References:

[1] H. M. Hashiesh, M.F. N. Meeran, C. Sharma, B. Sadek, J. Al Kaabi, S. K. Ojha, Nutrients, Volume 12, 2963

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ANA-PO-056

Multi-analyte method for biomonitoring studies: legacy and emerging pollutants in human serum

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Environmental research and public health in the 21st century face numerous challenges including the widespread use of substances potentially harmful to humans. Among the various anthropogenic pollutants present in the environment, persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), are particularly concerning due to their adverse effects on human health and wildlife[1]. However, restrictions have led to the emergence of new chemicals now referred to as "emerging contaminants" (ECs), such as novel brominated flame retardants (nBFRs).

The urgent need to gain a comprehensive understanding of everyone's exposome intersects with the necessity to assess how and how much chemicals are absorbed from the environment into the organism itself, along with the practical question of the methodology applied to measure the exposome. In this context, human biomonitoring (HBM) plays a crucial role in establishing exposure and risk assessment[2].

To contribute to the full characterization of the exposome, a new gas chromatography-mass spectrometry (GC-MS) method was developed to analyze target compounds in serum samples. A broad spectrum of legacy and emerging contaminants, such us PCBs and nBFR, were included.

The Design of Experiments (DoE) concept was utilized to optimize the MS assay, as well as critical methodological aspects such as chromatography separation, method sensitivity, and the extraction procedure of the contaminants. A validated model allowing the estimation of conditions for optimal chromatographic analysis was constructed through chemometric evaluation of the data. The proposed method was validated to achieve high analytical performance in terms of selectivity, linearity (R2 >0.995), accuracy (bias%≤ 10%), precision (CV%≤ 10%), robustness, ruggedness, limit of detection, limit of quantitation, recovery, matrix effect, and repeatability according to the international guidelines.

The developed method represents a powerful tool that can be used in HBM to investigate the impact of pollutants on human health and to expand the still limited knowledge on ECs. This method will be useful in future applications in the field of HBM, for example, involving subjects at high risk of exposure, to assess potential correlations between pollutant levels and disease development.

References:

[1] K. C. Jones, Environ. Sci. Technol. 55 (2021) 9400−9412
[2] J. Chatkin, L. Correa, and U. Santos, Clin. Rev. Allergy Immunol. 62 (2022) 72–89.

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A bivalent HF5 analytical approach for isolation and quality control of extracellular vesicles

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Extracellular vesicles (EVs) are key players in cell communication and immune regulation and impact tumor growth and therapy resistance: investigating their composition is essential for unraveling the mechanisms behind malignancy regulation. Characterization of EVs from plasma, a complex biological fluid, needs EV isolation, a challenging process due to their small size, high heterogeneity and low concentration. Common isolation techniques including ultracentrifugation, Size-Exclusion Chromatography (SEC), and ultrafiltration demand significant sample volumes (hundreds of µl) and can compromise the structural and biological activity of EVs by potentially causing damage.

Here we present a bivalent approach exploiting a Hollow-Fiber Flow Field-Flow Fractionation (HF5) system to isolate EVs from plasma and as a tool for performance separation control of commonly used EV isolation techniques, such as SEC. The latter is justified by HF5 ability to provide soft and native separation not achievable by other techniques. Assessing EVs content and size was possible thanks to the spectroscopic, light scattering and fluorescent detectors coupled with the separative system. We previously presented a methodology able to select EV-enriched fractions from human serum for online microfluidic biosensing[1], that in this work we transferred to collect vesicles from the plasma of healthy donors. EVs were both collected from plasma via a standard SEC protocol and through the optimized HF5 separation system, then both samples were re-analyzed with the HF5-multidetection platform to obtain a direct comparison of the profile, relative size and abundance, and aggregation state of the isolated EVs.

SEC- and HF5-derived EVs showed differences in population size and vesicles and protein amount; except for the presence of aggregates in SEC-EVs compared with HF5-EVs, no generalized differences between the two isolation methods were measured, while it emerged a high biological variability from donor to donor.

Isolated EVs were also characterized via Western blot and were positive for markers including ALIX, confirming the presence of specific EV markers. In addition, Flow Cytometry demonstrated the expression of EV marker (CD9, CD81) and platelet-associated markers (CD41a, CD42b) in EVs from both techniques.

References:

[1] Marassi, V.; Giordani, S.; Placci, A.; Punzo, A.; Caliceti, C.; Zattoni, A.; Reschiglian, P.; Roda, B.; Roda, A., *Sensors* 2023, *23* (23), 9432.

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Combining asymmetrical flow field-flow fractionation and analytical pyrolysis to explore model nanoplastics in pollen media

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Microplastic (MP) contamination has been extensively studied, while smaller particles known as nanoplastics (NPs, 1 nm – 1 µm) have been less investigated due to analytical challenges. NPs are generating more concern than MPs because of their potential to interact with organisms at cellular level. Furthermore, they are characterised by a high surface area and strong binding affinity, which enable the absorption of substances. This process can alter the particle's identity within the exposure media trough the formation of the so called eco/bio-corona (EC), a matrix-dependent layer strongly bound to the particle's surface, which may amplify their affinity with organisms. To date, the nature, formation and consequence of the EC on particle's identity remain largely unexplored. However, the investigation of these aspects is of outmost importance to trace M/NP's biodistribution. The present study aims to advance the understanding of the interaction between NPs and pollen. Recent findings indicated the presence of MPs on honeybees, suggesting that M/NPs may be transported by bees along with pollen. To the best of our knowledge, a limited number of studies involve NPs analysis in complex matrices and no studies have been conducted on pollen. To fill this gap, we propose a multi-technical approach. Asymmetrical Flow Field-Flow Fractionation (AF4) allowed hydrodynamic size-based fractionation of species, enabling the separation of fractions of NPs, pollen and their mixture. On-line multi-detection using Diode Array, differential Refractive Index and Multi Angle Light Scattering (MALS DAD-dRI-MALS) provided a size, morphological, and spectroscopical characterization of the fractions. Pyrolysis coupled with Gas-Chromatography and Mass Spectrometry (Py-GC-MS) provided the off-line chemical characterisation at molecular level of NP/pollen media. The development of appropriate pre-treatments of AF4 fractions to obtain samples amenable for quali-quantitative Py-GC-MS was the most challenging aspect. The on-line approach has allowed us to characterize the size modification that NPs undergo in the presence of the water-soluble macromolecular pollen species, as well as to assess the formation of EC around the particles. The off-line coupling with Py-GC-MS enabled the chemical characterization of pollen species and NPs, showing the potential to provide insight of the EC composition. Overall, this work represents the first effort in studying how NPs change in a complex matrix, such as an aqueous pollen environment, rather than their mere identification. Increasing and deepening the information in this field can help in elucidating the impact of the EC and NP/matrix interactions on the behavior of NPs in the environment.

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ANA-PO-060

Highly sensitive chemoresistive sensors based on pristine and doped CeO_2 for H_2 detection

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Chemoresistive sensors utilizing metal oxide semiconductors represent one of the most prevalent technologies for gas detection. These sensors are simple and low-cost devices but at the same time capable of rapidly detecting extremely low gas concentrations; on the other hand, they lack sensitivity and need to operate at high temperatures[1]. They are widely employed in various fields such as environmental monitoring, industry safety, and medical diagnostics[2]. In this study, we conducted a comparative analysis of the response exhibited by chemoresistive sensors based on pristine and doped CeO_2 prepared following two distinct fabrication methodologies. The first approach utilized Flame Spray Pyrolysis (FSP), enabling the synthesis and direct deposition of CeO_2 nanoparticles onto interdigitated electrodes (IDEs) through the combustion of liquid precursors in a flame. Additionally, CeO_2 nanoparticles were also synthesised via conventional wet-chemistry and sol-gel processes and deposited onto IDEs via drop-coating and spin-coating. CeO_2 nanoparticles were chemo-physically characterised using XRD, IR, DLS, BET, TGA, UV-Vis and ICP techniques to investigate their composition, dimensions, surface area, thermal stability, and band gap. Subsequently, the sensors were subjected to various gaseous analytes, and their performance was evaluated by comparing the outcomes of the different synthesis and deposition approaches. The most promising sensors showed selectivity to methanol over ethanol and to xylene over toluene and benzene; furthermore, Pd-doped CeO_2 sensors were found to be able to detect down to 150 ppb of hydrogen at room temperature.

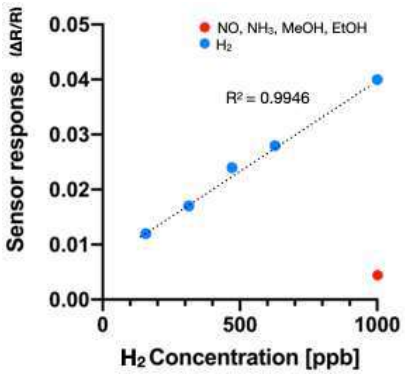

Figure1: Pd-doped CeO_2 sensors prepared with FSP, showing sensitivity to H_2 and absence of any interferences.

References:

[1] Florinel Gabriel Banica, Chemical Sensors and Biosensors: Fundamentals and Applications, 2012, 12, 246-256.
[2] Anshul Kumar Sharma, Aman Mahajan, Carbon Nanomaterials and their Nanocomposite-Based Chemoresistive Gas Sensors, 2023, 8, 223-245.

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All-paper-based analytical tool for hydrogen peroxide monitoring in exhaled breath

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Point-of-care sensing devices are crucial tools in assisting clinicians with fast analyses, easy management, and painless monitoring of patient diseases. Indeed, these sensing tools closely align with the ASSURED criteria set by the World Health Organization, where ASSURED stands for affordable, sensitive, specific, user-friendly, rapid, equipment-free, and deliverable to end-users. This concept was further updated to REASSURED, highlighting the real-time connectivity and ease of specimen collection.
In the last decade, the fabrication of innovative point-of-care sensors has extensively exploited the multifarious functionalities of paper, mainly based on its intrinsic properties such as porosity, capillary forces, and easy modification. Indeed, the paper has attracted considerable attention from the scientific community for electrochemical sensor development due to its numerous advantages, including the absence of external equipment for solution flow, the fabrication of reagent-free devices, and the easiness of multistep analyses using an origami approach. A crucial point of paper usage is its loading capability, enabling the storing of the reagents needed for the analysis. Thanks to this capability, it is possible to expose the paper-based sensor to aerosols, including breath, allowing for the wetting of the paper, with the consequent dissolution of the stored reagents. This allows for the use of exhaled breath aerosol as an analysis matrix, having the advantage of the easiness of its sampling by simply incorporating collecting paper into a face mask worn for some time.
In this overall context, we are developing a whole-paper-based analytical tool for hydrogen peroxide detection in exhaled breath, taking into account the high level of H_2O_2 in lung-associated diseases. In this work, we leverage the use of an office-paper electrochemical screen-printed electrode and a flower-like paper collector integrated into a face mask. In detail, the use of the paper-based collector enables the non-invasive sampling and the further treatment-free analysis of the biological sample carried out by the screen-printed electrode. This electrochemical sensor is ad-hoc modified with carbon black-Prussian Blue nanocomposite, enabling the reliable detection of hydrogen peroxide in the collected condensed aerosol breath. The applicability of the flower-like paper collector is under investigation, considering important features comprising the size, the thickness, and the shape, while the screen-printed sensor is under optimization, taking into account parameters such as linearity range, limit of detection, selectivity, and accuracy.
In conclusion, the proposed analytical platform has the potential to open up new possibilities for the design of face masks as active devices for breath analysis, aiming to facilitate health management and improve the quality of patient life.

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ANA-PO-062

A potentiometric pH sensor for monitoring chronic wounds

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Chronic wounds, defined as those persisting beyond three months without healing, pose a significant challenge to the healthcare system, exerting a substantial toll on patients' quality of life and necessitating considerable treatment resources. Parameters such as pH and temperature serve as valuable indicators of wound status and its progression towards healing, as these parameters usually decrease as the wound progresses towards healing [1]. In this work, a potentiometric pH sensor with integrated thermistors was devised to monitor both pH and temperature of a wound (Figure 1). The sensor fabrication involved electropolymerization of polyaniline onto a carbon screen printed electrode, which served as the pH-sensitive material. Furthermore, modification of the Ag/AgCl reference electrode with a poly-acrylic acid hydrogel was implemented to enhance both its electrical stability and adhesion to the skin. The sensor exhibited a linear response across the pH range of 3 to 10 in both liquid solutions and on pH-controlled semi-solid agar plates, effectively encompassing the potential pH variations in real wound scenarios. Finally, this sensor was able to measure pH of a real sample of wound exudate with an error within ±0.2 points of pH when compared with the results obtained with a reference glass electrode.

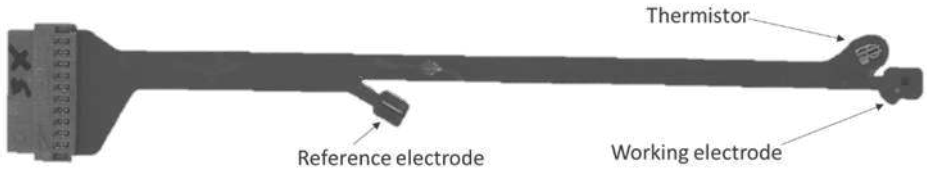

Figure 1: A picture of the potentiometric sensor.

References:

[1] L. A., Schneider, A. Korber, S. Grabbe, J. Dissemond Archives of dermatological research, 2007, 298(9), 413-420.

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ANA-PO-063

Novel low-cost sensor for water pollution monitoring based on Raspberry Pi

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Dissolved organic matter refers to a large pool of molecules present in freshwater environments, a major fraction of which are optically active, allowing them to be used as proxies for the analysis of changes in water quality[1]. Monitoring typically involves in-situ sampling and laboratory analysis (using spectrophotometer and fluorometer) or calibrated sondes, both of which present a number of analytical (scattering, transport) and practical (cost, calibration) challenges for large scale studies. Although different low-cost sensors working in the UV-Vis range have been recently developed, their performance have not been sufficiently validated and the results of the analysis still require additional equipment for data sharing[2]. Herein, we present a Raspberry Pi based low-cost sensor with a light emitting diode (LED) as RGB light source and light dependent resistors (LDR) for the visible light while for the ultraviolet region a modular UV-light sensor. The single-board computer (Raspberry Pi Zero W) performs calibration, data processing and datasharing, allowing for real-time in-situ measurements of chromophoric and fluorescent dissolved organic matter for water quality assessment. Data acquired from the sensor were compared with a laboratory spectrophotometer, showing high accuracy and precision. The low cost organic matter sensor is currently at a technology readiness level 4.

References:

[1] F, Zhang et al., Phys. Chem. Earth, 2020, 118–119.
[2] R, Bullis et al.” Journal of Chemical Education, 2021, 98(12), 3892–97.

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ANA-PO-064

Exploring Trikafta Therapy Effects on Exhaled Breath Molecules by Comprehensive Two-Dimensional GCxGC-Q-TOF

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Background: The introduction of Trikafta therapy has significantly improved the quality of life for individuals affected by cystic fibrosis (FDA approved in late 2019).[1] We investigated the possible effects of Trikafta therapy on exhaled breath chemical composition which may allow to obtain clinically relevant information about disease and treatment progression directly from the breath samples.

Methods: Mixed breath samples were collected at the University Children's Hospital Zurich from 19 patients (12-18 years) in 2L handmade Nalophan bags. An aliquot (250 mL) of breath was transferred at 50 mL/min into sorbent tubes (packed with 250 mg of Tenax GR 60/80 mesh)[2] and then analysed with thermal desorption unit (TD) coupled with a comprehensive two-dimensional gas chromatography (GCxGC) connected to a quadrupole time-of-flight mass spectrometer (Q-TOF).[3]

Results: We could tentatively identify 166 molecules which were significantly increased for the breath vs. room samples. We investigated the differences in breath chemical composition during Trikafta therapy (ANOVA with post-hoc t-test with p-value < 0.01) which resulted in 25 significantly different compounds (12 endogenous, 3 unknowns, 10 anthropogenic). The endogenous breath volatiles were mainly related to energy metabolism and often lipid peroxidation (Figure 1).

Conclusion: We can report significant differences in exhaled breath molecules after Trikafta therapy.

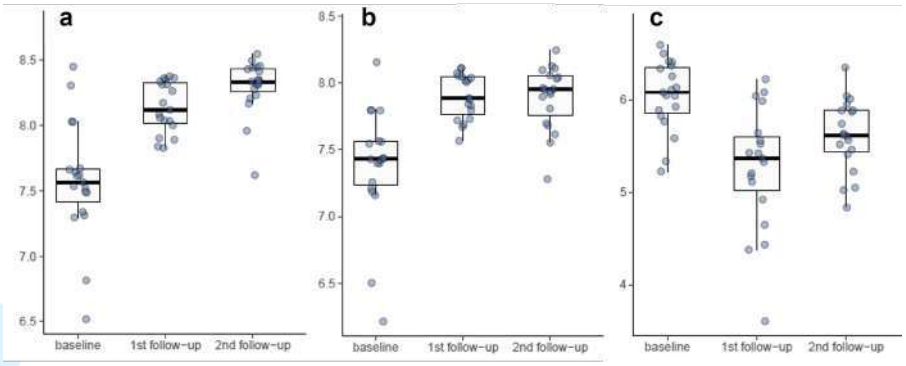

Figure 1: Box plots for three endogenous compounds with: a) acetone, b) pentane, and c) methyl octanoate.

References:

[1] M. Bacalhau, Pharmaceuticals 2023, 16, 410.
[2] S. Ghimenti, J. Breath Res. 2015, 9, 047110.
[3] M. Ripszam, T. Bruderer, Talanta 2023, 257, 124333.

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ANA-PO-065

Development and application of an electrochemical sensor for the detection of Benzophenone-3

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The presence of emerging microcontaminants, including organic UV filters (OUVAs), has been detected worldwide in the aquatic ecosystems. These pollutants, originated from various anthropogenic sources, can persist and transform within wastewater treatment plants (WWTPs)[1], posing a potential environmental hazard.

In this framework, this research presents an innovative electrochemical sensor based on molecularly imprinted polymers (MIPs) for the selective detection of Benzophenone-3 (BP-3), one of the OUVA most spread in the aquatic environment[2], to overcome the analytical challenges related to the quantification of this class of contaminants in wastewater samples.

Different monomers, gold screen-printed electrodes and cyclic voltammetry conditions were tested to select the best parameters for the electropolymerization of the MIP layer. The template washing step, polymer surface blocking and analyte rebinding conditions were also optimized to maximize the selectivity and sensitivity. Electrochemical detection was performed using electrochemical impedance spectroscopy (EIS) supported by an electrochemical probe. In addition, cross-reactivity tests were carried out in the presence of possible interferents, selected on the basis of their size, chemical structure and occurrence in wastewater samples. All the tests were conducted in parallel, using both MIP electrodes and non-imprinted polymer (NIP) electrodes. The sensor demonstrated a significant selectivity for the target analyte, showing an imprinting factor of 55, a linear range between 0.01 and 1 µM and a limit of detection of 5 nM.

The sensor has also been tested with real WWTP effluent samples previously spiked with a known concentration of BP-3, demonstrating no compromised analytical performance despite the complexity of the matrix.

In conclusion, the study showed interesting results that may lead to a specific and cost-effective approach, allowing widespread monitoring and supporting early detection of the target compound in wastewater samples.

References:

[1] N. B. Turan, H. S. Erkan, G. O. Engin, Process. Saf. Environ. Prot. 2021, 146, 77–84.
[2] F. Mao, Y. He, K. Y-H. Gin, Environ. Sci.: Water Res. Technol. 2019, 5, 209–223.

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ANA-PO-066

Laser-Induced Graphene electrochemical aptasensor for the detection of *Escherichia coli*

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Detecting and identifying pathogenic microorganisms is a matter of critical importance, due to the significant impact of them on both healthcare systems and economies. Laser-Induced Graphene (LIG) is a novel promising material that stands out and attracts interest due to its many properties, including mechanical resistance, high surface area, and easy and streamlined production processes[1]. These attributes have opened possibilities to develop low-cost and portable devices that can fulfill the needs of point-of-care applications. In this work, a LIG electrode (Fig. 1A) covalently functionalized with two different aptamers (P12-55 and P12-31[2]) was used for the development of an aptasensor for detecting E. coli. Using electrochemical impedance spectroscopy, the change in the charge transfer resistance (R_{CT}) of the aptasensor was monitored upon interaction with bacteria. The aptasensor showed a linear response in the presence of E. coli within 10^0 – 10^2 CFU/mL when tested in phosphate buffer saline (PBS) solution. Notably, the biosensor displayed minimal response in presence of Staphylococcus aureus and Pseudomonas aeruginosa, proving to be selective for E. coli. Furthermore, the sensor was calibrated using urine samples spiked with a known concentration of E. coli cells (Fig. 1B).

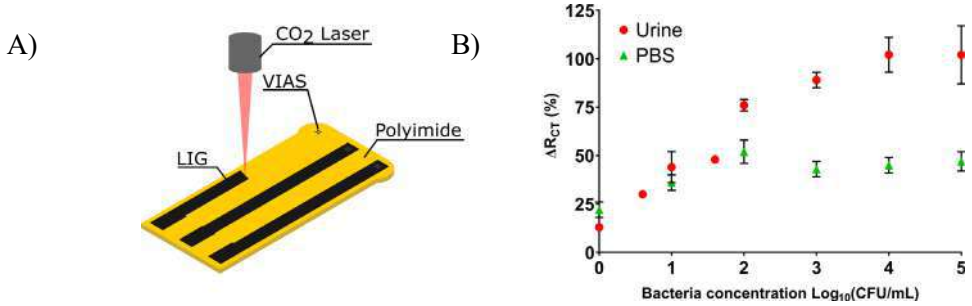

Figure 1: A) LIG electrodes scribed on polyimide. B) Calibration curves at increasing concentration of E. coli in phosphate buffer saline and in urine.

References:

[1] Vivaldi F., Dallinger A., Bonini A., Poma, N., Sembranti L., Biagini D., Salvo P., Greco F., Di Francesco F., ACS Applied Materials and Interfaces 13 (2021) 30245–30260.

[2] Marton, S., Cleto, F., Krieger, M. A., & Cardoso, J. (2016). Isolation of an aptamer that binds specifically to E. coli. *PloS one*, *11*(4), e0153637.

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ANA-PO-067

Sustainable LSPR-based platform for trace-detection of analytes in complex matrices

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In the last decades, several colorimetric sensor arrays have emerged as low-cost optoelectronic devices for the detection of various compounds. Among these, a class of sensors based on noble metal nanoparticles (NPs) has recently gained great interest. Gold and silver NPs, functionalized with specific receptors, have demonstrated to be powerful tools for trace detection of analytes of interest in various fields, including the food industry, environmental chemistry, and cultural heritage conservation.[1] These sensors exploit Localised Surface Plasmon Resonance (LSPR), offering remarkable advantages for analyte detection at exceptionally low concentrations. The mechanism behind these sensors relies on variations in the LSPR through NPs aggregation occurring upon the presence of the analyte, resulting in a shift of the plasmonic absorption and the corresponding colour change.

Another application of NPs, still based on LSPR and well-developed for trace-detection, is Surface Enhanced Raman Scattering (SERS) spectroscopy, consisting of the great amplification of the Raman signal of analytes in proximity to the metal NP. SERS is a powerful analytical technique that provides detailed information about the chemical composition of materials. It has applications in the conservation of cultural heritage objects, and has been already employed for the identification of molecule-specific fingerprint signals in a wide range of applications. The need for sustainable, uniform and flexible SERS platforms [2] has led to introducing metal NPs into polymeric brushes, opening new perspectives for composite nanostructured materials featuring unique mechanical, electrical and optoelectrical properties. Additionally, the gel-brush network has demonstrated to stabilise the NPs and induce their uniform spatial distribution.[3]

We report here on the synthesis and characterization of a new sustainable sensor made of properly functionalized silver nanoparticles (AgNPs) fixed on a polymeric substrate, to be used both as a sampling device and detection system. Different synthetic pathways were experimented, while the substrates were characterised through microscopic and spectroscopic techniques. The SERS performances were tested for probe molecules, which showed a potential for low concentration detection, potentially applicable on analytes of interest for different matrices.

References:

[1] K.M. Mayer, J.H. Hafner, Chemical Reviews 2011, 3828 – 3857.
[2] Y. Zhu, M. Li, D. Yu, L. Yang, Talanta 2014, 117 – 124.
[3] F. Costantini, E.M. Benetti, R.M. Tiggelaar, H.J.G.E. Gardeniers, D.N. Reinhoudt, J. Huskens, G.J. Vancso, W. Verboom, Chemistry European J. 2010, 12406 – 12411.

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ANA-PO-068

Validation of multi-step analytical protocols for microplastics detection in lipid-rich matrices

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The increasing amount of microplastics (MPs) in the environment has raised serious concern about human exposure to MPs in food. Several methods have been developed to extract and detect MPs in food matrices[1]. However, complex matrices, such as those rich in lipids, often require multiple pretreatment steps that, while not affecting the detection of other organic compounds, can lead to sample contamination and reduce recovery rates for MPs analysis. In addition, the presence of lipid material often inhibits filtration processes and compromises the potential chemical characterization of polymers by forming a lipid layer that can absorb radiation.

Here, several multi-step analytical protocols were optimized and validated to extract and purify MPs from different lipid-rich matrices from species suitable for human consumption, such as eggs and fish. First, the lipid content of each matrix was evaluated by gravimetric analysis. Then the most suitable digestion method was evaluated, from basic oxidative digestion to more elaborate enzymatic processes. Recoveries and precision (RSD) were calculated using standards. In addition, the efficiency of the digestion treatment to remove lipid matter was estimated through the compatibility of using μFTIR spectroscopy to chemically characterize the spiked standards. Spectroscopic analysis also allowed the integrity of the polymers to be assessed after the digestion treatment. Quality assurance and quality control were assessed through the entire processes. With the ability to remove all interfering materials, it will be possible to characterize MPs and thus provide an accurate ecological risk assessment on edible species[2].

The presence of MPs in food can pose a risk to human health and animal because of their potential bioaccumulation in organisms and their ability to act as a carrier for other toxic chemicals. Therefore, the validation of methods that accurately detect the presence of MPs in complex matrices such as food is crucial.

This research was supported by the European Union - Next Generation EU. National Recovery and Resilience Plan (NRRP) - M4C2 Investment 1.3 – Research Programme, PE_00000005 "RETURN" - CUP B83C22004820002.

References:

[1] Amanda L. D., Cherie A. M., Frederieke J. K., Front. Environ. Sci. 2020, 8, 563565.
[2] Z. Pan, Q. Liu, R. Jiang et al., Chemosphere 2021, 262, 127876.

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ANA-PO-069

Thread-based Bioluminescent and Chemiluminescent Biosensors for Sustainable and Accessible Point-Of-Care

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Microfluidic thread-based analytical devices (µTADs) are emerging as a new attractive platform for analytical assays due to their advantages in point-of-care (POC) settings such as their large availability, their light weight as well as their low cost. In particular, thread substrate is seen as a valid alternative to microfluidic paper-based analytical device (µPAD) that instead require hydrophobic barriers for the formation of microchannels and show lower mechanical strength, limiting their practical applications in POC assays[1]. Moreover, the µTADs flexible design achieved by sewing, knitting, weaving or twisting them and their small scale offers the possibility to work with reduced sample volumes[1]. All these features make thread-based devices sustainable analytical tools in accordance to the principles of green chemistry[2]. We report a proof-of-principle application of bio-chemiluminescent biosensing on cotton threads (fig. 1a). We first designed a bioluminescent (BL) thread biosensor in which the light-emitting molecule and the enzyme are immobilized onto two separate threads after twisted together to trigger the reaction. This spatial separation increases the shelf-life of the device and the possibility of quantifying different analytes in a small-volume sample (2 µL) in short time (5-10 min). The preliminary tests were performed for detecting ATP, used as indicator for microbial contaminants in food or hygiene monitoring[3]. In parallel, a thread-based chemiluminescent (CL) device which, to the best of our knowledge, has not been reported in literature yet, was tested. In this case, preliminary tests were performed exploiting the enhanced luminol/H_2O_2/horseradish peroxidase (HRP) CL system (fig. 1b), which can be adapted for different diagnostic applications such as the monitoring of the lactate levels for sport medicine[4]. To prompt future applications in point-of-care and point-of need settings we implemented smartphone detection for easy monitoring of the microfluidic thread-based analytical devices.

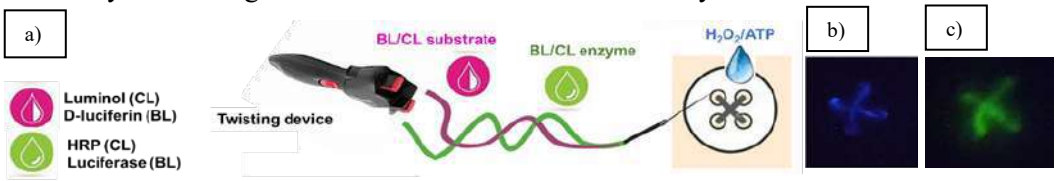

Figure 1: a) Scheme of the optimized thread-based BL-CL biosensor. b) and c) Respectively, BL and CL signals obtained with OnePlus 5 smartphone camera at 3200 ISO settings (30-s acquisition time).

References:

[1] K. Tomimuro, K. Tenda, Y.Ni, Y.Hiruta, M.Merkx, D.Citterio, ACS Sensors (2020), 5(6), 1786–1794.
[2] D. Agustini, L. Fedalto, M. F. Bergamini, L. H. Marcolino-Junior, *Lab on a Chip* (2018), 18(4), 670–678.
[3] M.M. Calabretta, R. Álvarez-Diduk, E. Michelini, A. Roda, A. Merkoçi, *Biosensors and Bioelectronics* (2020), *150*.
[4] A. Roda, M. Guardigli, D. Calabria, M.M. Calabretta, L. Cevenini, E. Michelini, *Analyst* (2014), *139*(24), 6494–6501.

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ANA-PO-070

Development and optimization of a method based on UHPLC and high resolution mass spectrometry for the determination of per- and poly- fluoroalkyl substances (PFAS) in serum

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Per- and poly- fluoroalkyl substances (PFAS) are a large group of compounds consisting of a hydrophobic carbon chain, partially or fully fluorinated, and a terminal hydrophilic group, such as a carboxylic acid, sulfonic acid, amine, or other. PFAS have been used in industry and consumer products since the 1940s because of their useful chemical and physical properties[1] due to their molecular structure. The highly fluorinated portion of the molecules brings them to not degrade through normal chemical, physical, or biological processes[2]. Despite being an attractive industrial property, perfluorocarbon resistance to degradation raises concerns about environmental fate and human health impact[3]. In humans, these substances are not metabolized, but they have a high affinity for proteins and are mainly found in biological samples such as plasma, serum, milk, and tissues[3]. Therefore, biological monitoring of traditional and emerging PFAS is a useful approach to conduct an integrated and representative screening of human exposure to these substances. The purpose of this project was precisely to develop and optimize an analytical method for the determination of different chemical classes of PFAS in serum, using liquid chromatography coupled with high-resolution mass spectrometry (UHPLC-HRMS, equipped with an Orbitrap mass analyzer). A particular focus was set on sample pre-treatment, which proved to be critical in breaking the bonds between proteins and PFAS in order to achieve good recoveries (between 80% and 120%). Pre-treatment was optimized by trying different types of solvents and a washing step after protein precipitation. After this, the optimal conditions were defined using Principal Components Analysis (PCA). Subsequently, the instrumental method (UHPLC-HRMS coupled with online-SPE) was optimized, starting with the online-SPE and the chromatographic conditions and then moving to the conditions concerning mass spectrometry. Validation of the method was performed in accordance with ISO 17025 evaluating linearity, inter- and intraday precision, LOD, LOQ recovery and matrix effect. Control charts were also used to estimate the stability of the instrument. Using this method, more than 25 traditional and emerging PFAS were determined. The method has been tested on real samples to accurately quantify the concentration of these substances in human serum.

This work has been developed in the framework of the SCENARIOS project (funding program H2020, project ID 101037509).

References:

[1] EPA.gov, 2023, https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas
[2] L.G.T. Gaines, American journal of industrial medicine, 2023, 66(5), 353–378.
[3] B. F. Da Silva et al., MethodsX, 2020, 7, 101111.

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ANA-PO-071

Development and optimization of a method based on online-SPE coupled to UHPLC-HRMS for the determination of per- and poly- fluorinated substances in water

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Per- and poly- fluoroalkyl substances (PFAS) are a large group of synthetic chemicals, which represent an important class of emerging contaminants[1]. These compounds are characterized by highly fluorinated alkyl chains that may also contain different functional groups depending on their use. In the last fifty years, they have been used in several industrial sectors and currently, over 9000 compounds belong to this class.

Due to their unique physicochemical properties, they are generally characterized by high persistence in the environment, making PFAS contamination a serious environmental problem. Nowadays, PFAS are widespread in the global environment, including wildlife and humans: they have now been detected at trace levels in both the environment and biota, including water[2]. Dietary intake (from drinking water and food) is considered the main pathway of human exposure to these substances[3], and it can lead to immune, fertility and endocrine dysfunctions. For this reason, it is extremely important to assess the degree of PFAS contamination of waters.

The aim of this work is to develop a method based on online solid phase extraction (online SPE) and high-performance liquid chromatography coupled to high resolution mass spectrometry (UHPLC-HRMS) for the simultaneous determination of almost 40 PFAS in water. The validation was carried out according to ISO17025 and the analytical method was further applied to the analysis of real water samples. Recent studies normally found in the literature concerning the use of online SPE include the simultaneous determination of a restricted number of PFAS substances[4], whereas this work aims to broaden the number of compounds determined simultaneously to include more emerging substances and putting efforts in increasing the sensitivities. This may then facilitate analyses for environmental monitoring and perhaps promote future regulations, especially regarding relatively newer compounds.

The work is conceived within the framework of the SCENARIOS project, which is funded by the European Union's H2020 programme (Grant Agreement No. 101037509).

References:

[1] R.A. Brase, E.J. Mullin, D.C. Spink, 2021, 22, 1 - 30.
[2] Z. Abunada, M.Y.D. Alazaiza, M.J.K. Bashir, 2020, 12, 3590 – 3618.
[3] A.O. De Silva, J.M. Armitage et al., 2021, 40, 631 – 657.
[4] M. Zhong, T. Wang, C. Qi, G. Peng, M. Lu, J. Huang, L. Blaney, G. Yu, 2019, 1602, 350 – 358.

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ANA-PO-072

NIAS migration from polymeric materials in contact with dry food: optimization and validation of the extraction procedure

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The release of Non-Intentionally Added Substances (NIAS) from polymeric articles into food poses a health risk. This scientific work was focused on the optimization of a analytical method that allows the identification and quantification of NIAS migration which could occur following contact of a silo's polyurethane gasket intended for dry food contact. The migration of aniline, acetyltributylcitrate, bis(2-ethylhexyl)adipate, 2,6-tertbutylhydroxytoluene (BHT) and 1,4-butanediol from this polymeric manufact was studied.

Migration tests were carried out as indicated by law regulation (EU Regulation 10/2011) simulating the worst conditions inside the silo [1], using Tenax as appropriate food simulant [2], and directly on real dry food (rice, flour, powdered milk, cocoa powder, sugar, corn starch). The analytical method is based on GC-MS analyses. During the method development phase, based on some articles in the literature, several analytical criticalities were evidenced. The most critical were the presence of matrix effect for several real dry food and some very low recovery yields. With the aim of overcoming the problems mentioned, an extraction method has been developed which involves the smallest number of steps possible and avoids the loss of the analytes through volatilisation. Finally, the extraction yields were evaluated and the correct migration values were calculated by external calibration or, where required, employing the standard addition method. Finally, the entire primary validation procedure is performed on the optimized method (Figure 1).
The results obtained show how the process is influenced not only by the chemical nature of the migrant, but also by the physical-chemical nature of the simulant or of the food matrix used.

Figure 1: NIAS determination procedure

References:

[1] I. Reinas, J. Oliveira, J. Pereira, F. Machado, M. F. Poças, 2012, 28, 333–337.
[2] L. Rubio, L. Valverde-Som, L.A. Sarabia, M. C. Ortiz, 2019, 1589, 18-29.

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ANA-PO-073

Enhancing Product Quality Control in Industrial Processes through the Identification of Critical Process Steps

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In industrial processes, guaranteeing the high quality of final products is crucial. For this purpose, it is essential to identify the process phases that mostly affect product quality parameters in order to accurately estimate them before the process is completed. This not only helps to minimize waste and losses, but also enhances environmentally friendly manufacturing practices.

The case-study presented here concerns the industrial production of Acrylonitrile-Butadiene-Styrene (ABS). ABS is currently synthesized through a nine-stage process monitored using multiple sensors installed in different areas of the plant and that acquire physical (temperature, pressure, flow rate measurements) and chemical (near-infrared spectra) information during its progression. The objective of this work is to determine at which process stage the information acquired is sufficient for a correct prediction of ABS quality. To this end, various multivariate regression methodologies (namely, Partial Least Squares – PLS – Local-Weighted PLS – LW-PLS[1] – MultiBlock PLS – MB-PLS – Locally Weighted MultiBlock-PLS – LW-MB-PLS – and Response-Oriented Sequential Alternation – ROSA[2]) will be employed to model the ensemble of data blocks resulting from all the process phases in an incremental fashion. In other words, these different data blocks will be sequentially gathered and processed as if they were collected in real time during ABS manufacturing. By assessing how the predictive performance of the aforementioned regression methodologies evolves as the amount of available information increases, this approach will permit to highlight whether satisfactory estimates of ABS quality can be obtained before the end of the production process and, as outlined before, at which exact stage of its time evolution.

References:

[1] M. Lesnoff, M. Metz, J.M. Roger, J. Chemom 2020, 34, e3209
[2] K.H. Liland, T. Næs, U.G. Indahl. J. Chemom., 2016, 30 651–662.

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ANA-PO-074

Recycled cellulose acetate microspheres doped with graphene oxide for the determination of xenobiotics from human urine via in-syringe-dispersive-solid phase extraction

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Biopolymers are a suitable starting point for the development of sustainable sorbent materials thanks to their environmental friendliness, low toxicity, recyclability, and biodegradability. Moreover, most of them can be recovered from waste products, such as cellulose acetate from filters of cigarette butts. Although overlooked until recently, cigarette butts are harmful litter with dramatic effects on the environment being a source of contaminants and bioplastics, namely cellulose acetate. In fact, it was estimated that globally about 6 trillion cigarettes are smoked each year, 70% of which end up polluting terrestrial and aquatic ecosystems.
Looking at this worrying background, this study aimed at: i) developing an effective procedure to recover cellulose acetate from cigarette butt filters; ii) using the recovered biopolymer to prepare a microspheres in which graphene oxide can be dispersed; iii) applying the composite sorbent to isolate xenobiotics from human urine via in-syringe-dispersive-solid phase extraction.
The initial phase of the research was focused on obtaining clean cellulose acetate from cigarette filters. This was achieved by eliminating wrapping paper and unburned tobacco and washing the filters with hot water and hot ethanol to remove most impurities generated during cigarette combustion. The efficacy of the cleaning process was confirmed by characterizing the washed polymer by UV spectroscopy, attenuated total reflection Fourier transform infrared spectroscopy (ATR-FTIR), and thermal analysis (TGA, DSC), and comparing the results with those from pristine cellulose acetate (obtained from unsmoked cigarette filters) taken as a reference. The synthesis of the composite sorbent took advantage of a microemulsion-solidification process in which the organic polymer solution was first forced to a fine dispersion in a saturated water solution of NaCl and n-dodecyl-amine (2% w/v); later on, the polymer was precipitated in form of microspheres shaped by the addition of milli-Q water drop by drop. The sorbent was characterized by ATR-FTIR, TGA and SEM, confirming the graphene oxide dispersion and its morphological characteristics (average diameter = 10-100 µm).
Finally, the microbeads were applied for the determination of several potential xenobiotics (63 analytes from different chemical classes) detectable in human urine performing in-syringe solid phase extraction. In this configuration, the sorbent was packed into a syringe and the device was used to carry out a low-cost, saving-time, simple, and effective method.

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ANA-PO-075

Synthesis of α-, β- and γ-cyclodextrin-based nanosponges as sustainable sorbents for the extraction of pesticides from water samples

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As recommended by the first principle of Green Analytical Chemistry (GAC)[1], direct analyses are the viaticum for sustainable methods. Nevertheless, in cases of analytes present at trace level and/or interfering compounds, a sample pretreatment is essential and, according to the 3rd criteria of Green Sample Preparation[2], sustainable, reusable, and renewable materials are the most attractive alternative to polymeric sorbents. From this point of view, cyclodextrin nanosponges (CD-NS) are biosorbents responding to all these requirements, being harmless, biodegradable, and biocompatible materials, based on CDs which are natural degradation products of the starch (one of the most abundant biomasses in the world)[3]. In this work, CD-NS were prepared by using α, β and γ-CD as the monomers; citric acid as the cross-linker and NaH2PO4 as the catalyst. Such reagents were homogeneously dispersed in the minimum volume of water and the polymerization was carried out at 160°C. The final products showed the distinctive morphology of a sponge and were characterised by means of thermal analysis (TGA, DSC), IR spectroscopy, and SEM imaging. Afterwards, α, β and γ-CD-NS were applied for the dispersive-solid phase extraction of pesticides from environmental water samples. In line with the 8th principle of GAC (multi-analyte or multi-parameter methods are preferred to methods using one analyte at a time) [1], eleven pesticides, belonging to different chemical classes and also including optical and geometric stereoisomers, were considered. In particular, after optimizing the best extraction conditions, the behaviour of the different sponges towards the target analytes was evaluated in terms of recoveries and reproducibility. The analyses were performed by high performance liquid chromatography-tandem mass spectrometry (HPLC-MS/MS) on a cholesteryl analytical column and on a chiral polysaccharide-column to assess the potential capability of stereo-discrimination of the different nanosponges.

References:

[1] A. Gałuszka, Z. Migaszewski, & J. Namieśnik, 2013, *50*, 78-84.
[2] Á. I. López-Lorente, F. Pena-Pereira, S. Pedersen-Bjergaard, V. G. Zuin, S. A. Ozkan, & E. Psillakis, 2022, 148, 116530.
[3] A. Gentili, 2020, 1609, 460654.

ANA-PO-076

Enhancing the specificity of CRISPR-based Sensing Platform via Triplex DNA Probe

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The last years have seen the emergence of Class II CRISPR-based diagnostic technologies as potent molecular diagnostic tool.[1] Among the different Cas effectors CRISPR-Cas12 incorporate both DNA target recognition along with enzyme reconfiguration, activating not only the well-known site-specific cleavage activity but also the collateral a-specific cleavage. As a result, in the presence of FRET-based DNA reporters, this collateral activity generates fluorescence signal amplification upon target binding, enabling highly sensitive diagnostic assays.[2] Cas12a-based detection, however, still exhibits limited specificity in detecting single base mutations on the DNA target.

We present a method to overcome this limitation by utilizing a carefully designed DNA-based hybridization network to switch Cas12a cleavage activity on by combining the superior selectivity of Triplex Clamp-switch probes for DNA/RNA detection.[3] Specifically, the formation of Triplex Clamp-switch probes occurs only in the presence of a homopurine DNA/RNA target in the solution. This triggers the reconfiguration of the DNA-based hybridization network, activating Cas12a's collateral activity and generating a concentration-dependent fluorescence output. By adjusting the pH, we are able to fine control the selectivity of a single mutant base on short DNA targets. This demonstrates how crucial well-planned secondary structures are to enhancing CRISPR-based systems' detection capabilities.

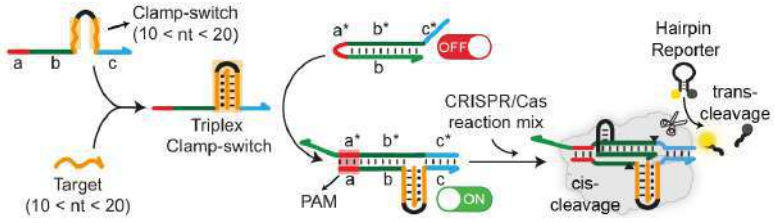

Figure 1: Schematic Clamp-like Triplex forming switch triggering Cas12a cleavage activity.

References:
[1] J.S. Chen, E. Ma, L.B. Harrington, M. Da Costa, X. Tian, J.M. Palefsky, J.A. Doudna, Science 2018, 360(6387), 436-439.
[2] M. Rossetti, R. Merlo, N. Bagheri, D. Moscone, A. Valenti, A. Saha, P.R. Arantes, R. Ippodrino, F. Ricci, I. Treglia, E. Delibato, Nucleic Acids Res 2022, 50.14, 8377-8391
[3] A. Idili, K.W. Plaxco, A. Vallée-Bélisle, F. Ricci, ACS Nano. 2013, 7(12), 10863-9.

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ANA-PO-077

Low-cost Inkjet-Printed nanostructured biosensor based on CRISPR/Cas12a system for pathogen detection

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The escalating global incidence of infectious diseases caused by pathogenic bacteria, especially in developing countries, emphasises the urgent need for rapid and portable pathogen detection devices. As traditional techniques are time consuming, expensive and do not allow for a point-of-need analysis, biosensors represent a valid alternative, because of their low-cost, portability, ease of use and availability for point-of-care/need applications. This study introduces a sensitive and specific electrochemical biosensing platform utilising cost-effective electrodes fabricated by inkjet-printing gold and silver nanoparticles on a plastic substrate[1]. The biosensor exploits the CRISPR/Cas12a system for detecting a specific DNA sequence selected from the genome of the target pathogen[2]. Upon detection, the trans-activity of Cas12a/gRNA is triggered, leading to the cleavage of rationally designed single-strand DNA reporters (linear and hairpin) labelled with methylene blue (ssDNA-MB) and bound to the electrode surface, leading to the decrease of the square wave voltammetry (SWV) MB associated signal. In principle, this sensing mechanism can be adapted to any bacterium by choosing a proper guide RNA to target a specific sequence of its DNA. The biosensor's performance was assessed for two representative pathogens (a Gram-negative, Escherichia coli, and a Gram-positive, Staphylococcus aureus), and results obtained with inkjet-printed gold electrodes were compared with those obtained by commercial screen-printed gold electrodes. Our results show that the use of inkjet-printed nanostructured gold electrodes, which provide a large surface area, in combination with the use of hairpin reporters containing a poly-T loop[3] can increase the sensitivity of the assay corresponding to a signal variation of 86%. DNA targets amplified from various clinically isolated bacteria, have been tested and demonstrate the potential of the proposed platform for point-of-need applications.

References:

[1] M. Urban, G. Rosati, G. Maroli, F. Della Pelle, A. Bonini, L. Sajti, M. Fedel, A. Merkoçi, Small 2023, 2306167.
[2] A. Bonini, N. Poma, F. Vivaldi, A. Kirchhain, P. Salvo, D. Bottai, A. Tavanti, F. Di Francesco, Journal of Pharmaceutical and Biomedical Analysis 2021, 192, 113645.
[3] M. Rossetti, R. Merlo, N. Bagheri, D. Moscone, A. Valenti, A. Saha, P. R. Arantes, R. Ippodrino, F. Ricci, I. Treglia, E. Delibato, J. Van Der Oost, G. Palermo, G. Perugino, A. Porchetta, Nucleic Acids Research 2022, 50 (14), 8377-8391.

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ANA-PO-078

Untargeted fingerprinting by UHPLC-Q-Orbitrap-HRMS to identify geographical origin and farming approach markers in *L. albus* L. samples from southern-center Italy

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Lupin seeds are the edible portion of lupin plants, included in the Fabaceae family. In recent years, they are gaining significant interest worldwide as a cheap alternative to other legume crops, for being stress-tolerant and climate-resilient plants and thanks to their potential nutritional value[1]. In fact, they are rich in proteins (>40%) and fibers (>28%), claiming a low-fat content (<6%); they also constitute a potential source of other nutrients, as minerals and vitamins. Lupins are rich in bioactive phytochemicals, such as polyphenols, phytosterols and triterpenes, providing antioxidant and anti-inflammatory properties; they are also known for a great presence of antinutritive compounds such quinolizidine alkaloids. The chemical composition of lupins could be influenced by several factors such as species or variety, geographical origin, farming practices, environmental stress, harvesting and processing methods[2].

In this work, *L. albus* L. samples originating from four southern-central Italian regions were subjected to an untargeted metabolomics approach using ultra-high performance liquid chromatography coupled to high-resolution mass spectrometry (UHPLC-HRMS). The aim was to distinguish samples based on their geographical origin and subsequently assess the metabolic variances resulting from distinct agricultural practices (conventional vs. organic farming). Unsupervised Principal Component Analysis (PCA) on lupins fingerprints was employed to have an overview of the natural tendency of the samples clustering. Additionally, a supervised Orthogonal Partial Least Square-Discriminant Analysis (OPLS-DA) was used for discriminative purposes, revealing good clustering capability and predicting power for further samples, allowing also the putative identification of over 30 markers, across various classes: alkaloids, amino acids, glycerophospholipids, fatty acids and other miscellaneous compounds.

The results highlighted the impact of the origin and farming techniques on the metabolomic composition and distinctiveness of lupin samples; this could be crucial for cultivation optimization, traceability and quality assessment of lupins, aiming to draw consumers attention and preferences, given their potential nutritional properties.

References:

[1] F. Eugelio, S. Palmieri, F. Fanti, L. Messuri, A. Pepe, D. Compagnone, M. Sergi, Molecules 2023, 24, 1531.
[2] A. Pereira, F. Ramos, A. Sanches Silva, Molecules 2022, 27, 8557.

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ANA-PO-079

Expanding CRISPR-Cas12a Biosensing Toolbox with Synthetic Antibody-DNA Conjugates

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CRISPR/Cas systems have been widely utilized for the development of biosensing platforms for precision molecular diagnostics[1]. Despite significant advances, current CRISPR platforms mainly focus on nucleic acid detection. To fully exploit the advantages of CRISPR-based diagnostics, current research efforts aim to develop CRISPR sensors capable of detecting a wide range of analytes in addition to nucleic acids[2]. In the present work, we integrated the CRISPR-Cas12a detection system with established analytical methods, such as immunoassays, to expand its diagnostic capabilities. Using an innovative approach involving DNA strands conjugated with Anti-IgG antibodies, we implemented two different immunosensing platforms to detect SARS-CoV-2 infection. Specifically, we developed an ELISA assay, CRISPR Enzyme-Linked Immunosorbent Assay (CRISPR-ELISA), and an Immunomagnetic assay, called Cas12a-Linked Immunomagnetic Fluorimetric Assay (CLIF), for the detection of the virus-associated Spike protein. Both assays demonstrated high sensitivity (LOD 3 ng/mL and LOD 12 ng/mL respectively) and specificity for the Spike protein, even in the presence of protein interferers.

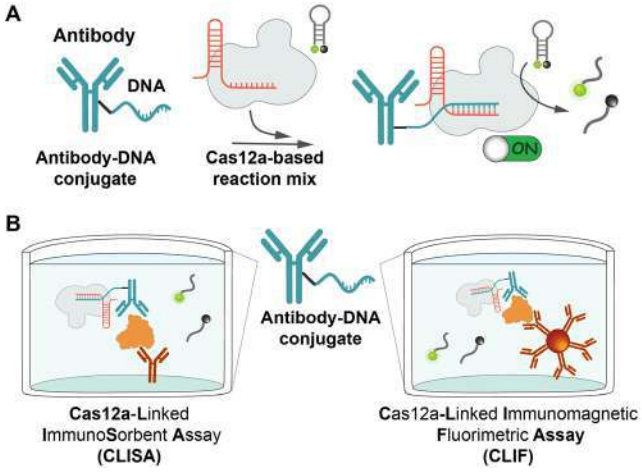

Figure 1: Schematic of the activation of Cas12a trans-cleavage activity on hairpin fluorescence reporters. (A) We explored the use of antibody-DNA conjugate as a recognition element for the detection of the SARS-CoV-2-associated spike protein. We implemented the assay in two formats (B), a standard sandwich ELISA (CRISPR-ELISA) and a sandwich assay based on magnetic beads (CLIF).

References:

[1] F. Deng, R. Sang et al., ChemRxiv 2024, Preprint.
[2] S. Del Giovane, N. Bagheri et al., Elsevier 2024, 172, 117594.

ANA-PO-080

Tungsten-coating as hydrogen permeation barrier on X60 steel

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Hydrogen is an environmentally friendly fuel as it does not generate CO_2. Utilizing pipelines and reservoirs for hydrogen transport and storage are generally made of steel, and hydrogen can cause detrimental effects on their mechanical properties due to a phenomenon called hydrogen embrittlement (HE). Therefore, introducing a barrier in steel is essential to prevent this effect. This research aims to explore tungsten coatings as possible hydrogen permeation barriers (HPB) on X60 steel. The goal is to prevent or at least decrease the hydrogen that can penetrate into the steel and prevent HE.

In this context, physical vapor deposition (PVD) was employed to deposit tungsten onto a X60 steel substrate; the surface morphology and the composition of X60 steel and tungsten-coated X60 steel (W-coated X60 steel) were characterised by scanning electron microscopy- energy dispersive X-ray spectroscopy (SEM-EDS), X-ray photoelectron spectroscopy (XPS) and X-ray fluorescence spectroscopy (XRF). Additionally, an analytical method was optimized for performing hydrogen permeation measurements both on X60 steel and on W-coated X60 steel using Stachurski's cell.

The SEM and XPS results have indicated that a tungsten coating has been deposited on steel, with a thickness of 0.2mm. Preliminary electrochemical tests have shown that the tungsten coated X60 steel exhibits a promising reduction in hydrogen diffusion compared to uncoated steel. The findings from XPS and SEM-EDX analyses will be discussed together with the results obtained from the in-situ electrochemical measurements.

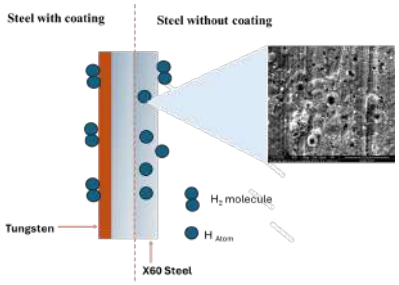

Figure 1: Hydrogen uptake in steel (right) and tungsten as a hydrogen permeation barrier (left)

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ANA-PO-081

Lipidomic Investigation in Plasma of Parkinson's Disease, Multiple System Atrophy and Progressive Supranuclear Palsy Diagnosed Patients

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Parkinson's disease (PD), ranking as the second most prevalent global neurodegenerative disorder, presents a multifaceted clinical profile[1]. The diagnostic process for PD remains a clinical endeavour, reliant on the expertise of healthcare professionals. This lack of definitive diagnostic tests poses significant hurdles, especially during the early stages of the disease, where subtle presentations may lead to misdiagnoses. Furthermore, distinguishing PD from related neurodegenerative disorders with overlapping early-phase symptoms, such as Multiple System Atrophy (MSA) and Progressive Supranuclear Palsy (PSP), poses its own set of complexities. This investigation aimed to characterize possible circulating lipid biomarkers for PD, MSA and PSP by untargeted and semi-targeted lipidomic analysis using LC-HRMS.

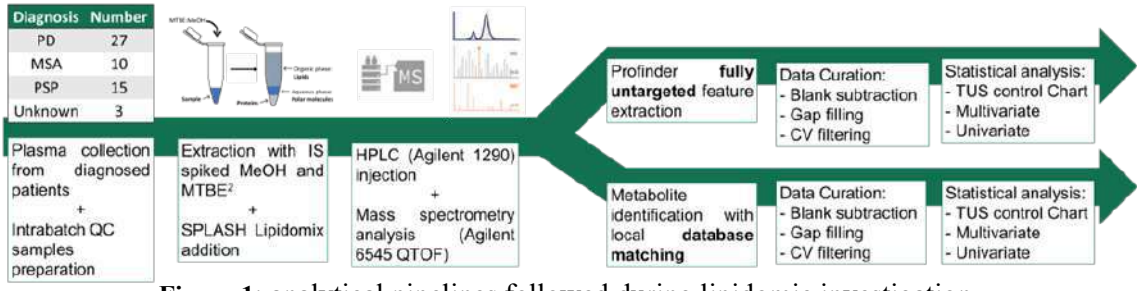

Figure 1: analytical pipelines followed during lipidomic investigation.

The lipidomics investigation was carried out on a HPLC coupled with a QTOF in an iterative DDA (Data Dependent Acquisition) mode. After data acquisition two different processing pipeline were essayed and compared, specifically a fully untargeted approach and a pseudo-targeted one (illustrated in Figure 1).

After dataset cleaning, a normalization method based on Total Useful Signal (TUS) was applied and after normalization both univariate and multivariate analysis were carried out. Finally, we refined our analysis to compare just two different groups: Parkinson's and non-Parkinson's. Employing this approach, we found 40 lipids that exhibited significant differences between these two groups and achieved an acceptable separation through PLS-DA.

References:

[1] J. Jankovic, E. K. Tan. JNNP 2020; 91(8):795-808.
[2] V. Matyash, G Liebisch, T.V. kurzchalia, A. Shevchenki, D. Schwudke, J Lipid Res. 2008, 49(5):1137-46.

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ANA-PO-082

Implementation of polyaniline in biocompatible supports for sensing and energy storage

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Conductive polymers represent an affordable and reliable answer to the stiffness of conventional electronics. Polyaniline (PANI) in particular shows a peculiar doping/dedoping process, with high conductivity and exceptional tuneability. On the other hand, this material is fragile and not flexible. Different supports can enhance the mechanical properties of PANI, donating resilience, tenacity, and flexibility. This contribution would like to study the composite material based on PANI and paper or hydrogel and to report the fabrication of two different biocompatible devices, respectively a paper-like sensor for humidity[1] and an all-in-one supercapacitor (SC)[2]. PANI was polymerized with poly (2-acrylamido-2-methyl-1-propanesulfonic acid) (PAMPSA) for a more mechanically stable structure. With the addition of PAMPSA, the emeraldine state of PANI is achieved, providing enhanced conductivity. For the fabrication of conductive paper, the polymerization was conducted in situ on cellulose fibres, which were then dried and consequently pressed. Humidity sensors were fabricated by cutting the obtained sheets in rectangles. Due to humidity (RH%), cellulose/PANI-PAMPSA conductivity increases and the considered analytical signal is the measured current flow through the material by applying a constant voltage. Another interesting application is in the medical field, as a breath or ECG sensor. We then investigated the insertion of PANI-PAMPSA in polyvinyl alcohol (PVA) hydrogel systems. PVA powder was dissolved in PANI-PAMPSA solution, inducing a physical crosslinking through freeze-thaw cycles and providing a self-healing ability to the SC. Since PANI-based hydrogel partially functions as an electrode, the need of an electrolyte is covered by PVA-H_2SO_4 hydrogel, with a high adhesion between the layers. The resulting structure composes the all-in-one supercapacitor.

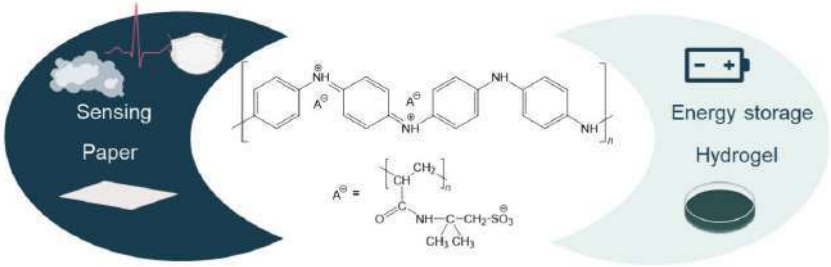

Figure 1: chemical structure of PANI-PAMPSA and a scheme of supports and their respective applications.

References:

[1] Ragazzini, I.; Gualandi, I.; D'Altri, G.; Di Matteo, V.; Yeasmin, L.; Cassani, M. C.; Scavetta, E.; Bernardi, E.; Ballarin, B., *Carbohydr Polym* **2023**, *316*, 121079.
[2] D'Altri, G.; Yeasmin, L.; Di Matteo, V.; Scurti, S.; Giovagnoli, A.; Di Filippo, M. F.; Gualandi, I.; Cassani, M. C.; Caretti, D.; Panzavolta, S.; Scavetta, E.; Rea, M.; Ballarin, B., *ACS Omega* **2024**, 6391-6402.

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DoE and Chemometric Analysis for the Safe and Sustainable-by-Design Synthesis of the 2D-Materials

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The synthesis of 2D materials with controlled morphology is having an increasingly prominent role in materials science, because the variation of the synthesis parameters allows optimizing the functional properties of the materials themselves. Not all the synthesis parameters can be modified as desired and the influence that each parameter has on the final characteristics of the product is different.[2] At the beginning, a proper definition of the chemical, structural and morphological characteristics that can drive the functional properties at nanoscale and molecular level can be scouted by an extensive literature search. In order to recognize the most significant parameters, a Design of Experiment (DoE) screening approach can be applied to the selected parameters to explain experimental variability. Starting from the synthesis conditions for the specific materials obtained through the screening DoE, series of morphology controlled 2D-materials can be synthetized and characterized with different analytical methods.[3] Finally, materials' characteristics can be collected and evaluated using Principal Component Analysis (PCA) and data fusion approaches. These chemometric techniques should allow us to establish the relationship between the synthesis parameters and the materials' characteristics. These relationships can be exploited to develop a DoE optimization model for the Safe and Sustainable-by-Design (SSbD) synthesis of specific 2D-materials.

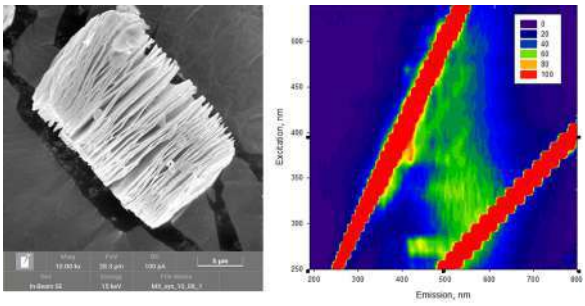

Figure 1: SEM micrograph of one of the synthesized MXene (left) and fluorescence matrix analysis on graphene oxide material (right).

References:

[1] F. Pellegrino, R. Isopescu, L. Pellutiè, F. Sordello, A. M. Rossi, E. Ortel, G. Martra, V.-D. Hodoroaba, V. Maurino; Scientific Reports, 2020, 10: 18910
[2] M. Minella, M. Demontis, M. Sarro, F. Sordello, P. Calza, C. Minero; J Mater Sci, 2015,50:2399–2409.

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ANA-PO-084

Chemometric application for qualitative carbohydrates analysis using Yeast-Direct Catalytic Fuel Cell bio-device.

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Fuel Cells of different types and configurations are able to convert the chemical energy into electrical energy, using hydrogen or more complex compounds as fuel, such as methanol, ethanol, or glucose. Fuel cells have also been used in the past, by present authors, to quantify alcohol or glucose content in foods, or drinks, while in more recent papers authors investigated the analytical survey of the Direct Catalytic Fuel Cell (DCFC) for "qualitative" analysis too, of aliphatic alcohols and so on, using suitable chemometric methods for DCFC data elaboration. In the present research we tried to extend the same format, for qualitative determination to several carbohydrates (Glucose, Xylose, Fructose, Galactose, Sucrose). **Figure 1** shows the experimental apparatus used for batch analytical measurements, by Fuel Cel and Yeast incubation.

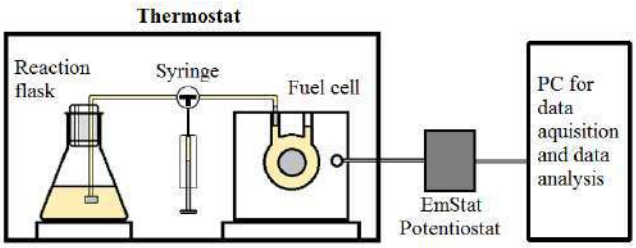

Figure 1: Incubation, DCFC and recording apparatus. Carbohydrates analysed at the same concentrations (0.03 mol L^{-1}). Incubation performed with 0.6 g of yeast, in glycine buffer, at 28.5 °C.

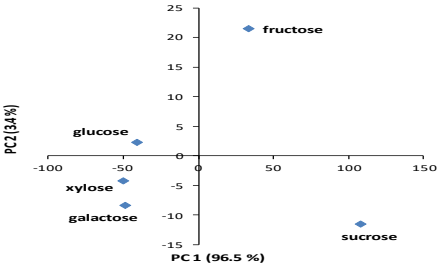

Figure 2: Projection of the five analysed carbohydrates, onto two first common components, extracted by PCA, (explaining 99.9% of the total variance).

Carbohydrates had to first be converted into alcohol using yeast solution. For this purpose, 50 mL glass flask, properly closed and filled with 30 mL of yeast-glucose-glycine solution, was kept at a constant temperature, for 12 h. At the end of the incubation time, 2 mL of solution was quickly extracted from the flask with a device made by graduated syringe, equipped with two small filters (see **Figure 1**), and injected in the DCFC. The end plate of the electrode of DCFC was made of a Pt-Ru black catalyst, assembled with a Nafion™ membrane. The cell was used in a potentiostatic mode, by measuring the so-called supplied current, using an EmStat potentiostat from Palmsens, connected to a PC. Current response trends to five investigated carbohydrate molecules have been recorded. Principal component analysis was then applied to the data set obtained by gathering all the data points of the response curves, after mean centering. The results of PCA are graphically displayed, in **Figure 2**, in terms of scores plot along the first two components, accounting for more than 99.9% of the total variance. The recoveries and differences about the behaviour among carbohydrates, can be appreciated by inspecting the scores plot reported in **Figure 2**.

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Simultaneous quantification of indigotin and indirubin in industrially produced natural indigo pigment

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Historically, indigo has played a crucial role in textile dyeing processes[1]. Traditionally sourced from plants like Indigofera tinctoria, Isatis tinctoria, and Persicaria tinctoria[2], natural indigo consists of two main components: indigotin, responsible for the blue hue, and indirubin, contributing to the red-violet shade[3]. The combination of these compounds imparts a distinct color to the fabric, in contrast to synthetic indigo, which solely contains indigotin. The industrial, sustainable production of indigo necessitates a unique extraction process wherein calcium hydroxide is added to promote hydrolysis of the precursor inside the plant and facilitate the isolation of the pigment. Commercially accepted natural indigo is formed by approximately 80% calcium carbonate and the remaining organic components[4]; the inorganic portion poses a significant challenge for the determination of colored compounds, as it is insoluble in both water and organic solvents. It is necessary to implement a method for quality control of the industrial pigment obtained.

Presently, methods for determining indirubin are based on High-Performance Liquid Chromatography (HPLC), involving the extraction of the analyte from the powder using an organic solvent such as methanol or acetone. In these solvents, indigotin is not very soluble, requiring a different technique for its determination. Indigotin determination involves chemical reduction, forming a water-soluble leuco-indigotin subsequently determined using a spectroscopic technique. In an industrial setting, it is crucial to possess a method that can quantify both indigotin and indirubin in a sample. This allows for determining the ratio between these analytes and controlling various parameters in the industrial production process.

To address these challenges, dimethyl sulfoxide with the addition of hydrochloric acid was used as a solvent to promote the complete dissolution of analytes. This allowed for the injection of the solution into a UHPLC-PDA system. Separation of indirubin and indigotin was achieved using a reverse-phase C-18 column and a mobile phase consisting of water and acetonitrile. Identification of the two analytes was conducted by exploiting the different absorption spectra in the UV-Visible region. This novel procedure can also serve as a reference method in view of the development of faster and more cost-effective methodologies based on electrochemistry or UV-Visible spectroscopy for the characterization of natural indigo.

References:

[1] N. Stasiak et al., Acta Pol. Pharm. 2014, 71, 215–221.
[2] G. Min et al., Int. J. Mol. Sci. 2022, 23, 553.
[3] C. Ahn et al., J. Korean Soc. Cloth. Text. 2013, 37, 827–836.
[4] E. Frignani et al., Life 2024, 14, 59.

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ANA-PO-086

Tracing the evolution of street art materials: A study of contemporary mural paintings stratigraphies from Graffity Alley (Ghent, Belgium) and Galeria del Arte Urbana (Lisbon, Portugal)

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Visual art in urban contexts consists of both commissioned and often non-commissioned street art. The ephemeral character, free access, and exposure to the environment and anthropic actions, make public paintings vulnerable to removal, vandalism, and degradation. Urban art is at present widely recognized by art history and by the wide society as an important part of contemporary cultural heritage, and a historical perspective on the evolution of materials and techniques is highly needed to gain a better knowledge of this form of art and to contribute to sustainable preservation strategies. The synthetic paint materials used by street artists in the last decades, such as spray paints, have undergone a fast evolution in their compositions. This aspect is related both to the implementation of new health regulations, leading to substances being banned from commercial use, and to the continuous improvement and evolution of commercial formulations. Targeted analytical experiments have been carried out to contribute to a comprehensive understanding of the chemical composition of paint materials used by street artists over the past decades, by studying samples which contain stratigraphies representing over 20 years of paint materials. Two case studies of great importance are presented: the Graffiti Alley and Galeria del Arte Urbana. These two locations are characterized by up to 25 years of repaintings on the same paint supports, giving a unique point of view on the evolution of the materials in a specific and well-defined time segment. The use of traditional analytical approaches on these samples did not provide an accurate evaluation of the distribution of the materials due to the thinness of the paint layers. In the presented study carried out at IPANEMA, a state-of-the-art European facility renowned for its expertise in multiscale and multispectral approaches in heritage science, we conducted Multi-spectral Luminescence Microscope, Mid-infrared Hyperspectral Imaging, and combined Micro-XRF/XRD analysis to obtain an exhaustive spatial resolution apt to study the stratigraphy of both the organic and inorganic materials. Moreover, SEM-EDX was carried out in Pisa to provide the elemental composition of the different paint layers. Subsection of the stratigraphies were also analysed by pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) to obtain a more detailed molecular composition of the samples. By applying this multiscale and multispectral approach combined with the micro destructive Py-GC-MS, we were able to obtain detailed chemical information about the different paint layers in the cross-sections. This allowed us to gain insight into the paint binder stratigraphy, differentiating between various classes of organic polymers, such as alkyds, acrylics, and nitrocellulose resins, present in each layer, and the evolution of their use in formulation during time. Additionally, the analysis provided valuable information about the inorganic content of the paint layers, revealing not only the presence of pigments and inorganic fillers. While some elements such as calcium and titanium were homogenously present in all the layers, specific metal were detectable only in the oldest paint layers. In particular, the presence of lead was highlighted only in the oldest layers. A detailed microscale element distribution can be crucial in the comparison with relevant literature to tentatively date the different paint layers.

The research has been carried out in the framework of the Italian PRIN2020 project SuPerStAr - Sustainable Preservation Strategies for Street Art.

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ANA-PO-087

Does the proline residue affect the coordination of divalent metal ions?

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The aim of the present work is to investigate the interaction of metal ions with short model peptides containing proline residues next to the metal binding site. In these peptides, the metal binding site is represented by a histidine imidazole, an effective anchoring site for metal ions such as Cu(II), Zn(II) and Fe(II), already at acidic pH. In the case of Cu(II), increasing the pH value of the solution, the binding to backbone N-amides can occur towards both the N- or C-terminal direction, but with a different level of affinity.[1] On the other hand, the occurrence of this coordination behaviour for Zn(II) and Fe(II) is controversial.[2,3] The present study concerns the terminally protected short peptide Ac-AAAHAAA-NH_2 and two mutants: Ac-AAPHAAA-NH_2 and Ac-AAPHPAA-NH_2. In the former peptide, the Ala residue in position 3 has been replaced with a proline, while, in the latter one, the two alanines adjacent to the histidine residue (position 3 and 5) have been replaced with prolines.

The investigation allowed to better understand the coordination behaviour of the three metal ions under different pH condition, shedding light on the effect caused by the presence of proline residues close to the metal binding site. In fact, proline residues do provide greater structural rigidity to the peptide chain, hampering conformational changes and rearrangements around the metal center and making unavailable for the binding their corresponding backbone amide.

The thermodynamic and spectroscopic characterization of the metal complex-formation equilibria has been achieved by means of potentiometry, UV-Vis spectrophotometry, circular dichroism, electron paramagnetic resonance and mass spectrometry.

Financial support of the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.1-NextGenerationEU (PRIN PNRR 2022-P2022EMY52) is gratefully acknowledge.

References:

[1] E. Gralka, D. Valensin, E. Porciatti, C. Gajda, E. Gaggelli, G. Valensin, W. Kamysz, R. Nadolny, R. Guerrini, D. Bacco, M. Remelli, H. Kozlowski, 2008, Dalton transaction (Cambridge, England: 2003), (38), 5207-19.
[2] D. Bellotti, C. Tocchio, R. Guerrini, M. Rowińska-Żyrek, M. Remelli, 2019, Metallomics, 11 (12), 1988-1998.
[3] E. Székely, G. Csire, B. Balogh, J. Erdei, J. Király, J. Kocsi, J. Pinkóczy, K. Várnagy, 2022, Molecules, 27 (11), 3435.

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Comparison of three spectral ranges in monitoring alcoholic/acetic fermentation in red wine must using FT-NIR spectroscopy

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Wine vinegar is produced through a two-phase fermentation of grape must: initially, yeast converts grape sugars into ethanol, and subsequently, acetobacteria oxidizes the ethanol into acetic acid. This process, spanning weeks, requires constant monitoring for ethanol and total acidity levels. To enhance the quality and efficiency of process monitoring, the food industry is shifting to faster, environmentally sustainable methods. Near-Infrared (NIR) spectroscopy, recognized for its non-invasiveness and speed, is ideal for online implementation in process control[1].

This study tracked dual fermentation in red wine must over an extended period, monitoring two batches simultaneously to assess fermentation kinetics and reproducibility. Ethanol and total acidity were analyzed in fermenting musts for almost four months, using both classical laboratory analyses and FT-NIR spectroscopy. Principal Component Analysis (PCA) was used to explore the spectral dataset, then Partial Least Squares (PLS) was used to develop calibration models predicting ethanol and acidity.

The models for the entire spectrum were compared with those obtained for two narrower zones, where more cost-effective and easily miniaturizable sensors are available on the market[2]. The FT-NIR analysis effectively determined the ethanol content and acidity ($R^2_{Pred} > 0.98$), both over the entire range (12500-4000 cm^{-1} corresponding to 800-2500 nm) and in the region 10526-6060 cm^{-1} (950-1650 nm). Although less optimal, still acceptable results were obtained in the 12500-9346 cm^{-1} (800-1070 nm) region ($R^2_{Pred} > 0.81$), confirming the potential for cost-effective devices in real-time fermentation monitoring.

References:

[1] D. Cozzolino, Applied Spectroscopy Reviews 2016, 51(4), 282 – 297.
[2] K.B. Beć, J. Grabska, C.W. Huck, Foods 2022, 11, 1465.

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An IMS prototype for the detection of explosives on crime scene investigation

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Ion Mobility Spectrometry (IMS) has been proven to be a very effective analytical technique in security and police applications for the detection of explosives, chemical weapons and illicit drugs. This study focuses on a new IMS prototype, developed by MasaTech, and investigates its efficacy on the crime scene by analysing explosives within the scope of the RISEN project (Horizon 2020, Grant Agreement No 883116). The MasaTech prototype vaporizes chemical substances pointing a laser beam at different types of surfaces. Vapours are transferred into the IMS module by a pump, where molecules are ionized and separated in the gas-phase. The analytical outputs considered in this study were the drift time, ion mobility, reduced mobility and collision cross-section.

The effectiveness of the IMS prototype was established by analysing explosives and explosive products: TNT, RDX, PETN, 2,6-DNT, 2,4-DNT, and 3,4-DNT. Little amounts of chemicals were settled on different substrates, such as drywall, stainless steel, and ceramic to simulate realistic crime scenarios.

Chemometrics methods were employed for reliable data processing of plasmagrams. Multivariate data analysis was carried out using Python code within a Jupyter Notebook environment, using the following packages: NumPy, Pands, Matplot library, Plotly and Scikit-Learn. The data analysis workflow involved various pre-processing steps of raw IMS plasmagrams, unsupervised and supervised pattern recognition techniques and model evaluation through Leave-P-Out cross-validation. Moreover, following the guidelines developed by the European Network of Forensic Science Institutes (ENFSI), a complete validation of the method was carried out taking into account the repeatability, reproducibility, and sensitivity. The signal variation was assessed to evaluate each analyte's response repeatability and reproducibility. All the analytes showed a coefficient of variation lower than 1% for both repeatability and reproducibility.

Therefore, the data obtained was treated with different classification models, such as Linear Discriminant Analysis (LDA), Partial Least Squares Discriminant Analysis (PLS-DA), Logistic Regression (LR) and Support Vector Machines (SVMs), in order to establish the relevance in comparison to conventional IMS technologies. The results highlighted the importance of the data pre-processing method employed to obtain an accurate classification. A Design of Experiment (DoE) approach was used to identify the best combination of pre-processing techniques and determine which factors influence the model's response by using the accuracy of the final chemometrics model. The PCA-LDA model appears as the most effective classification model reaching an accuracy of 95% and showing satisfactory results for real implementation in forensic field applications.

Merit to its high sensitivity and ease of use, the instrument can be employed to detect latent traces on crime scenes, on small traces unsuitable to traditional approaches such as spot tests. In conclusion, the IMS prototype developed by MasaTech, coupled with the chemometrics approach, presents a promising methodology for the detection of explosives and explosive products in real forensic criminal cases.

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Bio-Nano Interactions of Functional DNA Origami Targeting Cell Receptors

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The DNA origami technique streamlines the independent assembly of customizable DNA structures, enabling precise patterning at the nanoscale of a variety of conjugated biomolecules. With their inherent compatibility with biological systems and the ability to control shape, size, and ligand arrangement, DNA-based nanostructures hold great promise for applications in nanomedicine[1,2]. Despite demonstrations of effective binding in various scenarios, the underlying biophysical dynamics governing membrane binding remain largely unexplored. In this study, we explore the binding dynamics of two rod-shaped DNA origami nanoconjugates: one decorated with anti-EGFR (Epidermal Growth Factor Receptor) antibodies and the other with anti-EGFR aptamers. Through single-particle tracking (SMT) microscopy, we monitor the trajectories of ligand-modified DNA origami in both free solution and bound states on the cell membrane, enabling the calculation of their diffusion coefficient (D). We show that we can quantify the fraction of DNA origami specifically bound to the targeted receptor, distinguishing them from nonspecific bindings. Furthermore, SMT aids in determining the first-order rate constant for complex dissociation (Koff), a critical parameter revealing the average duration of the interaction between the DNA origami and the membrane receptors. The ability to finely adjust Koff values can be crucial for modulating potential therapeutic and stimulation effects[3]. Our DNA origami nanoconjugates demonstrate specific binding with a Koff profile potentially favoring preferential binding to cancer cells, opening new avenues in selective cell targeting for biomedical applications.

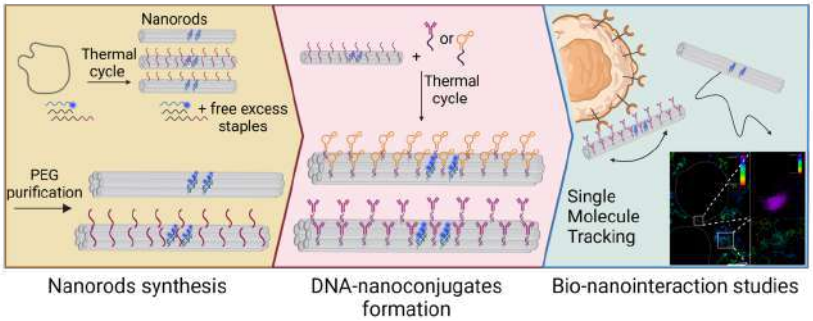

Figure 1: Schematic rendering of the workflow

References:
[1] Wagenbauer, K. F. et al. Nature Nanotechnology. 2023, 18, 1319–1326
[2] Zhang, P. et al. Nature Communications. 2020, 11:3114
[3] Corzo, J. Biochemistry and Molecular Biology Education. 2006, 34:413–416.

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High-throughput fabrication of DNA condensates for bioanalytical applications

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Liquid-liquid phase separation (LLPS) is a physical process that gives rise to membrane-less biopolymer condensates. Engineering LLPS processes has proven to be a powerful approach for creating mimics of cells and cellular organelles, driving advancements in the field of synthetic biology[1]. In particular, DNA-based condensates have garnered interest due to the versatile design capabilities of DNA, allowing for the fine-tuning of their physical properties and functions[2]. DNA condensates are generally formed by multi-armed DNA nanostructures, known as DNA nanostars, and their cross-linking can be mediated through sticky-ends[3] or through hydrophobic cholesterol molecules[4].

Although the traditional manual approaches have demonstrated to be effective for DNA condensates preparation, they are laborious and time-consuming. Motivated by these considerations, we propose here the development of a high-throughput method for DNA condensates fabrication that allows the production of a large number of samples in a relatively short amount of time. To do this, we employed pre-annealed DNA nanostars and we studied their isothermal assembly using the Opentrons® OT-2 liquid handling robot. We also performed a high-throughput analysis to characterize the size and stability of the condensates using Differential Dynamic Microscopy (DDM) technique, as developed for similar DNA condensates obtained through a manual approach involving thermal annealing[5]. The results showed that condensates exhibited varying sizes depending on incubation time and z-levels within the well. Notably, they were stable for at least to 8 days. The achievement of a high-throughput method for DNA particles synthesis and analysis allows for a rapid screening and testing of various compositions and parameters, facilitating a potential transition from laboratory-scale to industrial-scale production. Building upon these results, the next step involves exploring bioanalytical applications of DNA condensates.

References:

[1] C. D. Crowe, C. D. Keating, Interface Focus, 8 (5), 20180032.
[2] T. Masahiro, Interface Focus, 13 (5), 20230021.
[3] N. Seeman, Nature, 421 (6921), 427-431.
[4] R. A. Brady, N. J. Brooks, P. Cicuta, and L. Di Michele, Nano Letters, 17 (5), 3276-3281.
[5] M. Walczak, R. A. Brady, L. Mancini, C. Contini, R. Rubio-Sanchez, W. T. Kaufhold, P. Cicuta, L. Di Michele, Nature Communication, 12 (1).

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Cell-free *in-vitro* transcription and CRISPR/Cas systems for ultrasensitive biomarker detection

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Detection of specific antibodies and other protein biomarkers plays a crucial role in disease diagnosis, infections, and other pathologies such as cancer and autoimmune diseases.[1] In recent years, the possibility to couple the advantages of synthetic nucleic acids (i.e., programmability of interactions, low-cost, and ease of synthesis) together with the sensitivity and the specificity offered by cell-free transcription/translation systems has led to the development of innovative sensors for the detection of different targets,[2] including antibodies. Despite this, most of the cell-free biosensors for the detection of antibodies reported to date reach high picomolar/low nanomolar detection limit that appear not enough to identify early stages of infections.[3,4] Motivated by this, we report here a cell-free biosensor for antibody detection that takes advantage of CRISPR/Cas system. We have designed a synthetic gene that contain the transcriptional sequence of crRNA for Cas enzyme and an incomplete T7 RNA polymerase promoter domain to prevent the efficient binding of the enzyme. The binding of the specific antibody to a pair of antigen-conjugated DNA strands triggers the reconstitution of the T7 RNA polymerase promoter domain and thus the *in-vitro* transcription of the crRNA. The developed cell-free biosensor allows the sensitive (low picomolar detection limit), specific (no signal is observed in the presence of non-specific antibodies) and selective (the system can be employed in complex media, including 50% blood serum) detection of target molecules. Due to the programmable nature of the sensing platform, it can be adapted to different target molecules (using a direct or competitive formats).
We demonstrate the detection of different antibodies, including the clinically relevant Anti-MUC1 antibody and Cetuximab and protein markers as Mucin1 and EGFR. Given all these advantages, the CRISPR/Cas-based cell-free biosensors may be of utility for different applications including point-of-care diagnostics.

References:

[1] M. Urdea, L.A. Penny, S.S. Olmsted, M.Y. Giovanni, P. Kaspar, A. Shepherd, P. Wilson, C.A. Dahl, S. Buchsbaum, G. Moeller, D.C. Hay Burgess, Nature 2006, Suppl 1,73-9.
[2] J.K. Jung, K.K. Alam, M.S. Verosloff, D.A. Capdevila, M. Desmau, P.R. Clauer, J.W. Lee, P.Q. Nguyen, P.A. Pastén, S.J. Matiasek, J.F. Gaillard, D.P. Giedroc, J.J. Collins, J.B. Lucks. Nature biotechnology 2020, Vol. 38(12), 1451-1459.
[3] A. Patino Diaz, S. Bracaglia, S. Ranallo, T. Patino, A. Porchetta, F. Ricci, Journal of the American Chemical Society 2022, 144(13), 5820-5826.
[4] S. Bracaglia, S. Ranallo, F. Ricci, Angewandte Chemie (International ed. in English) 2023, 62(8), e202216512

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Detailed characterization of phenolic compounds in medicinal plants by means of ultra-high performance liquid chromatography coupled to high-resolution mass spectrometry

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Hypericum perforatum L. and *Sideritis scardica* (commonly known as Mountain tea) are two medicinal herbs widespread throughout the European Mediterranean region and commonly used for brewing herbal teas. These plants are known to possess a range of soothing properties[1,2], which can be attributed to the high abundance of polyphenols within the extracts obtained from these plants.

Polyphenols constitute an extremely heterogeneous class of metabolites produced by plants both for their growth and for protection against oxidative stress. These compounds are known to have various beneficial effects on human health, particularly due to their antioxidant activity[3]. For this reason, the analysis of the polyphenolic profile in products for human use has become increasingly sought.

Given the number of phenolic compounds present within the plant kingdom, their extreme variability, and the low quantities produced for some of these molecules, obtaining such results via conventional target methodologies is not feasible. Hence, the utilization of untargeted approaches based on ultra-high-performance liquid chromatography (UHPLC) coupled with high-resolution mass spectrometry (HRMS) becomes necessary[4].

The objective of this work is the characterization of *Hypericum perforatum* L. and *Sideritis scardica* extracts from Albania in terms of phenolic content by using a UHPLC-Q-Orbitrap system operated in untargeted data dependent acquisition (DDA) scan mode. To achieve orthogonal information, both C18 and Hydrophilic Interaction Liquid Chromatography (HILIC) columns (Waters, Milford, MA, USA) with the same geometry and particle size were employed.

References:

[1] Z. Dimitrova, D. Nedialkov, P. Kitanov, Gerassim Pharmacogn. Mag. 2010, 6, 74-78.
[2] Z. Tunalier, M. Kosar, N. Ozturk, K. H. C. Baser, H. Duman, N. Kirimer, Chem. Nat. Comp. 2004, 40, 206–210.
[3] S. Augustin, W. Gary, J. Nutr. 2000, 130, 2073S-2085S.
[4] A. Cerrato, G. Cannazza, A.L. Capriotti, C. Cittib, G. La Barbera, A. Laganà, C.M. Montone, S. Piovesana, C. Cavaliere, Talanta 2018, 209, 20573.

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Protein-DNA Nanoswitches for the Monitoring of Therapeutic Antibody Bioavailability

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Monoclonal antibodies (mAbs) constitute a primary therapeutic avenue in the management of chronic illnesses[1]. Therapeutic drug monitoring (TDM) offers a promising approach for personalized treatment strategies, particularly in chronic diseases where overtreatments can lead to significant side effects. Aiming to enhance TDM strategies, the NanoHybrid (NH) platform developed by Ulisse BioMed S.p.A.[2] has been re-engineered into a novel protein-DNA nanoswitch sensor. This new format leverages whole protein binding moieties to detect mAbs by exploiting the presence of different recognizable epitopes. Nanoswitch probes consisting of rationally designed DNA strands conjugated to whole tumor necrosis factor α (TNFα) proteins enabled the one-step quantification of various mAbs such as Infliximab, Adalimumab in a range between 2.4 µg/mL and 19 µg/mL directly in blood serum. Since mAbs can elicit patient-specific immune responses, anti-drug antibodies (ADAs) are often raised against biological drugs, which can significantly influence the actual bioavailability of therapeutic mAbs. Motivated by this, the nanoswitch platform was applied to the detection of Infliximab in the presence of an anti-Infliximab Ab, showing a substantial decrease in the detected concentrations of infliximab when in the presence of such ADA. These outcomes highlighted that the developed nanoswitch platform is capable of specifically discerning bioavailable antibodies, providing valuable insights for pharmacokinetic studies. Leveraging its modular design, the present nanoswitch platform holds potential as a multi-epitope nanosensor for the quantification of bioavailable mAbs and biosimilars.

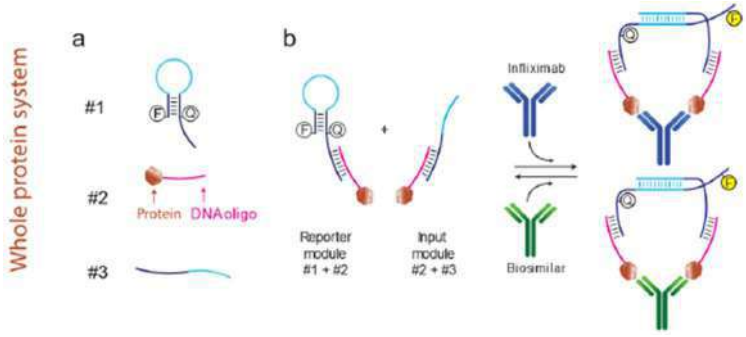

Figure 1: Pictorial representation of the protein-DNA nanoswitch platform

References:

[1] S.Brijen, L.Mayer, Expert review of clinical immunology 2010, vol. 6,4, 607-620.
[2] M.Mocenigo, et al., ACS sensors 2020, vol. 5,10, 3109-3115.

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Addressing sustainability in the electroplating industry: an all-round challenge

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Electroplating is a key process in many industrial fields such as automotive, electronics and decorative applications; it allows to provide new properties to substrates materials like corrosion resistance, hardness and aesthetic value. Nonetheless, electroplating is considered one of the most non-sustainable industries related to the manufacturing sector, both from an environmental and social point of view[1].

For over two decades, sustainability in the plating industry has been one of the key concerns of the industry. This makes it critical for the industry to assess the entire sustainability of virtually every plating facilities and then come up with both short-term and long-term approaches for improving sustainability performance.

In our work, the state of art was evaluated regarding three different but complementary lines of actions to improve the sustainability in Agenda 2030 SDGs optic of the electroplating industry[2], especially in non-mandatory fields such as the decorative one. Either different plating techniques, *in-silico* simulations and the metal recovery are linked to each other in minimizing the material usage and, consequently, metal extraction.

It is fundamental to fashion designers to take care of the whole production processes, thinking out of the schemes for new sustainable geometries and for industries to embrace simulations to test them[3]. Hence, deposition techniques should improve by trying to merge the properties of modulated currents with three ways rectifiers engineering and calibrate the deposition parameters with analytical techniques such as spectroscopies. Furthermore, electroplating facilities are needed to dedicate forces to select and optimize recovery methods according to their specific internal needs.

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References:

[1] P. Xu et all, Environ. Sci. Pollut. Res. 2022, 30, 31905–31915.
[2] United Nations Sustainable Development Goals Available online: https://sdgs.un.org/goals.
[3] E.A. Iñigo, L. Albareda, J. Clean. Prod. 2016, 126, 1–20.

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Towards green NH_3: How to improve ammonia production and its reliable quantification?

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In this current century, climate changes and energy production are some of the most significant and pressing challenges that humankind is facing. In this context, ammonia is a carbon-free energy-source for the end-users, thus resulting an alternative energy resource and also a promising energy vector, as it can be also used as an indirect H_2 storage compound. It is a matter of fact that photocatalytic N_2 fixation to achieve the so-called green NH_3 is emerging as hot area of fundamental and applied research[1]. Inspired by biological nitrogen fixation through nitrogenase enzyme, NH_3 can be photochemically produced from N_2 and H_2O in the presence of a semiconductor material and in this respect, the metal-free catalyst, namely graphitic-carbon nitride (g-C_3N_4), is considered a rising star material due to its excellent photocatalytic behaviour, suitable electronic properties (*viz.* band gap), and good photo-corrosion resistance. At the same time, its low absorption coefficient, fast recombination charge carrier and low surface area are challenges to overcome. Hence, in this work heterojunctions with metal halide perovskites ($Cs_2AgBiCl_6$) have been investigated in the whole weight ratio between perovskite and g-C_3N_4. The experimental results highlighted that g-C_3N_4-rich systems (90% wt) are more effective in the nitrogen photofixation reaction with ammonia production rates up to 40 μmol g^{-1} h^{-1}. Indeed, the active sites are the nitrogen vacancies in the nanostructure of g-C_3N_4, with a positive effect of small perovskite amounts mostly related to its superior light absorbance and reduced carrier losses. The design of an optimal photocatalyst is for sure the key step, but also the need for reliable methods for ammonia detection and quantification is a point to be addressed. NH_3 is typically detected by one of a number of possible methods, but serious concerns exist regarding the accuracy of current methods since different parameters can adversely impact ammonia detection and quantification. In this work, the Nessler's colorimetric assays and NH_3 Ion Selective Electrode (ISE) have been compared, evaluating the role of some possible interferences, namely the pH, colour and turbidity of the solution, the presence of certain metal ions and of sacrificial agents (mainly MeOH). Finally, the ammonia production rates have been accurately determined by ISE because an overestimation of the NH_3 concentration has been experimentally verified when using the colorimetric method. A calibration curve is daily constructed plotting the potential value recorded (mV) against the Log concentration, to verify the slope (varying in the range - 54 ÷ -60 mV).

References:

[1] S. Ghavam, M. Vahdati, I. A. Grant Wilson, P. Styring, Front. Energy Res. *Trend. Anal. Chem.* 2021, 9, 580808.

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Waste biomass reuse for preconcentration of emerging pollutants in environmental waters

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Industrialisation and population growth lead to the release of various types of pollutants from different sources into the environment, such as untreated municipal waste and effluents, agricultural releases, and industrial chemical discards. At this regard, among pharmaceuticals, the widespread of steroid hormones (SHs) and fluoroquinolone antimicrobials (FQs) residues in the environment, their fate, effects, and threats associated with their occurrence are reasons of great concern.[1] Proper analytical methods should be developed for their monitoring, possibly combining sensitivity and accuracy with sustainability, in the perspective of green chemistry.

Biochar is a carbon material produced by thermal decomposition of biomass in absence of oxygen, in the circular economy approach. It is distinguished by its unique characteristics such as high specific surface area, porous structure, and many surface functional groups (carboxylic, hydroxyl, and carbonyl units). Biochar is a relatively inexpensive and environmentally friendly sorbent because it can be produced from agricultural wastes that are abundant and do not have an economic value.[2]

In this work, biochar prepared from pumpkin, melon, and orange peels, packed in cartridge for Solid-Phase Extraction (SPE), were tested for antimicrobials and steroids preconcentration in environmental waters. Biochar was home-made obtained by a pyrolysis treatment performed at 650° C for 6 hours in a tubular furnace under N_2 flow and characterized by TGA, XRPD, IR, SEM and BET.

SPE tests were carried out to evaluate the adsorption of those analytes. Preliminary trials were performed on 50 mg of each material in tap water samples (50 mL, native pH) enriched separately with 5 μg L^{-1} of 16 SHs (8 glucocorticoids, 3 estrogens, 2 progestins and 2 androgens) or 11 FQs (6 for human and 5 for veterinary use) as bioactive compounds representative of water emerging contaminants.

Adsorption was quantitative for all FQs and SHs on all prepared biochar. Quantitative elution was obtained for antimicrobials with 2 mL of 10 mM TBAH-ACN (85:15, v/v) and for steroids using 2 ml EtOH, even if with a lower recovery for glucocorticoids. Quantification was performed by HPLC-ESI-MS/MS, MRM mode.

Immobilization of biochar on other supports to simplify the extraction procedure is ongoing to avoid the packed cartridge setting and increase the sample preparation throughput.

References:

[1] I. Vasilachi, D. Asiminicesei, D. Fert, M. Gavrilescu, Water 2021, 13, 181
[2] M. Jayakumar, A. Hamda, L. Abo, B. Daba, S. Prabhu, M. Rangaraju, A. Jabesa, S. Periyasamy, S. Suresh, G. Baskar, Chemosphere 2023, 345, 140515

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Dissipative Hybridization Chain Reaction for Responsive DNA Nanomaterials

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Supramolecular assemblies in biological systems exhibit a dynamic behaviour that is crucial to achieving environmental responsiveness. The possibility to develop chemically fuelled synthetic materials able to mimic such dynamic aspects of biological systems can lead to adaptable materials with unprecedented properties. Dissipative DNA nanotechnology, exploiting DNA programmability and the use of nucleic acids as chemical fuels to drive non-equilibrium processes, has recently emerged as a potential strategy to achieve adaptable and responsive biomaterials. Motivated by this, we propose here a novel approach to introduce a dissipative control over the Hybridization Chain Reaction (HCR). This is a DNA assembly technique based on the polymerization of two metastable DNA hairpins. Implementing a "tailed HCR" strategy[1], we introduce a dissipative behaviour via enzyme-mediated fuel consumption. Specifically, we have re-designed an RNA fuel that activates a strand displacement process followed by the disassembly of the DNA polymer. The presence of RNase H, an enzyme able to specifically recognize the RNA/DNA heteroduplex, can induce the degradation of this heteroduplex and the consequent rebuilding of the DNA nanostructure, thus driving a cyclic dissipative reaction.[2] This approach enables programmable assembly/disassembly of DNA nanostructures, suggesting the potential of dissipative DNA nanotechnology in creating time-controlled responsive biomaterials. Exploiting dissipative strategies, we equip DNA polymers with new properties that can have important analytical applications, including concentration-dependent adaptability and reversible multicomponent analysis.

References:

[1] X. Liu, D. Mao, Y. Song, L. Zhu, A. N. Isak, C.Lu, G. Deng, F. Chen, F. Sun, Y. Yang, X. Zhu, W. Tan, Sci. Adv. 2022, 8(2), eabk0133.
[2] E. Del Grosso, P. Irmisch, S. Gentile, L. J. Prins, R. Seidel, F. Ricci, Angew. Chem. Int. Ed. 2022, 61(23), e202201929.

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Innovative iron-doped carbon nitride material for CEC removal

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The removal of contaminants of emerging concern in water represents a challenge for the sustainable development of the society, where advanced oxidation processes are the main method for their abatement. This work focused on the synthesis of carbon nitride[1] (g-C_3N_4) based materials, added with iron. It is possible to introduce iron metal centers to extend Fenton reactions at neutral pH, otherwise hindered at pH > 4 by iron precipitation[2]. At the same time, the UVA irradiation of carbon nitride allows the production of H_2O_2 *in situ*, which can be used for Fenton reactions, through the reduction of dissolved oxygen.
The synthesis of the photocatalyst was carried out by adding $FeCl_3$•$6H_2O$ to melamine through a thermal polycondensation reaction under anoxic conditions at 500°C. The quantitative transfer of iron in the structure was confirmed by determining the Fe content after the thermal decomposition of the organic fraction. The photocatalytic performance was evaluated by measuring phenol (PhOH) 100 μM degradation under UVA irradiation, with a fixed amount of photocatalyst of 1.65 g L^{-1} at initial pH = 7.0. When needed, H_2O_2 1.0–25 mM was also employed.
Studies at different iron concentrations have shown that content of 0.28% w/w iron is optimal for the degradation of PhOH in the absence of external H_2O_2. In experiments carried out with 1 mM H_2O_2, the degradation rate of PhOH increased using g-C_3N_4, but this did not happen for Fe-g-C_3N_4. These observations and the disappearance of over 90 % of H_2O_2 in just 30 minutes of irradiation with Fe-g-C_3N_4, suggest that: 1) the reactive oxygen species (ROS) formed at the metal centers can react more easily with the structure of the photocatalyst than with the model contaminants; 2) high valent oxoiron complexes could contribute more to phenol degradation than ROS species.
Increases in the reaction kinetics with Fe-g-C_3N_4 was observed for additions of H_2O_2 concentrations > 5 mM. In these cases, the contribution of the photolysis of H_2O_2 is not negligible and industrial applications in wastewater treatment plants would be expensive.
Further studies are currently underway to study the working mechanisms by using spectroscopic techniques (i.e., EPR) and selective scavenging of the main ROS species ($^{\bullet}OH$, $^1O_2$, $^{\bullet}O_2^-$) involved in the degradation of phenol. This work will include material characterization and analysis on catalyst reuse.

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References:

[1] M. Minella, F. Sordello, C. Minero, Mater. Sci. Photocatal., Elsevier, 2021, 449.
[2] J. Fei, X. Peng, L.Jiang, X. Chen, Y. Zhao, W. Zhang, Dalt. Trans., 2021, 50, 16887-16908.

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ANA-PO-100

Non-invasive and early detection of Tomato spotted wilt virus infection in tomato plants using a hand-held Raman spectrometer and chemometrics

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Tomato spotted wilt virus (TSWV; species *Tomato spotted wilt orthotospovirus;* genus *Orthotospovirus;* family *Tospoviridae*) is a thrips-transmitted virus that induces outstanding economic losses in the agriculture, since infects more than 1000 different plant species from 90 botanical families, including ornamental, fruit, horticultural, and agronomic crops[1,2]. On tomato plants, it induces leaf bronzing, small brown flecks, dieback of growing tips, and ultimately death[3]. The leading management and containment strategies to fight TSWV infection consist in using resistant cultivars and spraying insecticides for thrips control. Early detection of plant pathogens is fundamental in a sustainable crop management context. The aim of this research is to disclose the presence of TSWV infection using a hand-held Raman device and Machine Learning (ML) approaches. For this purpose, four healthy plants and four TSWV-infected ones were analysed. Raman spectra were collected at 3 and 7 days post inoculation (dpi), acquiring six spectra per plant, obtaining a final data matrix of 96 spectra. Plants were scored for symptom development and the typical chlorotic spots appeared at 21 dpi. After a preliminary phase of spectra pre-processing using three different algorithms - asymmetrically reweighted penalised least squares (arPLS) smoothing, Savitsky-Golay filter, and Standard Normal Variate (SNV) transformation - a filter method based on Partial Least Squares Discriminant Analysis (PLS-DA) coefficients[4] was applied, to remove the redundant or irrelevant variables. The resultant reduced dataset was finally used for exploratory purposes with Principal Component Analysis (PCA) and then to build the PLS-DA model[5]. Interpreting the classification metrics, resulting from ten different train-test splits, we observe that Raman spectroscopy coupled with ML techniques provided promising results for an early detection of TSWV infection on tomato plants within the first 7 dpi, with an average accuracy >90%. Early detection of TSWV infection when symptoms are visually undetectable represents an important advantage from a productivity point of view. Moreover, these results have been obtained with a hand-held Raman spectrometer, easy-to-carry for field measurements in real time and less expensive than a corresponding benchtop instrument.

References:

[1] O. Batuman, T. A. Turini et al., 2020, Pathogens, 9(8):636.
[2] C. L. Ruark-Seward, B. Bonville et al., 2020, Scientific Reports, 10:15797.
[3] R. J. Best, 1968, Advances in Virus Research, 65-146.
[4] T. Mehmood, K. H. Liland et al., 2012, Chemometrics and Intelligent Laboratory Systems, 62-69.
[5] D. Ballabio, V. Consonni, 2013, Analytical Methods, 3790-3798.

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ANA-PO-101

Development of a UHPLC-HRMS method for simultaneous determination of abuse substances in whole blood by Salting-out Assisted Liquid-Liquid Extraction (SALLE)

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New psychoactive substances (NPS) are increasingly being used and their recognition, both in samples from findings and in biological samples, is a very topical analytical problem [1]. The purpose of the proposed work was the development of a UHPLC-HRMS/MS based method for the determination of 150 drugs (classical drugs and NPS) in whole blood. One of the objectives was to achieve a rapid, economical and versatile pretreatment method, suitable for the different classes of molecules considered. In this regard, Salting-out assisted liquid liquid extraction (SALLE) [2] was selected and, at a preliminary stage, it was essential to find the most suitable conditions for the development of the extraction parameters. The analysis was initially carried out on a smaller number of analytes (47 of 150), and for this purpose was performed a HPLC- MS/MS method with a triple quadrupole mass spectrometer. The work was then extended to all analytes (150) using a UHPLC-HRMS with orbital ion trap analyser at the Department of Scientific Investigations (Carabinieri) of Rome. It was possible to validate the entire HRMS analytical method for the multi-screening determination of drugs from whole blood in order to obtain the simultaneous extraction and quantification of 150 drugs. The proposed procedure allowed to speeding up of the SALLE extraction technique: the number of steps required and the volume of organic solvent have been reduced making the extraction process more sustainable on a long scale in terms of cost and environmental issues. The pre-treatment maintains also a higher concentration of the analytes, thus providing improved LODs and LOQs than reported in literature.

Another strength of the presented method was the applicability to an extensive and heterogeneous drugs and not limited to a specific class of psychotropic substances. The entire analytical procedure, once validated, was accurate, precise, sensitive, with a low matrix effect (for both low resolution and high resolution methods).

References:

[1] Peacock, A. et al. The Lancet (2019), 1668-1684.
[2] Tang, Y. Q. et al. Bioanalysis 5 (2013),1583–1598.

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ANA-PO-102

Development of a decentralized in-flow electrochemical platform for continuous monitoring of heavy metals

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Year after year, the need for decentralized tools to monitor heavy metals levels in the environment continually increases. Suitable electrochemical surfaces are widely established and particularly attractive for the production at low costs of miniaturized devices that can be applied as field-deployable analytical platforms.

This work reports the development of a fully automatable system based on electrochemical detection for the continuous on-site monitoring of heavy metals. The surface of electrochemical sensors is appropriately modified and then coupled to an optimized electrochemical procedure in order to achieve selectivity against the desired analytes.

At the same time, a suitable electrochemical cell coupled to a stirrer and connected to an integrated pump-based fluidic system was designed. This combined system allowed for the achievement of fast results while minimizing the sample volume used. To complete the prototype, a proprietary software capable of controlling both the fluidic system and the electrochemical measurement with the final data processing was developed.

Parameters such as flow speed, sample volume, and stirring steps were experimentally optimized, together with the parameters of the electrochemical measurement so as to obtain the best combination between analysis time and sensitivity.

The developed device was then applied to the multi-element analysis of heavy metals including, among others, Nickel, Aluminium, Cadmium, Lead, and Copper.

References:

[1] A. J. Borrill, N. E. Reily, J. V. Macpherson. Analyst 2019, 144, 6834
[2] J. C. Quintana, F. Arduini, A. Amine, F. Punzo, G. Li Destri, C. Bianchini, D. Zane, A. Curulli, G. Palleschi, D. Moscone. Analytica Chimica Acta 2011, 707, 171-177
[3] A. Merkoçi, M. Vasjari, E. Fàbregas, S. Alegret, Microchimica Acta 2000, 135, 29-33

Acknowledgements:
The European Climate, Infrastructure and Environment Executive Agency, HORIZON-MISS-2022-OCEAN-01, project iMERMAID, grant number 101112824, is acknowledged for financial support.

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ANA-PO-103

Valorization of Tomato Sauce Industry Wastes by Identification of High-added value Compounds.

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The development and implementation of innovative techniques are crucial for the valorisation and reuse of industrial waste products. In addition, the climate crisis has posed new challenges to our society, including how to make it sustainable despite large volumes of production. Therefore, the use of eco-sustainable (bio-based) raw materials and waste materials paves the way for a new and possible solution to this global issue. The food processing industry is responsible for producing considerable amounts of residues and by-products. Among the different food transformation and production chain, the vegetable processing industry generates significant amounts of various types of waste. One of the most significant global food markets is related to the tomato processing industry, which produces substantial by-products that are often discarded as waste rather than reintegrated into the supply chain with a new purpose [1]. However, these by-products could be excellent sources of ingredients, such as bioactive compounds including carotenoids, fibers, peptides, proteins, lipids, polysaccharides, polyphenols, antimicrobial compounds, and natural pigments [2].

Existing studies mainly focused on the revaluation of tomato pomace, peels, or seeds. On the other hand, the re-evaluation of tomato-based sauces discarded due to various errors in the production line, such as packaging or recipe errors, which make the product unsuitable for sale but potentially rich in bioactive compounds, remains unexplored. In this case, the production waste is a mixture of sauces (e.g., pasta condiments) in which tomatoes coexist with various other ingredients such as cheese, meat, and basil. From these premises the objectives of this work, aimed at finding one or more extracts of high-value components from finished product waste. Therefore, various sauce samples and a mixture of these were chemically characterized using different analytical techniques (UV-Vis, GC-MS, NIR), and the stability of their chemical composition was also investigated over time.

Moreover, a preliminary attempt to develop form this by-products a renewable raw materials for use in biobased packaging materials, has also been proposed.

References:

[1] C. Caldeira, V. De Laurentiis, S. Corrado, F. van Holsteijn and S. Sala, Resources, Conservation & Recycling Advances, vol. 149, p. 479–488, 2019.
[2] M. Sharma, Z. Usmani, V. Gupta and R. Bhat, Critical Reviews in Biotechnology, vol. 41, pp. 535-563, 2021.

ANA-PO-104

Analytical Characterization of ZnO-Alginate Films for Food Packaging Applications

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Food deterioration due to pathogen contamination causes a considerable economic burden and significant waste. Nowadays, plastic-based food packaging materials are the most used systems for preserving perishable goods. However, the environmental impact of plastic abuse should be limited, promoting the use of alternative greener materials, to improve food preservation. It is then envisaged to develop all-in-one biodegradable, renewable and antimicrobial materials. Biopolymers belonging to different families, such as carbohydrates (starch, cellulose, pectin, chitosan and alginates), proteins (whey proteins, wheat and corn proteins) and lipid derivatives may be used as valid substitutes[1]. Alginates are tasteless and odorless hydrophilic polymers extracted mainly from marine brown algae, showing good film-forming properties, low gas permeability, flexibility, water solubility[1]. Additionally, crosslinking with appropriate divalent cations (e.g. Ca^{2+}) improves physical-chemical and biological properties of alginate films. Such films can be further modified by blending with suitable additives to confer additional properties. To this aim, biodegradable coatings embedding antimicrobial nanostructures (NSs) can prolong product shelf-life, thus limiting pathogen growth and/or biofilm formation. In this communication, novel crosslinked alginate films embedding zinc oxide nanostructures (ZnO NSs) are presented. A green electrochemical-thermal method based on zinc anode oxidation in hydrogen carbonate solution in the presence of sodium dodecyl sulfate as a stabilizer was used to prepare ZnO NSs[2]. A suitable protocol for fabricating self-standing ZnO NSs/alginate films was developed. Morphological and spectroscopic (FTIR, XPS) characterizations were performed on NSs to evaluate their composition and morphology. Films were characterized by FTIR, XPS and water uptake experiments, showing that the addition of ZnO NSs improves significantly the film resistance, and supporting their potential application in food packaging studies. Finally, zinc release was also assessed spectrophotometrically and then used for the indirect prediction of antimicrobial efficacy.

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References:

[1] M.G. Kontominas, Foods 2020, 9, 1440.
[2] M.C. Sportelli, R.A. Picca, M. Izzi, G. Palazzo, R. Gristina, M. Innocenti, L. Torsi, N. Cioffi, Nanomaterials 2020, 10, 473.

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ANA-PO-105

Large freestanding 2D Covalent Organic Framework nanofilms

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Covalent Organic Frameworks (COFs), a class of organic materials known for their highly ordered, porous structures extended into two or three dimensions, have gained significant attention across various fields such as catalysis, gas storage, and sensing due to their fascinating properties, which include high surface area, tunable pore sizes, and chemical stability.[1] Among the different kinds of COFs, two-dimensional covalent organic frameworks (2D COFs) offer excellent platforms with high porosity for new technological applications, especially those involving film morphology. Here, we present the synthesis and characterization of freestanding imine-linked 2D COF nanofilms. 2D COF nanofilms have been successfully synthesized by condensation reactions at air-water and liquid-liquid interfaces. The develop method provides uniform centimeter-scale 2D COF films with thicknesses that can be tuned by the reaction times as well as the concentration of the monomers.[2] Our approach enables the direct transfer of the synthesized large-area COF nanofilm onto patterned substrates for physicochemical and mechanical characterization. Tensile tests are conducted on three different kinds of COF films measuring about 80 nm in thickness, with a testing area extending to 0.3 mm^2. The strength and the Young's modulus of the imine-linked COF nanofilms are 188 ± 57 MPa and 37 ± 15 GPa, respectively. The exceptional stiffness and strength of COF nanofilms across large areas render them suitable for applications necessitating robust mechanical performance, such as sensing and environmental remediation. This study paves the way for a fundamental understanding of the relationship between the macroscopic mechanical properties of 2D COFs with their composition and structure.

This study was carried out within the MICS (Made in Italy – Circular and Sustainable) Extended Partnership and received funding from Next-GenerationEU (Italian PNRR – M4 C2, Invest 1.3 – D.D. 1551.11-10-2022, PE00000004).

References:

[1] C.S. Diercks, O.M. Yaghi, Science 2017, 355, 923-931.
[2] M. F. Pantano, E. Missale, L. Gazzato, R. Pilot, F. Sedona, G. Speranza, M. Frasconi. Materials Today Chemistry 2022, 26, 101007-101015.

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ANA-PO-106

Environmental impact assessment of e-fuels – a review of LCA studies

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In 2019, the transportation sector accounted for about 26% of the total greenhouse gas (GHG) emissions in the European Union (27), significantly contributing also to the emission of other pollutants such as NO_x and $PM_{2.5}$, especially in densely populated areas.

According to the IPCC, in order to limit the global temperature rise below +1.5 °C by 2100 compared to preindustrial levels, it is mandatory to achieve net zero GHG emissions by 2050. In this context, e-fuels, which are produced combining CO_2 and (green) H_2, are gaining considerable attention as possible alternative to reduce CO_2 and pollutants emissions caused by the use of fossil fuels in private and commercial vehicles.

Several Life Cycle Assessment (LCA) studies examined the manufacturing/use of e-fuels and indicated they can effectively lower GHG emissions compared to their fossil counterpart;[1, 2] yet, results are highly affected by the considered electricity source and only a few have taken into account other impact categories such as acidification or eutrophication potential.

In this work, we reviewed multiple LCA publications discussing the environmental impacts of e-fuels production in order to emphasize both the potential benefits and drawbacks originating from their integration in the current transportation network.

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References:

[1] G. Zang, P. Sun, A. Elgowainy, A. Bafana, M. Wang, Environmental Science & Technology 2021, 55, 3888-3897.
[2] G. Zang, P. Sun, A. Elgowainy, M. Wang, Environmental Science & Technology 2021, 55, 5248-5257.

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ANA-PO-107

Development and validation of a UHPLC-MS/MS method for selected organophosphate esters flame retardants in gas-phase and aerosol of urban and mountain areas

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Organophosphate esters (OPEs) have emerged as alternative flame retardants due to strict regulatory measures (Regulation (UE) 2019/1021) that have banned or restricted more hazardous substances such as polychlorinated biphenyls (PCBs) and the major brominated flame retardants (BFRs). These compounds are included in the Stockholm Convention as persistent organic pollutants (POPs) both in Annex A to eliminate their production and use and in Annex C to reduce their unintentional release. These regulatory measures have been motivated by the recognized toxicity of these compounds to both the environment and human health, their tendency to bioaccumulate in the fatty tissues of organisms, their ability to biomagnify and to undergo long-range atmospheric transport even in remote areas[1]. OPEs also act as plasticizers and defoamers, expanding their potential scope of production, consequently increasing their diffusion into the environment[2]. Those compounds have been found in various matrices such as water, dust, sediment and air and are proving to be emerging environmental contaminants due to their various side effects and bioaccumulation potential, becoming a threat of exposure to human health and the environment[3]. The aim of this study is to develop and validate a highly sensitive and rapid UHPLC-MS/MS method for environmental matrix to determine with high selectivity six OPEs: *tris(2-chloroethyl)phosphate* (TCEP), *tris(2-chloroisopropyl)phosphate* (TCPP), *tris(1,3-dichloro-2-propyl) phosphate* (TDCP), *triphenyl phosphate* (TPP), *triethyl phosphate* (TEP), *trimethyl phosphate* (TMP). Isotope patterns have been investigated due to the presence of different combination of ^{35}Cl and ^{37}Cl in chlorinated OPEs. This analytical method allow to determine the presence of these emerging analytes in gas-phases and aerosols collected in urban (Mestre, Venice, 0 m a.s.l.) and mountain (Col Margherita, Falcade, Belluno, 2543 m a.s.l.) areas and to study their distribution and evaluate regional differences. Gas-phase and aerosol sampling was carried out using both high and low volume impactors. OPEs were found in urban samples with higher concentrations than at the mountain site; however, this confirms the potential for long-range transport to regions uncontaminated by human action[4].

References:

[1] M. Parolini, N. Guazzoni, A. Binelli, e P. Tremolada, 2012, pp. 29–44.
[2] T. G. Bekele *et al.*, 2021, pp. 49507–49528.
[3] C. Yao, H. Yang, e Y. Li, 2021, p. 148837.
[4] H.C. Kung, Y.-K. Hsieh, B.-W. Huang, N. K. Cheruiyot, e G.-P. Chang-Chien, 2022, p. 220148.

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ANA-PO-108

Mercury and selenium distribution in various tissues of sperm whale (*Physeter macrocephalus*) stranded near Naples, Italy

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The distribution of mercury (Hg) and selenium (Se) in marine mammals is crucial for assessing potential marine pollution and biological health. Understanding the distribution of these elements in various organs provides valuable insights into the physiological processes and potential detoxification mechanisms within these marine mammals [1]. This study investigates the concentrations of Hg and Se in different tissues of a sperm whale (*Physeter macrocephalus*) stranded in Forio (Na), Italy, in January 2019.

Tissue samples including liver, kidney, muscle, fat, intestine, stomach, pharynx, lung, heart, and testicle were collected and analyzed using DMA and GFAAS instrumentation. Our findings reveal significant variations in Hg and Se concentrations among the sampled tissues (**Figure 1**). Liver, kidney and stomach exhibited relatively high levels of Hg and Se, indicating these organs as potential sites for bioaccumulation of these elements. Moreover, a statistically significant positive linear correlation (p=0.0001, r=0.92) was recorded among Hg and Se concentrations.

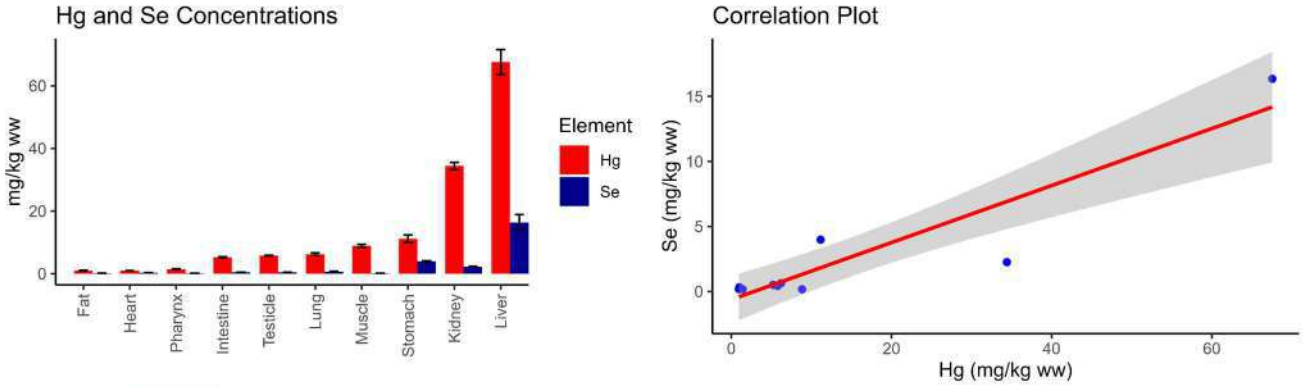

Figure 1: Hg and Se concentration (mg kg^{-1} ww) in different *P. macrocephalus* biological tissues.

References:

[1] S. Squadrone, P. Brizio, E. Chiaravalle, M.C. Abete, Ecological indicators 2015, 58, 418-425.

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ANA-PO-109

A GC-QEPAS prototype for the detection of chemicals of forensic interest: a chemometrics approach

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GC-QEPAS, a compact gas sensor designed for real-time analysis of Volatile Organic Compounds (VOCs) and Semi-volatile Organic Compounds (SVOCs), has been developed by CREO and validated within the scope of the RISEN project (Horizon 2020, Grant Agreement No 883116). This study focuses on the analysis of drug precursors and chemical weapons in the forensic field, to ensure the safety of operators. Compounds are transferred into the sensors by a pump and then concentrated employing two graphitized carbon sorbents (Carbograph 5TD and Carbograph 2TD). Thereafter, compounds are separated by a MEMS-based fast-GC and analysed by an IR sensor based on Quartz Enhanced Photoacoustic Spectroscopy (QEPAS).
The effectiveness of the GC-QEPAS prototype was established by analysing the following drug precursors and chemical weapons simulants: safrole, benzyl methyl ketone (BMK), benzaldehyde, acetone, piperidine, toluene, methyl ethyl ketone, dimethyl-methylphosphonate (DMMP), di-propylene-glycol-methyl-ether (DPGME) and methyl salicylate, diethyl sulfide (DES), diethyl methylphosphonate (DEMP) and trimethyl phosphonate (TMP). Following the ENFSI guidelines, a complete validation of the method was carried out considering the repeatability, reproducibility, and sensitivity. Repeatability and reproducibility calculated for IR spectra correlation were close to 100%. The Limit of Detection (LoD) for the majority of analytes, determined through the signal-to-noise ratio of chromatograms, was lower than 1 ppm.
Therefore, a chemometrics approach was developed for robust data analysis and forensic interpretation. Multivariate data analysis was carried out using Python code within a Jupyter Notebook environment, using the following packages: NumPy, Pands, Matplot library, Plotly and Scikit-Learn. The data analysis of QEPAS spectra workflow involved various pre-processing steps of raw data, unsupervised and supervised pattern recognition techniques, and model evaluation through Leave-P-Out cross-validation.
Analytical method performances obtained by the validation were evaluated as reliable and relevant for the criminal justice system. Therefore, the analytical data was treated with different classification models, such as Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QDA), Partial Least Squares Discriminant Analysis (PLS-DA), Logistic Regression (LR) and Support Vector Machines (SVMs), in order to establish the improvements in comparison to conventional hyphenate GC-spectroscopy instruments. The results highlighted the importance of the data pre-processing method employed to obtain an accurate classification. The PCA-LDA, PCA-QDA and PCA-LR, using the standard normal variate pre-processed spectra, appear as the most effective classification models, showing satisfactory results for real implementation in forensic field applications. In addition, SVM showed lower model accuracy than the beforementioned methods but appeared still adequate.
Merit to its good analytical performances and ease of use, the instrument can be employed to detect chemical traces on crime scenes, such as drug precursors, hazardous materials and chemical weapons to protect the health and safety of forensic personnel. In conclusion, the GC-QEPAS prototype developed by CREO, coupled with the chemometrics approach, presents a promising methodology for the detection of chemical substances of toxicological interest in the forensic field.

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ANA-PO-110

Dried Saliva Spot and Parallel Artificial Liquid Membrane Extraction – Design a combinate green microsampling and microextraction procedures for drugs of abuse

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Novel Psychoactive Substances (NPS) are a wide group of substances, principally of synthetic production, characterised by harmful pharmacological and toxicological properties. They can be grouped into different classes, according to their biological activities (e.g., hallucinogens, psychostimulants, sedatives, hypnotics) or to their chemical structures (e.g., cathinones, synthetic cannabinoids, synthetic stimulants, phenethylamines, and synthetic opioids). Oral fluid (OF) is a useful alternative biological matrix for forensic toxicology due to its correlation with blood concentration[1] and the advantages in terms of sample collection. The dried matrix spots (DMS) sampling approach is acknowledged as a useful collection technique, simplifying transport and storage, since a liquid matrix is dried on a filter paper. DMS typically involve blood samples, while there is a reduced number of studies which consider alternative matrices. Parallel artificial liquid membrane extraction (PALME) is a recent approach for liquid-phase microextraction based on a multiple-well filter plate that divides the acceptor and the donor solution by a hydrophobic polymeric flat and porous membrane. In this study, dried saliva spot (DSS) sampling and PALME were combined to develop a new method for multi-class illicit drug analysis in OF exploiting LC-MS/MS as detection technique. For the microsampling procedure a volume of 20 µL of fortified OF were deposited on a Whatman® 903 protein saver cards and let dry for ten minutes. After that the spot were cut and inserted into the PALME well with 96 positions. For what concern the microextraction, for the acceptor solution the acidic pH was achieved by adding formic acid at 0.1% v/v, acceptor volume was set at 40 µL meanwhile the basic pH in the donor solution was achieved by adding a carbonate/bicarbonate buffer (pH 10,5). The addition of 0.4 g NaCl to the donor solution was useful to increase the recovery of the procedure, ionic strength was shown to influence the partition the donor solution and organic solvent membrane (diesyl ether with 1% of trioctylamine) because of salting out effect. The results showed that PALME allowed to obtain a good clean-up removing the interferences of the matrix, enhancing the accuracy and the precision of the method. The method was validated according to SWGTOX guidelined by evaluating stability, precision, accuracy, recoveries, and matrix effect. This new approach could expand the possible application and combination of microsampling and microextracting strategies, winking to green chemistry, in the forensic toxicology field.

References:

[1] K. F. da Cunha, K. D. Oliveira, M.A Huestis, J. L. Costa, Journal of Analytical Toxicology, 2020, Volume 44 697-707.

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ANA-PO-111

Development of innovative analytical strategies for the identification of New Psychoactive Substances

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The detection and analytical recognition of New Psychoactive Substances (NPSs) is one of the main challenges in the clinical, toxicological and forensic field due to their rapid development and structural similarity to illicit substances already widely monitored [1][2]; for the latter reason, they are often not detectable with immunological tests and targeted methods that are designed for traditional drugs. They are not controlled by Single Convention on Narcotic Drugs (1961) or by Convention on Psychotropic Substances (1971), but represent a threat to public health, also because the purity and composition of such substances are still unknown. This situation underlines the need to develop new analytical strategies for their identification; actually, the development of new detection methods is also not easy due to the lack of analytical standards. For this purpose, this study, carried out in collaboration with the Italian Scientific Police Service, was aimed to the development of an analytical UHPLC-HRMS workflow for target and untarget determination of classic and newly introduced abuse substances in law enforcement seizures. UHPLC-HRMS has been used to perform target analyses both in Full Scan mode and MS/MS of known analytes belonging to the most common illicit substance classes, such as synthetic cannabinoids, synthetic opioids, stimulants, dissociative, hallucinogenic, sedative/hypnotic but also classical drugs; in this way, the information obtained from such analyses have been used for the creation of a chemometric model, based on their fragmentation spectra and neutral losses in a reasoned range of collision energy according to the chemical characteristics of the examined molecules.

The chemometric analysis represents the basis for the creation of a model capable of predicting the class of an unknown substance based on its fragmentation pattern, including neutral losses, thus allowing to perform untarget analysis on seized substances and potentially detect even unknown NPS. This approach promises to be interesting in addressing the growing number of new drugs flooding the market and at the same time in reinforcing existing sources of interest (such as opensource databases) with analytical information useful for the identification of new identifiable chemical structures with untargeted screening.

References:

[1] J. Rubicondo, L. Scuffi, L. Pietrosemoli, M. Mineo, F. Terranova, M. Bartucca, C. Trignano, E. Bertol, F. Vaiano, Journal of Analytical Toxicology (2022), volume 46, pp 262-273.
[2] N. Salgueiro-González, E. Zuccato, S. Castiglioni, Science of The Total Environment (2022), volume 843, 156982.

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ANA-PO-112

Multiclass analysis of psychoactive substances and NPS in oral fluid exploiting magnetic solid phase extraction (m-SPE) clean-up and HPLC-MS/MS

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The recent rapid spread of new psychoactive substances (NPS) has become a topic of interest for researchers, healthcare professionals and law enforcement. NPS are defined as new narcotic drugs that are not controlled by the United Nations Conventions on Narcotic Drugs (1961) or Psychotropic Substances (1971), but which may pose a comparable threat to public health[1]. In recent years, the interest in so-called "alternative" matrices to conventional ones (plasma, whole blood, serum, urine) used for toxicological analysis in the clinical and forensic field is growing sharply. Among these, oral fluid (OF) offers a series of advantages that justify its use in different fields of application. OF is a relatively clean matrix, collection is simple, non-invasive, no special skills are required in sampling which can be supervised without violation of privacy, while reducing the possibility of specimen adulteration or substitution. The aim of the present work is to develop a new method for the determination of several substances of abuse and NPS in OF. Magnetic solid phase extraction (mSPE) was applied as a sample clean-up technique and subsequently an HPLC-MS/MS analysis was performed for the determination of the analytes of interest. The magnetic nanoparticles (MNPs), designed synthetized for this work, have a core-shell structure of Fe_3O_4 -SiO_2-C_{18}[2]. Their characteristics of MNPs, dimensional distribution and functionalisation degree, were subsequently verified using FT-IR, DLS and microscopic techniques. The proposed procedure was then validated following the international guidelines SWGTOX showing good results in terms of recoveries and matrix effect, which proved the efficiency of the clean-up step; also, the limits of quantification and identification are low, in the order of pg/mL for almost all the analytes considered, thanks to the enrichment factor in pretreatment and the sensitivity of the HPLC-MS/MS analysis. In conclusion, this magnetic extraction in the solid phase allows the sample to be pretreated in a simple way, with benefits both in terms of time and solvent consumption, avoiding centrifugation and filtration phases and giving a "green" footprint.

References:

[1] United Nations Office on Drugs and Crime. World Drug Report. 2014
[2] Yu. X, C. Y. X. Lim, Dong. B, Hadinoto K; LWT - Food Science and Technology. 2020, 127, 109410

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Deep eutectic solvent-assisted matrix solid-phase dispersion extraction of phenolic compounds from pigmented wheat

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Wheat is a crop grown globally and consumed as a staple food in many countries[1]. Wheat-based foods can lower the risk of certain serious diseases, such as cardiovascular ones and some types of cancer. This work focuses on black wheat, a species that exhibits higher protein, essential amino acids, dietary fiber, vitamin K, total flavonoid (TF) and phenolic (TP) contents than soft wheat[1]. The incredible properties of wheat-based foods are attributed to the phytochemicals present in them, phenolic compounds in particular[2].

The aim of the work was to develop a green analytical method for the analysis of phenolic compunds improving the extraction yield of these compounds, using a deep eutectic solvent (DES) during the homogenization step of a matrix solid phase dispersion (MSPD) extraction. FLORISIL® was chosen as sorbent phase, and the analytes extraction was carried out by using a MeOH:H_2O mixture, 80:20 (v/v) ratio.

Type III DESs were prepared, characterized by a strong hydrogen bond between a hydrogen bond acceptor (HBA) and a donor (HBD), mixed at a specific molar ratio. In this case, choline chloride (ChCl) and betaine (Bet) were tested as HBAs while glycerol (EG) and ethylene glycol (Gly) were tested as HBDs.

An OVAT (one-variable-at–a–time) optimization permitted to evaluate the parameters able to give the highest extraction yield. The results, evaluated by the Folin-Ciocateau spectroscopic assay, were analyzed using the Box Behnken statistical program. By means of the response surfaces, it was possible to find the following optimal conditions: 1:3 as sample:dispersant material ratio (w/w), 87.65 µL as DES volume, 1 cycle and 1.42 mL as extraction phase volume. The final extract was analyzed by means of a high-performance liquid chromatography with diode array detection (HPLC-DAD) system. Finally, comparison with standard solutions permitted the identification of the following analytes: gallic acid, protocatechuic acid, kampferol, catechin, kampferol 3-o-rutinoside, and ferulic acid.

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References:
[1] L. Li, Q. Wang, X. Niu, C. Liu, X. Han, X. Zheng, Journal of Food Science 2024, 89, 306–319.
[2] O. R. Alara, N. H. Abdurahman, C. I. Ukaegbu, Current Research in Food Science 2021, 4, 200–214.
[3] E. L. Smith, A. P. Abbott, K. S. Ryder, Chemical reviews 2014, 114, 11060-11082.

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ANA-PO-114

Extraction and analysis of bioactive compounds from rocket: development of a green and innovative analytical method

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Bioactive molecules are substances of very varied chemical composition widely distributed in the plant world, in fact they are mainly found in fruits and vegetables. In recent years, rocket has been widely studied for its beneficial properties on human health as it is rich in antioxidant compounds that can been used in multiple applications, including cosmeceutical, nutraceutical and pharmaceutical industries[1]. However, the phenolic profile depends on several factors such as the species of the rocket, geographical area of origin, climate and sunlight. Modulation of growing parameters in experimental laboratories can increase phenolic compounds synthesis. Generally, bioactive compounds extraction is performed using organic solvents such as ethanol and methanol[2]. In recent years, the main engine of analytical chemistry is to move towards increasingly green and sustainable applications[3]. Following these principles, in this work traditional organic solvents were replaced by innovative and green solvents, such as deep eutectic solvents (DESs). They are easy to prepare using low-cost constituents, are non-toxic and biodegradable.

DESs are mainly a combination of two compounds: hydrogen bond acceptor (HBA) and hydrogen bond donor (HBD), which can interact through extensive hydrogen bonds.

An analytical method based on the use of deep eutectic solvents was developed and optimized to determine nutraceutical compounds in rocket plants growth at different conditions of light (80 PAR+LED; 80 PAR- no LED; 80 PAR + NEON), temperature (16°C; 22°C; 23°C) and salt stress induced with sodium chloride (0 mM NaCl, 150 mM NaCl, 300 mM NaCl). The optimization of the extraction procedure involved the study of type of DES, quantity of water to add to the selected DES, matrix to solvent ratio, times and temperature of extraction. Among the tested DESs, the best was choline chloride glucose (molar ratio 2:1), which gave the best quantitative results under the following optimized conditions: 1:50 w/v as matrix to solvent ratio; 30% of water added to the DES, extraction time of 30 min and extraction temperature of 50°C.

The rocket phenolic compounds profile was determined through high-performance liquid chromatography coupled with mass spectrometry (HPLC-MS): isorhamnetin, quercitin-3-O-galactoside, roseoside, quercitin, ferulic acid and chlorogenic acid were tentatively identified.

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References:

[1] J. Gil-Chávez, J. A. Villa, J.F. Ayala-Zavala, J. B. Heredia, D. Sepulveda, E. M. Yahia, G. A. González-Aguilar, Comprehensive reviews in food science and food safety 2013, 12,5-23.

[2] P. Anastas, N. Eghbal, Chemical Society Reviews 2010, 39,301-312.

[3] A. Sharma, R. Sharma, R.Arora, S. Arora, S. Arorac , B.Singh, Natural Product Communications 2017, 12, 1485-1489.

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ANA-PO-115

Sustainable Supramolecular Deep Eutectic Solvents based extraction for the recovery of bioactive phenolic compounds from olive pomace

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Agri-food industries generate large amounts of waste and the circular economy promises to be a valid solution: the reuse of by-products allows the extraction of some compounds, such as phenolic compounds, and at the same time, minimizes waste[1]. Bioactive phenolic compounds are secondary metabolites, which are present in many vegetable matrices, and thanks to their antioxidant power, prevent the onset of many diseases. According to the principles of green chemistry, the recovery of phenolic compounds from food waste chains should respect the use of economical, sustainable and environmentally friendly methods[2]. For this reason conventional organic solvent, such as methanol, hexane or acetone, are not suitable for this purpose and can be replaced with other green solvents, such as water and ethanol. In recent years, interest in innovative and sustainable new solvents has increased. Among these, Deep Eutectic Solvents (DESs) are widely studied in the literature, particularly for the extraction of phenolic compounds from food matrices and wastes[4]. In recent years, DESs have been also evaluated with the addition of β-cyclodextrins, which are cyclic oligosaccharides produced by enzymatic modifications of starch, and are characterized by a selective interaction with specific analytes, thanks to their structural characteristics. These innovative solvents are called Supramolecular Deep Eutectic Solvent (SUPRA-DESs) and promise to be a valid solution, instead of organic solvents, for the extraction of phenolic compounds[5]. The aim of this work was to develop and optimize an innovative extraction method based on the addition of β-cyclodextrins in the DES composed by ammonium acetate-lactic acid (1:7), in order to increase the analyte extraction yield. Specifically, the method was optimized by analyzing the time (30, 90 and 180 min) and temperature (30, 50 and 80 °C) of the extraction, the solid-liquid ratio (1:5, 1:10 and 1:50) and the different concentration of β-cyclodextrins (0.7, 1.8, 2.1, 4.5 % w/w). The optimized extraction procedure consists on the best extraction time of 30 minutes, temperature of 80 °C, solid-liquid ratio of 1:50 and the concentration of 1,8 % (w/w) of β-cyclodextrins. Furthermore, the extraction using SUPRA-DES enabled an increase in the extraction yield in comparison to the use of DES and also to conventional organic solvents. Finally, the olive pomace bioactive phenolic compounds were determinated through High-Performance Liquid Chromatography coupled with Mass Spectrometry (HPLC-MS).

References:

[1] A. Mir-Cerdà, O. Nuñez, M. Granados, S. Sentellas, J. Saurina, *TrAC Trends in Analytical Chemistry*, 2023, 161, 116994
[2] L. Panzella, F. Moccia, R. Nasti, S. Marzorati, L. Verotta, A. Napolitano, *Frontiers in Nutrition*, 2020, 7, 60
[3] T. El Achkar, H. Greige-Gerges, S. Fourmentin, *Environmental Chemistry Letters*, 2021, 19 (29)
[4]J. Werner, A. Zgoła-Grześkowiak, J. Płatkiewicz, J. Płotka-Wasylka, N. Jatkowska, A. Kalyniukova, S. Zaruba, V. Andruch, *Microchemical Journal*, 2023, 191, 108898
[5] R. Cai, Y. Yuan, L. Cui, Z. Wang, T. Yue, *Trends in Food Science & Technology*, 2018, 79, 19-27

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Optimization of enzymatic biosensor based on Horse Radish Peroxidase

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Horseradish peroxidase (HRP) has emerged as a versatile enzyme in the field of electrochemical biosensors, offering numerous advantages for sensitive and selective analysis. Its ability to catalyze a wide range of substrates makes it suitable for detecting various analytes, including small molecules, biomolecules, and environmental pollutants[1]. Furthermore, the enzyme exhibits high stability under a variety of conditions, enabling long-term storage and use in complex sample matrices. HRP has been widely used in the biosensing field exploiting both direct and indirect strategy of detection. Generally, establishing direct electron transfer between HRP and an electrode is difficult because the active sites of HRP are deeply embedded in the thick protein shell. The role of the mediator is to shuttle electrons efficiently between electrode and the active site of the enzyme, i.e. the heme group[2]. When the redox mediator (Med) is added, the reaction mechanism with the substrate, namely H_2O_2, can be summarized as shown in Figure 1. By selecting an appropriate mediator, sensitivity can be improved due to an optimized electron transfer kinetics[3]. The aim of this work is to unravel the effect of the redox mediator on the overall performance of HRP-based sensors. In particular, the study considers the storage and operational stability of the mediator, the efficiency of the catalytic enzymatic cycle and the kinetic of the enzymatic reaction with HRP through cyclic voltammetry and chronoamperometry.

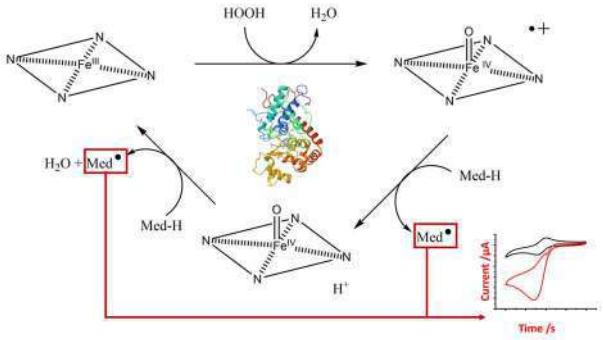

Figure 1: reaction mechanism of HRP for the reduction of H_2O_2 in presence of a generic redox mediator

References:

[1] C. Zhang, S.Chen, Carbon 2015, 94, 531-538
[2] H. Akbar, D.M. Sedzro, Journal of Chemical, Environmental and Biological engineering 2018, 2(2),52-59
[3] S.O. Malomo, R.I. Adeoye, Biokemistri 2011, 23, 124-128

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ANA-PO-117

Innovative Electroanalytical Platforms for Wearable Sensor

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During the past years, the increasing need to monitor biophysical parameters and enhance quality of life has led to the spreading of Internet of Things (IoT) and the development of smart and wearable devices. While these types of devices, which monitor physical parameters, are now part of our everyday life, the development of wearable electroanalytical platform for the monitoring of chemical parameters is more complex. Indeed, they need to be flexible, thin, conformable, but simultaneously resistant and low cost, possibly using sustainable and biodegradable materials.[1] Since urgent actions are required to ensure sustainable consumption and production patterns, a new revolution concerning the use of green technologies in the manufacture of electrochemical platforms is taking place.

This study aims to investigate the application of sustainable materials and technologies in the production of electroanalytical devices, such as biodegradable and flexible polymers [2] and thin graphitic carbon electrodes. Indeed, we explored different techniques to draw the conductive traces, such as graphitization of the surface using a CO_2-laser [3], the use of conductive inks [4], or a graphene-based paper [5], facilitating the manufacture, and reducing the costs of the electrodes.

The electrochemical performances of these innovative platforms were demonstrated through Cyclic Voltammetry (CV), Chronoamperometry (CA), and Electrochemical Impedance Spectroscopy (EIS). Their applicability as an amperometric sensor was assessed using glucose oxidase as a benchmark enzyme in the biosensing strategy. Furthermore, the electrocatalytic effect of these platforms for the detection of biomolecules belonging to the class of catecholamine was also evaluated, due to their importance in the biomedical field.

In conclusion, all the investigated platforms give promising results, making them suitable to replace commercial ones. Indeed, they also are flexible, thin, low cost and have low environmental impact that make them attractive candidates for sustainable and wearable sensing platforms.

References:

[1] Y. Yang, W. Gao, Chem. Soc. Rev. 2019, 48, 1465-1491
[2] G. Belletti, S. Buoso, Polymers 2021, 13, 1-19
[3] G. Cantarella, M. Madagalam, Adv. Funct. Mater. 2023, 22, 1-12
[4] A. Silvestri, S. Vázquez-Díaz, Small 2023, 19, 1-15
[5] F. Poletti, A. Scidà, Adv. Funct. Mater. 2022, 32, 1-10

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ANA-PO-118

SPE extraction coupled to HPLC-ESI-MS/MS for the screening and determination of short chain fatty acids

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Short-chain fatty acids (SCFAs) are generated as end products by the degradation and fermentation of indigestible carbohydrates by the gut microbiota, a process termed saccharolytic fermentation[1]. They can act as signaling molecules as ligands of G-protein-coupled receptors and they are implicated in the increase of anorexic hormone production and energy expenditure[2]. Consequently, SCFA production has been linked to preventing the progression of obesity and related complications, such as type 2 diabetes mellitus and nonalcoholic fatty liver disease (NAFLD)[3]. SCFAs are typically quantified by gas chromatography (GC), liquid chromatography (LC), nuclear magnetic resonance (NMR), and capillary electrophoresis (CE)[4]. The detection of the low-molecular weight fatty acids in negative-ion ESI, without chemical derivatization, is often problematic. LC coupled with mass spectrometry (MS) with electrospray ionization (ESI) is now the most widely used analytical technique in metabolomics and reversed-phase LC–MS with post-column neutralization, previously used also for the determination of SCFAs in the pig colon and blood. The complex instrument setup for these two methods, however, makes them unsuitable for routine analysis in most laboratories. This work aimed to develop a new analytical method for SCFA based on 3-nitrophenylhydrazone (3-NPH) derivatization followed by SPE clean-up, we decided to derivatize the molecular markers with the aim of improving their chromatographic retention, the ionization efficiency and the fragmentation behaviour. While the SPE clean-up was used to minimize the matrix effect and improve extraction selectivity. The LC-MS/MS method was performed both in Multi Reaction Monitoring (MRM) for quantitative analysis and in precursor ion scan analysis (PIS) to achieve semi-targeted analysis for an extended range of SCFA compounds based on derivatization reactions. This approach can be used for putative identification and screening of SCFA compounds in biological samples. Moreover, the derivatization process allows for greater stability of the analytes in the sample over the course of storage time.

References:

[1] A. Koh, F. De Vadder, P. Kovatcheva-Datchary, F. Backhed, Cell 2016, 165, 1332–1345.
[2] P.D. Cani, M. Van Hul, C. Lefort, C. Depommier, M. Rastelli, A. Everard, Nature Metabolism 2019, 1, 34–46
[3] A. Kindt, G. Liebisch, T. Clavel, D. Haller, G. Hoermannsperger, H. Yoon, D. Kolmeder, A. Sigruener, S. Krautbauer, C. Seeliger, C.; et al. Nature Communications. 2018, 9.
[4] M. Primec, D. Micetic-Turk, T. Langerholc, Analytical Biochemistry 2017, 526, 9–21.

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Comparison of colorimetric methods for the online measurement of hydrogen peroxide in a photo-Fenton process

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The scale-up of a photocatalytic process for the removal of pollutants from water encompasses several relevant aspects, among them, the timely analytical control and the optimization of operational parameters, to maximize efficiency and minimize reagent consumption. Indeed, when running Advanced Oxidation Processes, reagents consumption represents one of the main costs; in the specific case of photo-Fenton processes, that rely on the generation of hydroxyl radicals through the reaction between hydrogen peroxide and Fe(II) ions, an excess of H_2O_2 could even hinder the pollutant degradation kinetics, making therefore its proper dosage a key issue.

The automation of H_2O_2 concentration control and dosage is therefore worth to be implemented, seeking for reliable, fast and cheap devices.

In this work two different colorimetric methods were applied and compared for the online determination of H_2O_2 ; moreover, the role of H_2O_2 dosage on the photo-Fenton degradation of paracetamol and caffeine was studied.

The kinetics of substrate degradation, organic carbon mineralization and H_2O_2 consumption were compared to define the most suitable H_2O_2 dosage procedure to maximize process efficiency.

A peculiar H_2O_2 consumption trend was observed during caffeine degradation; HPLC-MS preliminary test suggest the formation of intermediate degration products capable to generate H_2O_2.

The results obtained in the present work evidence two opposite trends for kinetics and overall H_2O_2 consumption when moving from single, stoichiometric H_2O_2 dosing approach to a fractioned dosing one. In fact, both substrate and DOC removal rates were higher when a single and stoichiometric H_2O_2 dose was added at the beginning of the process, while H_2O_2 consumption took advantage from small successive H_2O_2 addition as long as the previously added H_2O_2 was consumed before the following dose was added.

References:

[1] E. Yamal-Turbay, E. Jaén, M. Graells, M. Pérez-Moya, 2013, 267 11–16.
[2] L. Santos-Juanes, J.L.G. Sánchez, J.L.C. López, I. Oller, S. Malato, J.A. Sánchez Pérez, 2011, 104,

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Development of Glucose Amperometric Biosensor operating in Industrial Bioreactors

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The advancement of disposable and cost-effective electrochemical devices for biomedical uses has seen a notable rise alongside the spread of remote diagnostic technologies. This surge can likely be attributed to the necessity of rejuvenating traditional sensor surfaces and the demand for manufacturing processes enabling the creation of disposable and portable electrochemical devices. These devices facilitate sample volume reduction, on-site detection, and cost reduction.[1]

Conductive inks play a crucial role in fabricating disposable electrochemical sensors, enabling the construction of screen- or stencil-printed electrodes with comparable efficiency to solid electrodes.[2] Specifically, eco-friendly conductive inks are formulated and stencil-printed onto a flexible substrate, facilitating their integration into smart devices for continuous and monitoring of substances like lactate and glucose. The optimization of conductive ink formulations is achieved through electrochemical and rheological measurements, utilizing a multivariate analysis model. Subsequently, active carbon electrodes are modified with osmium redox polymers (ORPs) to establish an electronic connection with enzymes, as glucose oxidase (GOx) cannot directly transfer electrons.[3,4] Finally, the prepared biosensors undergo testing in model solutions and industrial bioreactors sludges to determine various analytical parameters such as limit of detection (LOD), limit of quantification (LOQ), linear range, sensitivity, selectivity, reproducibility, stability, and storability.

References:

1. Bollella, P., Sharma, S., Cass, A. E. G., & Antiochia, R. Biosens.Bioelectron., 123, (2019) 152-159.
2. Camargo, J. R., Silva, T. A., Rivas, G. A., & Janegitz, B. C. Electrochim. Acta, 409, (2022) 139968.
3. Bollella, P., & Katz, E. Sensors, 20, (2020) 3517.
4. Bollella, P. Anal. Chim. Acta, 1234, (2022) 340517.

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Development and optimization of analytical method for the extraction of polyphenols and phycocyanin from spirulina followed by HPLC-MS analysis

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Spirulina (Arthrospira platensis) is a cyanobacterium that is considered an environmental friendly microalga. This cyanobacterium has received significant attention because of its high protein content, which accounts for up to 70% of its dry mass. Among the various nutrients that constitute spirulina, phycocyanin, phycobiliproteins responsible for the blue-green color of spirulina and polyphenol compounds, were known as important natural antioxidants [1,2]. Phycocyanin is known for its antioxidant properties and anti-inflammatory properties. It is a protein formed by an alpha chain with 162 amino acids and a beta chain with 172 amino acids, bound to three chromophore groups, called phycobilines. These monomers form a hexamer with a molecular weight of about 230 kDa. Usually, for the extraction of these bioactive compounds water is used as extractive solvent, but the obtained extract is unstable over time. For this reason, we evaluated the use of other extractive solvents. Deep eutectic solvents (DESs) are green solvents, formed by combining two or more components, that can act as hydrogen bond donors (HBDs), sugars, amine, or as hydrogen bond acceptors (HBAs), ammonium quaternary salts, according to specific molar ratio to form an eutectic mixture. The peculiar characteristics of DES (polarity, viscosity, and solvent capacity) are easily modulated varying the molar ratios of the components and the water content. In this work an ultrasound-assisted solid-liquid extraction, using DESs, was developed to recover phenolic compounds and phycocyanin from Spirulina. Many DESs were tested and the extraction procedure was optimized based on the obtained maximum content of phycocyanin and total phenolic content (TPC), obtain through spectrophotometric method. The optimized extraction procedure, applied for phenolic compounds and phycocyanin extraction from spirulina, provided the use of a DES composed by betaine and glucose in a molar ratio of 1:2 (with 30% water), added to 0.5g of spirulina powder with a matrix-to-solvent ratio of 1:20 w/w, in an ultrasonic bath for 1 hour at 50°C. The extraction procedure guaranteed to extract an amount of phenolic compounds of 11.77 ± 1.23 g GAE/100g and 25.56 ± 2.47 mg/g of phycocyanin from spirulina powder. DES extract stability was evaluated using spectrophotometric test, resulting better than that of water extract. The profile of the polyphenol content was evaluated through high performance liquid chromatography coupled with photodiode array and mass spectrometry detection and some phenolic compounds were identified.

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References:

[1] Debora Pez Jaeschke, Ingrid Rocha Teixeira, Food Research International, 2021, Volume 143, 110314
[2] Rajaa Seghiri ,1 Mourad Kharbach, Journal of food quality, 2019, Volume 2019, 3707219

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ANA-PO-122

Efficient and eco-friendly discrimination of bovine milk through AF4 fingerprinting of colloidal fraction

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Addressing food safety and detecting food fraud while fulfilling greenness requisites for analysis is a challenging but necessary task. The use of sustainable techniques, with limited pretreatment, non-toxic chemicals, high throughput results, is recommended. A combination of Field Flow Fractionation (FFF), working in saline carrier and with minimal preprocessing, and chemometrics was for the first time applied to bovine milk grouping.

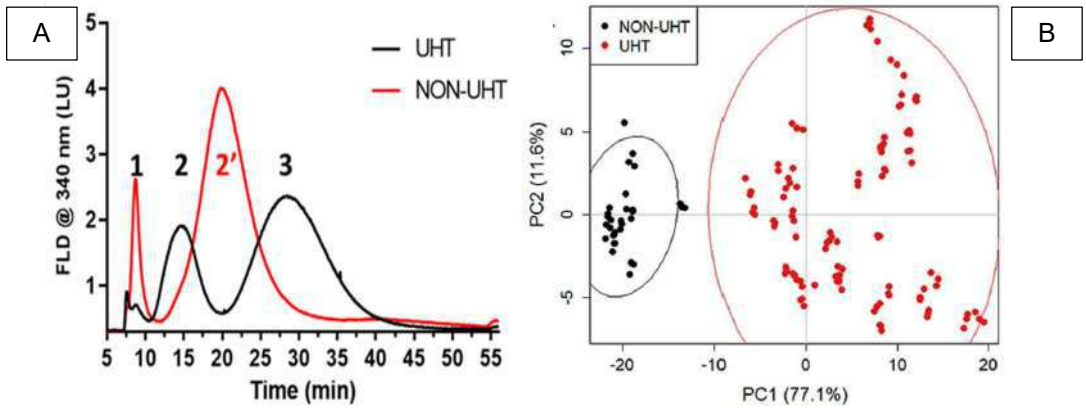

Figure 1: A shows the fractograms of UHT and not UHT milk. Figure B shows the grouping of these two classes

A set of 50 bovine milk samples was analyzed: a single analysis yielded a characteristic multidimensional colloidal dataset, that once processed with multivariate tools allowed simultaneously for different discriminations: fat content, thermal treatment, brand and manufacturing plant. The analytical methodology is fast, green, simple, and inexpensive and could offer great help in the field of quality control and fraud identification[1]. This work represents also the first attempt to identify milk sub-typologies based on colloidal profiles, and the most complete study concerning multivariate analysis of FFF fingerprint.

References:

[1] Zappi, A.; Marassi, V.; Kassouf, N.; Giordani, S.; Melucci, D. A Green Analytical Method Combined with Chemometrics for Traceability of Tomato Sauce Based on Colloidal and Volatile Fingerprinting. Molecules 2022, 27, doi:10.3390/MOLECULES27175507

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ANA-PO-123

Waste Stabilization Sequestration (SS) in alkali activated geopolymers with chelating agents

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Geopolymers, based on aluminosilicate powders via alkali activation, have been developed and successfully used to sequester and stabilize sludge from electroplating plants. Their semi-crystalline three-dimensional silico-aluminate structure consisting of linked SiO_4 and AlO_4 tetrahedra, allows them to be used in a variety applications.
Analyses carried out 28 days after geopolymer preparation have shown the encapsulation of all pollutants present in the sludge, such as soluble metal ions, anions and surfactants.[1]
Leachate analyses, carried out according to the UNI EN 12457-2-2004 standard and at well-defined time intervals, allow the stabilization capacity to be studied in order to guide the reuse or correct disposal of the resulting materials. The results showed a good retention capacity of the effluent components.
Additional analyses carried out on the leachate were aimed at evaluating the release of the 3D aluminosilicate network formers (mainly Al and Si). These main constituents of the geopolymeric matrix are found in high concentrations in the leachate when the reticulation process is inefficient. This second part of the investigation allowed the optimisation of waste treatment, geopolymer paste formulation and curing conditions to improve encapsulation performance.

References:

[1] G. Boldrini, C. Sgarlata, I. Lancellotti, L. Barbieri, M. Giorgetti, M. Ciabocco, S. Zamponi, M. Berrettoni, C. Leonelli, Sustainable Environment Research, 2021, 31(1), 33.

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ANA-PO-124

Bacteriophage-based electrochemical magneto-assay for point-of-care detection of bacterial infections

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A magnetic electrochemical assay based on the use of bacteriophages as innovative receptors was developed for rapid and point-of-care (POC) detection of bacterial infections that hospitalized patients acquire while receiving health care. Additionally, various types of foodborne, airborne and/or waterborne bacteria are responsible for moderate to severe illness. Early detection and classification of the bacterium responsible for the infection are crucial to determine the most appropriate therapy. Conventional bacterial detection techniques, such as cell culture and colony counting, PCR, and ELISA testing, are time-consuming, expensive, and typically require highly skilled operators.[1] Recently, bacteriophages have been successfully used as innovative receptors for the detection of bacteria. Their advantages include high specificity, tolerance to organic solvents, high temperatures and pH, as well as ease and low cost of production in large amounts.[2]

To meet the demand for early detection, there is a need for portable POC diagnostics based on inexpensive, rapid, and sensitive methods for the detection of bacterial infections.

To achieve this goal, we functionalized the surface of magnetic beads with engineered bacteriophages that specifically recognize *Escherichia Coli* and exploited electrochemical transduction to enable portability of the sensing device.[3] The analytical signal was obtained using a labelled phage that binds both the bacterium and an enzyme used for the electrochemical signal generation. Different immobilisation strategies were investigated, comparing the performance of amino-modified beads with carboxyl-modified beads. Although the former showed a more intense signal, they also showed a higher non-specific interaction. Furthermore, comparing carboxyl-modified beads of different size, smaller magnetic beads (1 μm) were more effective in capturing bacteria than larger beads (2.8 μm), showing a positive/negative ratio of 20 for the determination of for the determination of 10^6 CFU/mL *E.Coli*. The proposed magneto-assay successfully demonstrated proof-of-concept rapid and sensitive detection of bacteria at clinically relevant concentrations and could provide wide potential applications in POC testing.

References:

[1] Z. Aliakbar Ahovan, A. Hashemi, L.M. De Plano, M. Gholipourmalekabadi, A. Seifalian, Nanomaterials 2020, 10, 501.
[2] U. Farooq, Q. Yang, M.W. Ullah, S. Wang, Biosensors and Bioelectronics 2018, 118, 204–216.
[3] S. Fortunati, M. Giannetto, C. Giliberti, M. Mattarozzi, A. Bertucci, M. Careri, Analysis & Sensing 2023.

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ANA-PO-125

Spectroscopic and Electrochemical Characterization of a new apta-sensor based on gold electrodes functionalized with poly-L-DOPA film.

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Keywords: Electroanalysis, Apta-Sensors, Spectroscopy, Aptamers, Electro Polymers, Lysteria

As reported by the Codex Alimentarius[1]: "*Food hygiene is the set of all the conditions and measures necessary to guarantee the safety and suitability of food at every stage of the food chain*", implying that a food will not cause harm after it has been consumed according to the use for which it is intended. The food can be a source of chemical, physical or microbiological dangers, where the last mainly include pathogenic bacteria such as *Salmonella, Clostridium botulinum, Listeria monocytogenes* and *viruses*. Therefore, the development of innovative diagnostic approaches for detection of microorganisms responsible for food poisoning is increasingly in demand. From this perspective, the development of new biotechnologies and their integration into miniaturized devices has opened up new interesting scenarios in the biosensor sectors. Specifically, the present work involves the development of an electrochemical apta-sensor for detection of pathogenic microorganisms *Lysteria monocytogenes*. For this purpose, screen printed electrodes, appropriately modified with specific aptamers immobilized on poly-L-DOPA electropolymerized film, have been studied. A fully electrochemical and spectroscopic characterization of the proposed biosensor has been reported together with the electroanalytical performances in terms of LOD, linear and/or dynamic range, and sensitivity.

We acknowledge the support of the EU by the Next Generation EU project PRIN2022 – 2022JRKETK_PE7 - Versatile hybrid in-fiBer Optical-electrocHemical systEMs for wIdely Applicable bioseNsing – BOHEMIAN.

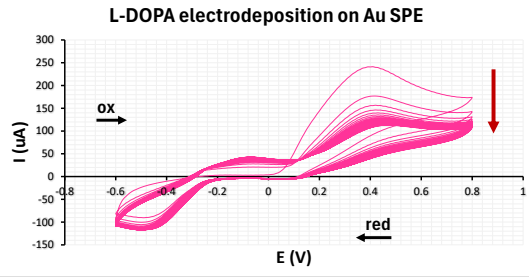

Figure 1: Cyclic voltammetry related to the poly-L-DOPA electrodeposition on gold electrode. Scan rate 200 mV/s.

References:

[1] Fao & Who. General principles of food hygiene. *Codex Alimentarius Code of Practice, No. CXC 1-1969. Codex Alimentarius Commission. Rome,* 2023

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ANA-PO-126

Detection of nucleic acids in food and biological samples after liquid/liquid extraction by using ionic liquids and loop-mediated isothermal amplification

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Nucleic acid analysis is rapidly becoming a pillar for clinical diagnostics [1], food safety [2], genomics [3], and microbiology [4]. Usually, nucleic acids amplification is performed by polymerase chain reaction (PCR). This method is widely known for its reliability and flexibility but requires the employment of specialized laboratories and competent personnel, the use of complex and expensive equipment, and rather long analysis times. In recent years, an alternative technology named loop-mediated isothermal amplification (LAMP) has been developed. Differently from classical PCR, this technique not requires a thermal cycler, allowing the analysis of extracted DNA/RNA directly from material collected on site.

A critical aspect of such procedures is the low tolerance to interfering constituents within complex biological, food or environmental sample matrices [5,6].

In the present study, a promising liquid/liquid extraction (LLE) method based on the use of ionic liquids (IL) was taken into consideration for DNA and RNA extraction from food and biological matrices. The optimized procedure, easy to automatize, not requires the use of any organic solvents, in line with the Green Chemistry principles. The nucleic acid amplification was performed through an innovative all-in-one molecular biology system that takes full advantage of the LAMP technology (ICgene Plus). This portable equipment, coupled with a fluorescence detector, has been employed for the rapid isothermal amplification of nucleic acids, real-time detection, and automatic interpretation of obtained data.

References:

[1] T. G. Drummond, M. G. Hill and J. K. Barton, Nat. Biotechnol. 2003, 21, 1192–1199.
[2] H. P. Dwivedi and L. A. Jaykus, Crit. Rev. Microbiol. 2011, 37, 40–63.
[3] L. A. Garraway and E. S. Lander, Cell 2013, 153, 17–37.
[4] P. C. Y. Woo, S. K. P. Lau, J. L. L. Teng, H. Tse and K. Y. Yuen, Clin. Microbiol. Infect. 2008, 14, 908–934.
[5] I. G. Wilson, Appl. Environ. Microbiol. 1997, 63, 3741–3751.
[6] R. Alaeddini, Forensic Sci. Int.: Genet. 2012, 6, 297–305.

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ANA-PO-127

Univocal discrimination of hydrocarbon isomers by means of a novel integrated GC-FTIR/MS approach

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Hydrocarbons are the principal constituents of petroleum, which represents a very important raw material, as it can be used to produce fuels lubricants, plastics, fibers, rubbers, solvents, industrial chemicals, etc. Understanding the composition of such complex samples is particularly challenging because of the huge number of chemical compounds they have.

The hyphenation of gas chromatography and mass spectrometry (GC-MS) with electron ionization (EI) source is the gold standard for identification of unknown volatile compounds. However, for hydrocarbons, the high number of possible geometric and positional isomers makes the identification challenging because of the identical molecular weight as well as their similar fragmentation pattern. On the other hand, Fourier Transform Infrared Spectroscopy (FTIR) provides a wealth of molecular information of GC-separated analytes, related to the vibration of molecular functional groups which are complementary to the MS ones.

In this research, a new GC-*sd*-FTIR/MS instrument was developed, based on post-column GC flow splitting to GCMS-QP2020 NX mass spectrometer (Shimazdu, Kyoto, Japan) and DiscovIR-GC solid phase FTIR detector (Spectra-Analysis Instrument Inc., Marlborough, MA, USA). By means of this integrated instrumentation, it was possible to obtain three complementary information from a single analysis: the linear retention indices (LRI) of the separated compounds, their *m/z* spectra and IR fingerprint. Therefore, the definitive discrimination of hydrocarbon isomers was achieved.

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ANA-PO-128

Chemical characterization of *Citrus australasica* peel essential oil by using different chromatographic techniques

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Finger lime (*Citrus* australasica L.) is a *Citrus* species endemic to Australia but it is also cultivated in other parts in the world. This fruit, whose interior is characterized by spherical vesicles, is widely used in cooking to embellish fish dishes and in making cocktails.

In addition to its function as a flavoring agent, this fruit can be used also for the production of juices and essential oils, which contain a good amount of bioactive molecules: these and other characteristics classify finger lime as a functional food.

The fruits used for the present study were collected in Calabria (South Italy) throughout the entire productive season, from October 2022 to June 2023.

The aim of this research was to investigate volatile and non-volatile fraction of the essential oil obtained by cold pressing extraction of the finger lime peels, also allowing the evaluation of differences in chemical composition during the production season.

The volatile fraction was investigate by gas chromatography coupled to mass spectrometry (GC-MS) and flame ionization detector (GC-FID). The enantiomeric distribution of some volatile components was studied by employing a multidimensional GC (MDGC) system and a chiral column in the second dimension, with an approach based on the heart-cut mode.

Additionally, the oxygen heterocyclic compounds (coumarins, furocoumarins and polymethoxyflavones) were analysed by liquid chromatography coupled to a triple quadrupole as mass spectrometer (HPLC-MS/MS).

The results reported in the present study were compared to the literature and provides new elements, in particular referred to the quali-quantitative profile of OHCs in cold-pressed finger lime essential oil and about the investigation of thirteen chiral couples, more than half never studied so far.

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ANA-PO-129

Impact of microplastics on the lipid metabolism in *Trematomus bernacchii* from the Ross Sea, Antarctica.

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Research studies have showed that exposure of marine specimens to microplastics (MPs) induces a variety of toxic effects, including oxidative stress, metabolic disorder, changes in immune response, neurotoxicity, reproductive and developmental toxicity [1, 2]. The purpose of the present study was to evaluate for the first time the effects of MPs on the muscular lipid component in specimens of wild *Trematomus bernacchii*. The fish were caught during the 37th Italian Antarctic Expedition (2021-2022) for the SBAM - PNRA project. In Italy, the gastrointestinal tracts (GITs) of each fish were digested in order to isolate the MPs. Twenty *T. bernacchii* specimens were classified in positive (samples found to be contaminated by MPs in their GITs) and negative (samples MPs free) groups according to RAMAN spectroscopy analyses. The lipid fraction of the selected *T. bernacchii* samples was analyzed by gas chromatography technique coupled to mass spectrometry and flame ionization detectors. A total of fifty fatty acids methyl ester (FAME) compounds were identified and quantified in the analyzed samples. The lipid distributions among the positive and negative fish groups were correlated in order to evaluate the impact on the metabolic activities of fatty acids in muscle tissues. This is the first research study in which the effects of MPs are used for establishing the nutritional quality of wild marine species.

Acknowledgments: This study has been funded by the Italian National Antarctic Research Program (PNRA, SBAM project, 2020–2023) PNRA18_00041 - B2 - Study of Bacteria resistant to Antibiotics and heavy Metals (water, sediment and Trematomus bernacchii) and detection of heavy metals", funded by Italian Minister of University and Research (MUR). The research was conducted within the PON Research and Innovation 2014–2020 project funded by Italian Ministry of University and Research (MUR). The authors thank Maurizio Azzaro and Francesco Smedile for the sampling activities in Antarctica.

References:

[1] S. Sangkham, O. Faikhaw, N. Munkong, P. Sakunkoo, C. Arunlertaree, M. Chavali, M. Mousazadeh, & A. Tiwari, Marine Pollution Bulletin, 2022, 181, 113832.

[2] M. Contino, G. Ferruggia, R. Pecoraro, E.M. Scalisi, G. Cavallaro, C. Bonaccorso, C.G. Fortuna, A. Salvaggio, F. Capparrucci, T. Bottari, M.V. Brundo. Fishes, 2023, 8(3).

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ANA-PO-130

A sustainable analytical approach towards assessing olive oil adulteration

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Knowledge of the composition of TAGs in vegetable oils is important for dietary and nutritional reasons, due to the influence of the different properties of each fatty acid on the human organism. Specifically, olive oil is a popular food ingredient worldwide, and for this reason, detecting economically motivated adulteration is important to protect consumers' interest and health [1].

Current research on the fraud detection of olive oil involves a wide array of methods, including infrared spectroscopy, Raman spectroscopy, liquid chromatography (LC), and gas chromatography [2]. In this study, a fast, simple and green methodology was optimized to detect intentionally adulterated olive oil with common seed oils at different levels (between 5% and 50%), by means of subcritical fluid chromatography (SubFC) with UV detection, followed by statistical analysis.

The developed method is a more sustainable alternative to conventional non-aqueous reversed phase methods (NARP-LC), for routine analysis aimed to guarantee olive oil quality. Separation was achieved on four Ascentis Express C18 columns serially coupled (for a total stationary phase length of 60 cm), with a CO_2-based green mobile phase, which provided high efficiency without reaching a prohibitive backpressure. Remarkably, small amounts of organic modifier (5%) were sufficient for elution, thus minimizing both solvent consumption and waste (around 1.5 mL per analysis).

References:

[1] J. Zhang, H. Sun, W. Lu, ACS Food Sci. Technol. 2022, Volume 2, 415-42.
[2] M. Buchgraber, F. Ulberth, H. Emons, E. Anklam, Eur. J. Lipid Sci. Technol. 2004, Volume 106. 621-648.

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ANA-PO-131

Development of a solid deposition GC-FTIR library as a powerful tool for the identification of hydrocarbon isomers

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Gas chromatography coupled to mass spectrometry detector (GC-MS) with electron ionization (EI) source is a widely used analytical technique for identification of volatile compounds. The highly reproducible fragmentation pattern provided by MS, allows reliable identification by comparing experimental spectrum with commercial spectra database, but in many cases, misidentification can occur due to a high spectral similarity. The Linear Retention Indices (LRI) approach can be used in combination with conventional mass spectral search with the goal of boosting the identification of "challenging" molecules.

However, when it comes to molecules which present a high number of positional, as well as geometrical isomers such as hydrocarbons, the identification by GC-MS becomes challenging, because they show the same *m/z* fragmentation and a very similar retention behaviour. On the top of that, the lack of reference materials and of published retention data makes the reliable identification trickier. On the other hand, Fourier Transform Infrared (FTIR) spectroscopy can provide a wealth of molecular information of GC-separated analytes which are related to the specific vibrations of the chemical bonds present in a molecule. Such vibrations are different for each isomer, therefore making possible their discrimination.

For this reason, in this research, a database containing the spectra obtained by GC-FTIR analyses of hydrocarbon standard mixture was created, and it was successfully applied for the identification of unknowns. It allowed the reliable discrimination of the isomers which presented a very similar mass spectrum, as well as linear retention index. Such isomers, indeed, presented a considerable difference in terms of similarity score in the FTIR library search.

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ANA-PO-132

A fast RP-HPLC-QqQ-MS method to identify and quantify 36 Oxygen Heterocyclic Compounds in *Citrus*-based products

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Oxygen Heterocyclic Compounds (OHCs) are a group of secondary plant metabolites mainly represented by coumarins (Cs), furocoumarins (FCs) and polymethoxyflavones (PMFs). These molecules are characteristic of *Citrus* fruits, often employed to flavour foods and cosmetics. Unfortunately, these molecules can cause harmful effects by ingestion and following exposure to UVA. So, coumarin content is regulated both in food and cosmetic, while FCs content is regulated only in cosmetic products[1,2,3]. For these reasons, over the years differents analytical approaches were applied to determine OHCs in *Citrus* products (GC-FID, HPLC and SFC coupled with UV, fluorimeter, or mass detectors). These methods involve long analysis times or the use of toxic solvents.

Therefore, this work will focus on the development of a fast and more eco-sustainable liquid chromatography tandem mass spectrometry method (HPLC-QqQ-MS) to determine OHCs in complex matrices. The analyses were carried out on a liquid chromatographic Nexera X2 system coupled with a triple quadrupole mass spectrometer LCMS-8060 (Shimadzu Europe, Germany) via an APCI interface, set in positive ionization mode. Water and Ethanol were employed as mobile phase A and B, respectively; the column was an Ascentis Express C18 (50 x 2.1 mm, 2.7 µm) (Merck, Darmstadt, Germany). The quantitative characterization was based on calibration curves built in Multiple Reaction Monitoring (MRM) acquisition mode for each target. Method validation was performed in terms of linearity range, limit of detection (LoDs), limit of quantification (LoQs), repeatability, and accuracy.

The proposed analytical method allowed to determine 36 OHCs in 3.5 minutes with a consumption of about 3 mL of ethanol per analysis. LoDs and LoQs were less than 1 ppb for most target compounds. This method can be used to quantify OHCs, contained at trace levels, in *Citrus* products.

References:

[1] European Commission. Regulation (EC) No 1334/2008 on flavorings and certain food ingredients. Off. J. Eur. Union, 2008.
[2] European regulation (EC) No 1223/2009, Off. J. Eur. Union. 2009.
[3] IFRA Standard, 50th Amendment, 2021.

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ANA-PO-133

Chemical and ecotoxicological characterization of microplastics derived from Plasmix-based materials

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The implementation of recycling techniques represents a potential solution to the plastic pollution issue. To date, only a limited number of plastic polymers can be efficiently recycled. In the Italian plastic waste stream, the residual, non-homogeneous fraction is called 'Plasmix' and it is intended for low-value uses.

Figure 1: From Plasmix to materials.

However, Plasmix can be used to create new materials through mechanical recycling but, before being used, needs to be tested for its eco-safety because, once in the environment, it can interact with aquatic and terrestrial organisms, mainly after its breakage and/or fragmentation in microplastics. Naïve (*Px*) and additivated Plasmix-based (*APx*) materials obtained by mechanical recycling procedure were characterized. Then were grinded to obtain microplastics (*MPs*) and tested to assess their eco-safety.

The potential acute and chronic toxicities induced by the exposure to different concentrations of microplastics were evaluated on two organisms: the terrestrial earthworm *Eisenia fetida* and the freshwater Cladoceran *Daphnia magna*. The obtained results were correlated to the potential bio-disponible compounds that can migrate and up taken by the organisms.

Head-space sampling coupled to GC-MS analyses were used to determine the release via volatilization of chemical compounds from *Px-MPs* and *APx-MPs*, simulating the exposure of organisms occurring in soil.

Instead, to simulate the release that can occur in the aqueous media a water extraction of the *Px-MPs* and *APx-MPs* followed by GC-MS analyses were performed.

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ANA-PO-134

New insights into iron speciation in the soluble fraction of atmospheric particulate matter

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The constituents of the atmosphere, and in particular the particulate matter (PM), play important roles in the geochemical cycles of the metal cations. The atmospheric deposition of mineral dust from continental regions is a significant source of both iron and aluminium to the ocean[1,2], and Fe is essential to control of biomass production in ocean water. To better understand the biogeochemical cycles of the elements, it is important to evaluate their distribution between solid phase and solution as well as to define the main species that can be formed, because chemical processes occurring in the soluble fraction of the aerosol may affect the photo-reactivity and the bioavailability of metal cations[3-5]. In a previous work[6] the main ionic components occurring in water extracts of Artic atmospheric depositions were quantified, and a chemical model was applied to identify the main species occurring in the samples. The speciation models suggested a significant role of oxalate as ligand for Al^{3+}, Fe^{3+}, and Cu^{2+}, but the chemical model used was just a first approximation of the chemical speciation of the real samples, because the formation constants used were referred to 25 °C and infinite dilution. In this work the model capability was enhanced, by considering formation constants defined in the temperature range 5 – 25 °C and at ionic strength 0.05 – 3 mol L^{-1} in NaCl medium, especially for iron – oxalate complexes that mainly affect the chemical system. Hence, new models were proposed varying the temperature and the ionic strength, and highlighting the role of both parameters on Fe(III) speciation. Moreover, the formation constants here defined allow for improving the reliability of the modelling process, thereby making the chemical model more suitable to describe the chemistry of the PM soluble fraction in real environmental conditions.

References:

[1] T.D. Jickells, Z.S. An, K.K. Andersen, A.R. Baker, G. Bergametti, N. Brooks, et al. Science 2005, 308, 67–71.
[2] G. Henderson, R. Anderson, J. Adkins, P. Andersson, E.A. Boyle, G. Cutter, et al. Geochemistry 2007, 67, 85–131.
[3] R. Paris, K.V. Desboeufs, Atmos. Chem. Phys. 2013, 13, 4895–4905.
[4] D.L. Sedlak, J. Hoigné, Atmos. Environ. Part A Gen. Top. 1993, 27, 2173–2185.
[5] Z. Shi, M.D. Krom, T.D. Jickells, S. Bonneville, K.S. Carslaw, N. Mihalopoulos, A.R. Baker, L.G. Benning, Aeolian Res. 2012, 5, 21–42.
[6] M. Marafante, S. Bertinetti, L. Carena, D. Fabbri, M. Malandrino, D. Vione, S. Berto, Anal. Bioanaly. Chem. 2024, 416, 1389–1398

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Profiling of seized *Cannabis* flowering tops by means of gas chromatography analyses

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The present study aimed to support police forces in their battle against illicit drug trafficking by means of a multi-technique approach, based on gas chromatography. The research was carried out in collaboration with the Scientific Investigation Department RIS Carabinieri of Messina, which provided 25 essential oils extracted from the seized *Cannabis* flowering tops. All the samples were distilled by using microwave-assisted hydro-distillation (MAHD) system. In a first step, the Δ^9-tetrahydrocannabinol (THC) content, useful to classify cannabis plant as hemp (≤ 0.2% of THC) or as marijuana (> 0.2%), was investigated. On the other hand, the terpene profile was determined by GC-MS and GC-FID analyses. Lastly, a heart-cutting multidimensional gas chromatography (MDGC) approach was implemented, based on the combination of apolar and chiral stationary phases in the first and second dimension, respectively. The system was coupled in parallel to an isotope-ratio mass spectrometry (C-IRMS) and MS detection, for studying the enantiomeric and carbon isotopic ratios of selected chiral compounds. Finally, all the data were combined in a statistical model, to demonstrate the existence of useful parameters to be used for the classification of confiscated samples.

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Development of ion mobility-high-resolution mass spectrometry-based untargeted metabolomics for food safety assessment

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The growing demand for an antibiotic-free food chain requires both the use of effective analytical strategies in monitoring raw materials and the improvement of production processes. To date, many analysis methods are based on targeted approaches[1]; however, the comprehensive evaluation of the metabolomic changes related to the use of antibiotics requires the development of untargeted strategies.

In this context, ultra-high-performance liquid chromatography-ion mobility-high-resolution mass spectrometry (UHPLC-IMS-HRMS) currently represents the best tool to address the challenges related to the complexity of the metabolome. UHPLC provides fast and efficient separation of compounds, whereas HRMS is characterized by enhanced specificity, sensitivity and availability of large spectral databases. In addition, IMS offers great potential for improving throughput and depth of coverage in metabolomics studies, being able to separate ions according to their collisional cross-section (CCS)[1].

In the present study, UHPLC-IMS-HRMS is proposed for the evaluation of the metabolomic response of the different organs from antibiotic-treated and untreated pigs. Spectra were acquired in both positive and negative electrospray ionization modes, operating in data independent High-Definition MS^E acquisition mode, allowing for the simultaneous acquisition of CCS values, precursor and fragment ions which are key parameters for univocal identification of the metabolites[2]. Relative standard deviation within QCs samples <30%, percentage of missing values (cut-off of 40%) and a minimum 3-fold change compared to the method blanks were used for data filtering. A supervised Partial Least Squares-Discriminant Analysis pattern recognition approach was applied on the autoscaled data allowing for the annotation of features responsible for the discrimination between antibiotic-free and antibiotic-positive samples.

References:

[1] T. Ramatla, L. Ngoma, M. Adetunji, M. Mwanza, Antibiotics 2017, 6, 34.
[2] N. Riboni, F. Bianchi, M. Mattarozzi, M. Caldara, M. Gullì, S. Graziano, E. Maestri, N. Marmiroli, M. Careri, Journal of Agricultural and Food Chemistry, 2023, 71, 15407 – 15416.

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ANA-PO-137

Mass spectrometry-based discovery of faecal biomarkers for colorectal cancer towards non-invasive diagnostic tests

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Advanced mass spectrometry (MS)-based proteomics is a powerful approach for discovering new disease biomarkers, towards the development of reliable diagnostic tests for early and accurate diagnosis.[1,2] Colorectal cancer (CRC) stands as the second leading cause of cancer death, for which non-invasive diagnostic screening tests are strongly needed to improve the prognosis and the efficacy of the pharmacological therapy.[3] In order to increase participation in preventive care screening it would be ideal to find a biomarker detectable in samples collected through a totally non-invasive method such as stools.

The present work is part of a research project aimed at combining the discovery of faecal CRC biomarkers, with the perspective to implement point-of-care testing based on smart electrochemical sensing devices.

Stool samples were obtained from a cohort of patients subjected to colonoscopy and carrying at least one adenomatous polyp or carcinoma. Patients were stratified according to histology into three groups: low-grade dysplasia, high-grade dysplasia, and carcinoma; healthy controls were also included in the study.

A nano-LC coupled to an Orbitrap Exploris 480 with a High-Field Asymmetric Waveform Ion Mobility Spectrometry System was used for untargeted MS-based shotgun proteomics. Different sample preparation strategies were investigated and the extraction procedure that allowed the highest number of identified human proteins involved a lysis buffer combined with sonication and protein precipitation with acetone/ethanol (1:1 *v/v*). In particular, a total of approximately 500 proteins were identified and quantified across all the samples. Statistical analysis highlighted the presence of several enriched proteins compared to healthy subjects in low-grade dysplasia, high-grade dysplasia, and carcinoma patients.

The developed MS-based proteomics strategy permitted the shortlisting of potential CRC biomarkers for further validation.

References:

[1] M. Manfredi, E. Conte, E. Barberis, A. Buzzi, E. Robotti, V. Caneparo, D. Cecconi, J. Brandi, E. Vanni, M. Finocchiaro, M. Astegiano, M. Gariglio, E. Marengo, M. De Andrea, Journal of Proteomics 2019, 195, 138 – 149.
[2] M. Mattarozzi, M. Giannetto, M. Careri, Talanta 2020, 217, 120991.
[3] J. Zou, Z. Xiao, Y. Wu, J. Yang, N. Cui, Clinica Chimica Acta 2022, 524, 123 – 131.

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ANA-PO-138

Characterization of bergamot, grape and olive pomaces using different analytical techniques

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In the last years, agrifood processing wastes have been used for the development of multifunctional materials possibly capable of effectively and selectively interacting with organic (pesticide, dyes) and inorganic (metals, anions) pollutants, through adsorption mechanisms[1]. This contribution presents the preliminary results of an investigation focused on the characterization of bergamot (BP), grape (GP) and olive (OP) pomace samples from different cultivars, representative of various harvesting seasons. The waste biomasses were provided after juice and essential oil extraction, berries pressing for the must production and olive oil extraction, respectively. Aliquots of the pristine pomaces were mechanically ground using a grinder, dried in an oven at T = 333 K until constant weight and blended again to gain a fine powder. The resulting solids (*raw*) were divided in diverse portions and pretreated for 6 hours at T = 303 K using deionized water and nitric acid solutions, according to procedures reported in literature[2]. The *raw* and pretreated samples were characterized by means of BET and SEM-EDX techniques to get information on the superficial area and the particles sizes distribution. The TG-DTA and the FT-IR ATR spectroscopy were used to study the pomaces thermal properties and to confirm the presence of functional groups possibly capable to interact with metal cations, respectively. The acid-base properties of the biomasses active sites were potentiometrically investigated at I = 0.10-1.00 mol dm^{-3} in $NaNO_{3(aq)}$ and T = 298.15 K. To confirm the obtained results, some checks were also carried out on grape and olive pomaces pretreated with H_2O by using the classic volumetric method with calcium acetate[3]. Lastly, the dependence of protonation constants on ionic strength was modelled using an extended Debye-Hückel type equation.

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References:

[1] N. Mahato, K. Sharma, M. Sinha E. R. Baral, R. Koteswararao, A. Dhyani, M. H. Cho, S., Cho, J. Adv. Res. 2020, 23, 61–82.
[2] A. Irto, S.G.M. Raccuia, G. Lando, C. De Stefano, K. Arena, T.M.G. Salerno, A. Pettignano, F. Cacciola, L. Mondello, P. Cardiano, Microchem. J. 2023, 193, 109183.
[3] M. Eshwar, M. Srilatha, K. Bhanu Rekha, S. Harish Kumar Sharma, Int. J. Curr. Microbiol. App. Sci 2017, *6*(10), 1768-1774.

ANA-PO-139

Sorption of cortisone on polypropylene, polystyrene, and polyethylene microplastics

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Microplastics (MPs) are particles with sizes in the 5 mm – 1 µm range in their largest dimension. MPs can easily enter the environment through various routes and persist for many years in the oceans; recent studies have shown that polypropylene (PP), polystyrene (PS), and polyethylene (PE) are the most frequently detected MPs in the aquatic environment[1]. Although MPs can already pose a risk on their own, they also have the capacity to act as carriers for many substances, both inorganic and organic[2]. For this reason, kinetic and isotherm sorption studies involving MPs are extremely valuable assets to consider since they allow to provide information on the efficiency of the adsorption process and its nature, to know the limits of the sorption process and the performance of the sorbents, and to evaluate the maximum capacity and the rate of the sorption process[3]. To carry out these types of studies, kinetic and isothermal models can be applied to experimental data to understand the mechanisms involved in the retention of analytes on sorbents. In this work, a complete study of the sorption behaviour of a natural glucocorticoid, cortisone, in polypropylene (PP), polystyrene (PS), and high-density polyethylene (HDPE) MPs in two different matrices (Milli-Q water and artificial seawater) was carried out, using high-performance liquid chromatography coupled to an ultraviolet detector for the determination of the analyte. Cortisone is frequently found in natural environments, especially in aquatic ones, and it could potentially become a risk if preconcentration occurs within the MPs and their migration to a living organism that has ingested them, leading to adverse health effects[4]. Kinetic and isotherm studies were performed through batch sorption experiments under controlled conditions: 1 g of MP pellets of 3 – 5 mm diameter, magnetic agitation at 1000 rpm, and 20 ± 2 ºC. For this purpose, sorption kinetics and isotherms have been obtained and their fitting to different models (pseudo-first order, pseudo-second order, intra-particle diffusion, Langmuir, Freundlich, Temkin, Henry, Redlich-Peterson, Dubinin-Radushkevich) have been studied and commented. Despite all types of plastics showed sorption affinity towards cortisone, the comparison of results in Milli-Q water and artificial seawater revealed changes in sorption capacity and the predominant sorption mechanism involved.

References:

[1] J. Li, K. Zhang, H. Zhang, Environmental Pollution 2018, 237, 460 – 467.
[2] M. A. Dias, P. R. Batista, L. C. Ducati, C. C. Montagner, Chemosphere 2023, 318, 137949.
[3] L. Meng, H. Tian, J. Lv, Y. Wang, G. Jiang, Journal of Environmental Sciences 2023, 127, 791–798.
[4] X. Shen, H. Chang, Y. Sun, Y. Wan, Environment International 2020, 134, 105278.

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Revolutionizing biosensing: exploring synthetic receptors for small molecule detection

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Therapeutic drug monitoring (TDM) is crucial for evaluating and improving treatment effectiveness, enabling personalized treatments and precision medicine to enhance patient survival. Since drug effects vary among individuals, adjusting dosages based on individual pharmacokinetic profiles maximizes treatment benefits and minimizes adverse effects.

Biosensors represent an innovative technology that can offer an opportunity for the rapid, sensitive and specific detection of analytes (drugs, protein biomarkers, etc.). Selective receptors are the key to allow any biosensing platform to properly work. For decades antibodies (Abs) were employed as the receptors of election, and so it is nowadays. However, although Abs are very specific for proteins, they might not for small molecules. Moreover, they are also sensitive to environmental conditions such as pH, temperature, which could limit their stability and biosensor performance. Finally, their production can be expensive and time-consuming.

In this respect, aptamers and peptides might offer a valuable alterantive.[1-4] Aptamers are single-stranded oligonucleotides that can be designed to target a wide range of molecules, including small molecules. Their defined structure facilitates their binding to targets with high specificity and affinity. Furthermore, aptamers exhibit remarkable stability, superior to that of proteins or antibodies. Peptides are also a promising category of bio-recognition elements, primarily valued for their stability and selectivity towards a specific target analyte. Furthermore, they can be both chemically synthesized, which allows for straightforward production and modification. This process is typically more rapid and cost-effective compared to the production of Abs, thus making them suitable for the development of novel biosensing architectures.

Herein we discuss aptamer- and peptide-based biosensing platforms enabling the recognition of small molecules with high specificity and selectivity.

References:

[1] S. Tartaggia, A. Meneghello, O. Bellotto, A. S. Poetto, M. Zanchetta, B. Posocco, D. Bunka, F. Polo, G. Toffoli, Analyst 2021, 146, 1714 – 1724
[2] G. Moro, L. Ferrari, A. Angelini, F. Polo, Chemosensors 2023, 11, 234
[3] G. Moro, P. S. Sfragano, J. Ghirardo, Y. Mazzocato, A. Angelini, I. Palchetti, F. Polo, Biosens Bioelectron 2022, 213, 114477
[4] P. S. Sfragano, G. Moro, F. Polo, I. Palchetti, Biosensors 2021, 11, 246

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Biochar: an environmentally sustainable approach for removing potentially toxic elements (PTEs) from contaminated water

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Nowadays, to mitigate the negative effects caused by pollution, particular attention is being paid to the eco-sustainability of human and industrial activities and the development of alternatives to the use of charcoal as a source of energy production. Biochar fits perfectly into these objectives, being used as a soil amendment or as an adsorbent of organic and inorganic environmental contaminants. Moreover, it is obtained through a sustainable process, which yields biofuels, synthetic gases, and clean energy as by-products.

An important source of contamination in the Friuli Venezia Giulia Region is the Raibl dismissed mining district, located in Cave del Predil (UD), which was active for the extraction of galena (PbS) and sphalerite (ZnS) until 1991. A large amount of mineralised waste-rocks and tailings from the flotation plant operating at the Raibl mining district were disposed from 1976 to 1991 in tailings impoundments set up on the western bank of the Rio del Lago stream. Leaching processes involving tailings and the subsequent release and dispersion of potentially toxic elements (PTEs), especially Thallium (Tl), are promoted during periods of intense rainfall and high flow river conditions. The main aim of this study was to experimentally determine the ability of biochar to adsorb PTEs (such as Pb, Tl and Zn) from contaminated water. The biochar used in this study is obtained from the processing of vineyard pruning waste, produced by slow pyrolysis, and characterised by a high degree of carbonisation, aromaticity, hydrophobicity, and porosity.

Several adsorption tests were performed with two types of biochar, fine-grained and heterogeneous coarse-grained, in different solvents (MilliQ water and fluvial water from the Tagliamento River). A quantity of 200 mg of biochar was exposed to 20 mL of solutions with concentrations of 1, 5, 10, 25 and 50 mg/L of the three elements individually. The tests were also repeated with solutions containing the three elements in a mixture to assess if competition occurred between them in absorption. Using ICP-AES, the residual metals in solution were quantified, and then the adsorbed metals were calculated, expressed both as a percentage in solution and per gram of biochar used. The tests showed that fine biochar has a higher adsorption capacity than coarse biochar due to its greater homogeneity, and that the maximum amount adsorbed by this type of biochar was approximately 2000 µg/g of metal. Furthermore, neither pH nor the presence of cations in fluvial waters (Na, Ca, Mg and K) affect adsorption. By comparing the results of the single-element and multi-element tests, it was concluded that the three metals compete in adsorption, with a recurring order of affinity $Pb^{2+} > Tl^{+} > Zn^{2+}$ most likely due to the formation of a double layer on the surface of the biochar in contact with the solution, in agreement with Stern's theory.

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ANA-PO-142

Unveiling Sasanian secrets: Elemental analysis of ancient drachmas using μ–EDXRF

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Chemical analysis of ancient coins provides valuable information about the metallurgy and economy of the time when the coins were minted[1]. Due to the high value and rarity of ancient coins, museums and collectors of numismatic items often require chemical analyses using exclusively non-destructive techniques. Among these, X-Ray Fluorescence (XRF) has firmly established itself in the field of cultural heritage and, more specifically, in the analysis of ancient coins due to its cost-effectiveness, non-destructive nature, speed, and its ability to analyse the sample as is, without requiring pre-treatment or cleaning[2].

In this study, 29 drachmas minted during the Sasanian dynasty (6^{th} – 7^{th} century AD) were characterised using μ-EDXRF. Specifically, these coins were issued between 498 and 628 AD, during the reign of four Sasanian kings (Kavad I, Khosrow I, Hormizd IV, and Khosrow II) and today belong to a private collection of the Department of Humanities of the University of Trieste.

As the availability of other historical evidence from this period is limited, the coinage of the Sasanian dynasty remains the most critical source for the study of its political and economic history[3]. Therefore, this study aimed to determine the elemental composition of the alloy's surface, with the objective of ascertaining the fineness of the 29 drachmas and identifying any potential forgeries or devaluation processes that may have occurred during the period covered by these coins.

After cataloguing the coins and measuring their mass, diameter, and thickness, eight XRF spectra were acquired for each sample using a micro-XRF spectrometer ARTAX 200 (Bruker Nano GmbH). From an initial qualitative analysis of the collected XRF spectra, it was concluded that the drachmas were primarily composed of Ag, with traces of Cu, Au, and Pb. Thanks to the availability of a sterling silver standard (92.5% Ag, 7.5% Cu supplied by Goodfellow, UK), it was possible to semi-quantitatively determine the contents of these two elements in all 29 coins. The Ag content was above 95% in almost all the coins, with the exception of one coin that had a high copper content and the presence of characteristic zinc and mercury peaks: this led to the hypothesis that it might be an ancient forgery. In addition, a group of five coins with a higher silver content (> 99.8%) was observed. These coins bear the inscription "afid" on the recto, which means "good" or "excellent" in ancient Persian. The analyses conducted in this study affirmed the superior quality of these coins compared to similar coins minted in the same period but lacking the inscription, corroborating the historical hypothesis. Finally, the Au/Ag ratio, which can provide additional insights into the silver's origin, potentially identified two distinct groups of coins that may have been forged from two different raw minerals. In order to confirm the results obtained, the 29 drachmas will be analysed using the quantitative LA-ICP-MS technique.

References:

[1] B. Sodaei, P. M. Khak, M. Khazaie, Interdisciplinaria Archaeologica Natural Sciences in Archaeology 2013, IV.

[2] R. Linke, M. Schreiner, Microchimica Acta 2000, 133, 165–170.

[3] K. Uhlir, R. Padilla-Alvarez, A. Migliori, A.G. Karydas, I. Božičević Mihalić, M. Jakšić, I. Zamboni, R. Lehmann, M. Stelter, M. Griesser, N. Schindel, M. Alram, Microchemical Journal 2016, 125, 159–169.

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Chemometric strategies in forensic sciences: two case studies

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This work presents two forensic case studies where the application of chemometrics played a crucial role.

The first study explores the potential of a multiblock platform (IRIS, XGLab SRL – Bruker Nano Analytics, Milano, Italy) capable of simultaneously capturing X-ray fluorescence (XRF) data along with visible & near-infrared (VNIR) and short-wave infrared reflectance spectra (SWIR) to identify dehydrated biological fluids. Various fluids including blood, urine, semen, and saliva from different donors were analysed on wood specimens at different deposition times using chemometric methods. The study aims to achieve two objectives: firstly, to detect the presence of biological fluids on the substrate and, secondly, to differentiate between them. Chemometric analysis, including Principal Component Analysis (PCA) and Multivariate Curve Resolution - Alternating Least Squares (MCR-ALS), proved highly effective in recognizing and distinguishing between biological fluids through detailed chemical maps, even in cases with similar vibrational bands and elemental compositions, like urine and saliva.

This research contributes to the development of new techniques for forensic investigations, addressing the challenges of complex sample matrices and degradation effects commonly encountered in this field.

The second study focuses on the estimation of the time since the discharge of firearms, analysing the decay of gunshot residues (GSR) over time. GSR consists of a complex mixture of organic (O-GSR) and inorganic (I-GSR) compounds, released after the firing of a firearm. So, this research employs solid phase microextraction followed by gas chromatography - mass spectrometry (SPME-GC-MS) for the detection of O-GSR in weapon and ammunition components. The initial phase involves optimizing and validating a method to detect O-GSR in spent shells. Chemometrics, using a multivariate statistical approach based on Principal Component Analysis (PCA) and Design of Experiments (DoE), was utilized to define both the target compounds to be investigated and the optimal experimental conditions to analyse them. In the second phase, the developed method was applied to the analysis of O-GSR in semi-automatic pistol barrels, monitoring decay over time with multiple linear regression.

Preliminary findings suggest that SPME-GC-MS analysis of firearm components could offer valuable insights into recent firearm use, paving the way for potential advancements in forensic firearm investigations.

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Biomarker discovery for precision diagnosis of mechanical ventilation-associated pneumonia (VAP)

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Ventilator-associated pneumonia (VAP) is one of the most common infections in the Intensive Care Unit (ICU)[1]. The diagnosis of VAP is complex, invasive, non-specific and slow, and results can take days; hence, it is often necessary to initiate a broad-spectrum antibiotic therapy, which in many cases leads to overtreatment of the patients[2,3]. Therefore, the need for new diagnostic biomarkers, which can limit the inappropriate use of antibiotics and contribute to the reduction of antibiotic resistance, remains very important.

Exhaled breath condensate (EBC) is the exhalate from breath which has been condensed using a cooling device. It is a promising source of biomarkers, especially for lung diseases. Several biomarkers of pathogens responsible for viral infections were already identified in the EBC through metabolomics analyses[4], while knowledges on proteins are still limited.

The aim of this work was to identify novel bacterial-derived proteins responsible for infections in the ICU, through untargeted proteomic analysis of the EBC collected by condensation with a non-invasive technique. After the collection of EBC, proteins were precipitated, then digested with trypsin and peptides were desalted and analysed using nano liquid chromatography coupled with high resolution mass spectrometry (Orbitrap Exploris 480, Thermo). Using this approach, several novel biomarkers from both GRAM+ and GRAM- bacteria were identified.

Hence, with our work, we aim to make a step forward on the non-invasive diagnosis and monitoring of VAP.

References:

[1] H. Mumtaz, M. Saqib, W. Khan, S. M. Ismail, H. Sohail, M. Muneeb, S. S. Sheikh, Annals of medicine and surgery, 2023, 85, 2932–2939.
[2] S.M. Fernando, A. Tran, W. Cheng, M. Klompas, K. Kyeremanteng, S. Mehta,S. W. English, J. Muscedere, D.J. Cook, A. Torres, O.T. Ranzani, A. E. Fox-Robichaud, W. Alhazzani, L. Munshi, G. H. Guyatt, B. Rochwerg. Intensive Care Med, 2020, 46, 1170–1179.
[3] J. P. Wiener-Kronish, H. I. Dorr. Clinical anaesthesiology, 2008, 22, 437–449.
[4] E. Barberis, E. Amede, S. Khoso, L. Castello, P. P. Sainaghi, M. Bellan, P. E. Balbo, G. Patti, D. Brustia, M. Giordano, et al. Metabolites 2021, 11, 1–11.

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Immobilized Lipases on Spent Coffee Grounds for Enhanced and Sustainable Oil Hydrolysis

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Free fatty acids (FFAs) play a fundamental role in industry as they are used in various sectors, from the food and pharmaceutical industry to biofuels production. Traditionally these molecules are produced employing aggressive chemicals and high temperatures [1], so, the use of immobilized lipases has recently emerged as a promising alternative. Also, the use of lignocellulosic wastes as lipase supports has aroused great interest [2] due to their wide availability, non-toxicity, renewability, etc. [3,4]. For these reasons, this work aimed to use spent coffee grounds (SCG) for the synthesis of solid biocatalysts capable of synthesizing FFAs from olive oil. Three solid biocatalysts derived from the immobilization of commercial lipase from *Candida rugosa* (C-CRL), lipase (isoenzyme 1) from *Candida rugosa* (Lip1), and lipase from *Rhizopus oryzae* (ROL) were studied. The solid biocatalysts were obtained through adsorption [5] on the treated waste material and immobilization parameters such as time, pH, and initial activity in the immobilization mixture were optimized for all three types of enzymes. The aim was to obtain the solid biocatalyst with the highest possible activity and the success of the immobilization procedures was evaluated by considering the activity recovery (%), immobilization efficiency (%), and activity of the solid biocatalyst (U/g). The synthesized solid biocatalysts were also characterized in terms of pH and thermal stability and each was found to be more stable than the starting free enzyme. Finally, all optimized solid biocatalysts were used in the hydrolysis of olive oil at 30 °C. Operational stability was also tested by repeating the hydrolysis procedure for several cycles and washing the solid biocatalyst after each use. All three solid biocatalysts demonstrated excellent operational stability, being able to be reused for up to 6 consecutive cycles. However, immobilized C-CRL showed the best hydrolysis percentage (23%) and the best specific Space-Time Yield (STY) [6] (8.8 g L^{-1} d^{-1}).

In conclusion, this study addressed the pressing need for sustainable methods of raw material production using lipases immobilized on a lignocellulosic waste. The procedure was proved to be a promising alternative to traditional methods, offering advantages such as eco-friendliness and enzyme reuse.

References:

[1] V. Ramachandra Murty, J. Bhat, P.K.A. Muniswaran, Biotechnol. Bioprocess Eng. 2002, 7, 57–66.
[2] A.M. Girelli, V. Chiappini, J. Biotechnol. 2023, 365, 29–47.
[3] A. Mora-Sandí, A. Ramírez-González, L. Castillo-Henríquez, M. Lopretti-Correa, J.R. Vega-Baudrit, Polymers (Basel). 2021, 13, 1–15.
[4] A. Gil, Chem. Eng. J. Adv. 2021, 8, 100186.
[5] A.M. Girelli, V. Chiappini, P. Amadoro, Biochem. Eng. J. 2023, 192, 108827.
[6] M. Bausch, C. Schultheiss, J.B. Sieck, Biotechnol. J. 2019, 14, 1700721.

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ANA-PO-146

HPLC-DAD validated method for DM4 and its metabolite S-Me-DM4 quantification in biological matrix for clinical and pharmaceutical applications

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The present study focuses on the development and validation of an HPLC-DAD methodology for the detection of a potent chemotherapeutic agent, Maytansinoid Ravtansine (DM4), and its metabolite, S-methyl-DM4 (S-Me-DM4), in plasma samples.

Methodologically, after a simple protein precipitation with acetonitrile and after drying 1 mL of supernatant, the sample was directly analyzed by HPLC under isocratic elution. Employing a flow rate of 1.0 mL/min and a reversed-phase GraceSmart RP18 column thermostated at 40°C, a complete resolution and separation of DM4 and S-Me-DM4 within 13 min was achieved. The optimized injection volume of 20 µL and the wavelength set at 254 nm were utilized for quantitative analyses. The limit of detection and quantification of the method were 0.025 and 0.06 µg/mL for both the analytes, respectively. The calibration curve showed a good linearity in the range 0.06–20 µg/mL. For both analytes, the intraday precision and trueness were 2.3–8.2% and -1.1 to 3.1%, respectively, while the interday values were 0.7–10.1% and -10.4 to 7.5%, respectively.

The developed methodology [1] enables the concurrent determination and quantification of free DM4 and its metabolite, free S-Me-DM4, making it a valuable tool for assessing the pharmacokinetics and pharmacodynamics of DM4-based therapies. In addition, the procedure was successfully applied to analyse the presence of free DM4 or its metabolite, free S-Me-DM4, in human plasma samples spiked with the 1959-sss/DM4 antibody-drug conjugate (ADC). The utilization of the herein validated methodology allowed confirming the presence of these analytes, thereby providing insights into their potential release from the ADC structure.

References:

[1] G. Lovato, L. Ciriolo, M. Perrucci, L. Federici, R. Ippoliti, S. Iacobelli, E. Capone, M. Locatelli, G. Sala, Journal of Pharmaceutical and Biomedical Analysis, 2023, 235, article 115642.

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Synthesis and optimization of polynorepinephrine nanoparticles for enhanced bioanalytical applications and immunotherapy

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Monoclonal antibodies (mAbs) are currently almost the only choice in the field of molecular recognition applied for the development of bioanalytical assays, therapies, or diagnostics. Due to their high production costs and low stability, new systems need to be developed to replace them. In this context, molecularly imprinted polymers offer an effective alternative. With the ability to create selective recognition sites in synthetic polymers, MIPs offer the specificity and selectivity of naturally occurring receptors with the added benefits of ease and speed of preparation, low cost, and good stability under various environmental conditions. Among the potential polymers, polycatecholamines (pCAs) have gained prominence in the scientific literature. Inspired by the adhesive system of mussels[1], polymers derived from endogenous neurotransmitters such as dopamine (DA) and norepinephrine (NE) can be used for the synthesis of nanofilms or nanoparticles with remarkable adhesive properties on virtually any surface and are easily molecularly imprintable to obtain mimetic receptors of a new generation, namely Molecularly Imprinted Bio-Polymers (MIBPs)[2]. In particular, the synthesis of polynorepinephrine nanoparticles (PNE-NPs), achieved through alkali-induced autoxidation of NE, has been investigated and tuned by a multivariate approach of the synthesis conditions to optimize their use for various applications, from clinical diagnostics to therapy. The approach has been performed first on non-imprinted PNE NPs, and then on MIBPs. Noncovalent molecular imprinting has been exploited to create molecular recognition cavities within the polymer matrix by incorporating the protein template (or a portion of) after the initial nucleation step of PNE-NPs. Several analytical techniques can be coupled with these PNE-NPs: benchtop sensors based on Surface Plasmon Resonance (SPR), Quartz Crystal Microbalance (QCM), or Fiber-Optic Bio-Layer Interferometry (BLI). MIBPs also hold promise as an alternative to mAbs, emulating the natural process of antibody-antigen recognition in vivo, with potential applications in the treatment of diseases such as cancer, autoimmune disorders, or infections[3].

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References:

[1] H. Lee et al., Science 2007, 318, 426-430

[2] V. Baldoneschi et al., Anal. Bioanal. Chem. 2020, 412, 5945-5954

[3] S. Xu et al., Angew. Chem. International Edition 2021, 60, 3858-3869

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Reliable and miniaturized profiling of pesticides in *Cannabis Sativa L.* inflorescence by means of gas chromatography coupled to triple quadrupole mass spectrometry.

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The goal of the present research is to develop innovative, fast, reliable, and environmentally friendly analytical methods to determine pesticides in *Cannabis Sativa L.* inflorescences. The cultivation of cannabis has significantly increased in proportion to market demand and with it the use of pesticides in order to increase the crop yield. Although there are numerous analytical methods for the extraction and characterization of bioactive compounds in cannabis, the determination of pesticides in this matrix is still a relatively new area that requires further study and evaluation. Bureau of Cannabis Control Text of Regulations, the California regulation concerning the limits admitted for pesticides in *Cannabis sativa L.*, describes the Residual Pesticides Testing criteria. Pesticide residue admitted in cannabis plant materials in any case should not exceed action levels expressed as low part per billion (ppb) [lower limit of quantification (LLOQ)].

In this research study particular emphasis has been placed on the development of analytical strategies in order to meet the criteria of green and especially white chemistry, the latter aimed at encouraging the ecologic approach of researchers in the development of new instrumentations and methods, but without loss of functionality at the expense of analytical performance. Based on this assumption, a reliable and miniaturized strategy has been developed for the extraction of pesticides from hemp inflorescences with the objective of automating the entire analytical workflow. The characterization of specific pesticides or chemical classes of pesticides in hemp inflorescences was carried out by using gas chromatography coupled to a triple quadrupole mass spectrometer. For this purpose, selective MRM transitions have been optimized for each pesticide by injecting pure analytical standards. One of the main issues in pesticides context concerns the large number of compounds belonging to a broad spectrum of chemical classes. As a result, particular care has been paid to the selection of pesticides present in the agricultural cannabis scenario in order to embrace a broader spectrum of compounds.

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Recycled plastics and reuse of food contact materials: outcomes from analytical characterisation and performance evaluation

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The new Regulation on Packaging and Packaging Waste encourages the diffusion of reused and recycled plastic items to replace single-use plastics. The conformity of materials for repeated use is checked according to the EU Regulation 10/2011 based on three consecutive migrations, considering that contaminant amount decreases with increasing number of uses. It is generally accounted that migrant amount is proportional to its initial concentration, according to the law of diffusion based on coefficients constant over time[1]. However, it is not taken into account that aged materials exhibit a different behaviour respect to new items, since washing procedures before reuse, and recycling processes, result in mechanical, thermal and chemical stress affecting additives amount, and leading to the potential formation of non-intentionally added substances (NIAS) from degradation reactions[2]. Therefore, there is a need for deeper analytical controls, and for performance evaluation of the material during ageing and after repeated industrial processing.

Within a collaboration with some companies, a series of experiments was performed on food contact articles for repeated use, and on virgin and industrial processed PET. To determine the identity of potential contaminants, solvent extraction was carried out before performing migration in simulants. The effect of the use of different solvents has been investigated, and showed a variable patterns of extracted analytes. Additives and NIAS have been identified by chromatographic techniques coupled to mass spectrometry, and quantification was then performed on simulants for the substances whose standards were available.

A different trend depending on the substance was observed: a decrease with ageing was shown for colorants in reused items, whereas compounds deriving from material degradation increased. As for recycled plastics, the effects of industrial processing and recycling procedures were investigated to explore if could lead to additives degradation and formation of NIAS. Preliminary results showed differences in the profile of analytes in PET virgin granules compared to processed material. Aged and recycled bottles were also investigated.

References:

[1] R. Brandsch, D. Schuster. Food Additives and Contaminants A 2020, 37, 2184-2203.
[2] Bignardi C., Cavazza A., Laganà C., Salvadeo P., Corradini C. Food Control 2017, 71, 329-335

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Activity-based biosensors for the monitoring of MutyH DNA glicosylase

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DNA is continually subject to interactions with mutagens which can lead to structural damage of the molecule, affecting human health. The most frequent oxidation-induced lesions in DNA are 8-oxo-7,8-dihydroguanine, often resulting in G:C to T:A transversion mutations. When this modified base pairs with cytosine on the double helix, it is recognized by the DNA glycosylase OGG1 and removed, initiating the base excision repair (BER). However, if OGG1 fails or the damage occurs during replication, it leads to a mismatch of 8-oxo-guanine:A, recognized by a specific glycosylase, MUTYH, which removes the adenine. The literature presents various molecular methods for assessing DNA repair activity, primarily centred on the use of indirect techniques.[1] However, these methods have a variety of issues, including long analysis times, limited applicability in clinical settings. To enable direct monitoring of MUTYH activity, only few examples using chemically modified DNA probes with fluorescence readout have been reported.[2] Although they offer advantages as simplicity, rapidity, good specificity, and sensitivity. Here I propose developing a synthetic biology toolkit for real-time analysis of MUTYH activity. I will design programmable nucleic acid capable of transducing glycosylase activity into downstream CRISPR-powered ultrasensitive detection. This is achieved by using a rationally designed DNA-based hybridization network based on the switching activity of a DNA probe called "DNA activator module" whose structural switch is controlled by glycosylase activity. Only when the DNA activator module populates an ON state the CRISPR/Cas12a is activated, thus generating a fluorescence signal output. (Figure 1)

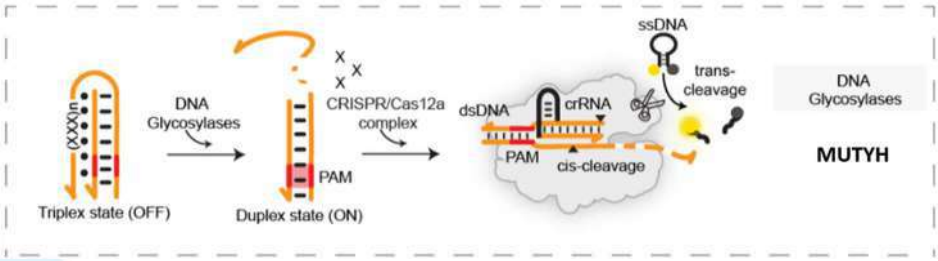

Figure 1: Description of Glycosylase-triggered CRISPR-Cas12 activity assay where the DNA activator module is identified in a DNA Triplex module.

References:

[1] Z.D. Nagel et al., Proceedings of the National Academy of Sciences 2014, 111.18, 1823-1832.
[2] D.L. Wilson, and E.T. Kool, ACS chemical biology 2017, 13(7), 1721-1733.

ANA-PO-151

A preliminary evaluation of the physico-chemical and sensorial properties of Sicilian hemp seed cake flour, with a focus on the VOCs distribution

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Hemp seed cake flour (HSCF) is obtained by industrially processing the press cake derived from the extraction of the oil from the seeds of *Cannabis sativa* L. The hemp market has today grown exponentially, becoming distant from that of a decade ago or so, when it was bound to the textile, biofuel, and papermaking fields. The proven health-promoting effects of hemp and hemp-based products have become strongly appealing to the public interest. As an example, hemp seed oil (HSO) represents an active ingredient in the formulation of food supplements and cosmetic products, useful for the relief from a variety of ailments, such as psoriasis, dermatitis, hypertension, dyslipidemia. Hemp seed cake has been widely demonstrated to contain important bioactive molecules: up to 50% proteins, 9-20% lipids, 6-7% dietary fiber, considerable amounts of minerals [1]. On November 2023 the European Commission has published a revised version of the Novel Food Catalogue which includes cannabinoids and cannabidiol as new entries, confirming the importance acquired by hemp products in the Union. Furthermore, the use of HSCF fits a virtuous model of circular economy: only in 2018 the amount of press cake produced in Europe from HSO processing was estimated to be 2.18 Mtons [2]. Recovering hemp by-products meets therefore the criteria of environmental protection, both in terms of waste removal and of providing functional ingredients with no further depletion of natural sources. In this scenario, scope of the present study was the evaluation of the physical, chemical and sensorial properties of some samples of HSCF produced in Sicily. Beyond the flour, bread samples were prepared by using mixtures of wheat flour and HSCF at different ratios - 0%, 10%, 20%, and 30% HSCF, respectively. Moisture, ashes, fiber, carbohydrates, proteins, polyphenols, tocopherols, sterols, and fatty acids were assessed in HSCF samples. Additionally, Headspace-Solid-Phase Microextraction (HS-SPME) was applied to the analysis of the volatiles released by bread samples; alongside, a panel test was carried out by trained personnel in order to evaluate the sensory quality of bakery products containing HSCF, hence, consumer's acceptance.

References:

[1] T. Capcanari, E. Covaliov, C. Negoiţa, R. Siminiuc, A. Chirsanova, V. Reșitca, D. Ţurcanu, Foods 2023, 12, 4327.
[2] European Industrial Hemp Association, Hemp cultivation & production in Europe in 2018, www.eiha.org (accessed March 29, 2024).

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ANA-PO-152

PERICARD: a targeted Plasmatic pEptidomic profile foR monItoring CARdiovascular Diseases

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Cardiovascular diseases (CVDs) are a group of heart and blood vessels disorders including heart failure, thromboembolism, coronary artery disease, and chronic kidney disease[1]. They currently stand as the leading cause of global mortality because of their challenging diagnosis and their non-specific symptoms[2]. Current diagnostic strategies rely on assessing risk factors and dosing biomarkers i.e., protein and peptide levels in human plasma, by using commercial immunoassays. However, the approaches are typically employed when symptoms are already present. Moreover, the analysis of CVDs biomarkers can be hampered by the high cross-reactivity with structurally similar species[3].

Here we present, an ultra-high performance liquid chromatography-electrospray ionization-tandem mass spectrometry (UHPLC-ESI-MS/MS) method to determine targeted plasma peptidomics overcoming immunoassay limitations. The importance of a reliable plasma sample pre-treatment procedure for the determination of low-abundant (unit-tenths of pg/mL) intact peptides (such as endothelins, fibrinopeptides, guanylins, urotensins) is discussed. Additionally, strategies to mitigate the potential risks, such as secondary adsorption phenomena and peptide degradation have been also investigated.

Microextraction by packed sorbent (MEPS) technique has been tested as an alternative procedure for sample pre-treatment and analyte pre-concentration. Finally, the suitability of this methodology will be established for the analysis of human plasma from patients affect by CVDs.

PERICARD seeks to meet the need for an efficient, high-throughput tool for early identification of at-risk individuals. Its potential applications such as diagnosis, prognosis, prediction of disease recurrence, and therapeutic monitoring, may pave the way in the management of CVDs.

References:

[1] WHO/Europe | Non communicable diseases | https://health.ec.europa.eu/ | Accessed on 01/03/24;
[2] Vasan, Ramachandran S. "Biomarkers of cardiovascular disease: molecular basis and practical considerations", *Circulation*, 113.19 (2006): 2335-2362;
[3] Maurer, Jonathan, Eric Grouzmann, and Philippe J. Eugster. "Tutorial review for peptide assays: An ounce of pre-analytics is worth a pound of cure", *Journal of Chromatography B* (2023): 123904.

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Penetration depth in NIR and XRF spectral imaging: the INSIDE research project

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The two-year research project INSIDE, funded by the Italian Ministry of Universities and Research – MUR as a frame for the "PRIN 2022" call, involves three Italian universities: Genova, Bologna and Torino. The project is aimed at revolutionising the concept of hyperspectral imaging (HSI) in the near-infrared (NIR) and X-ray fluorescence (XRF) spectral domains, evolving from a surface analytical technique to an in-depth 3D spectral tomography. The impact of such a cutting-edge analytical solution will be exploited and validated in three main application fields: food analysis, cultural heritage, and forensic sciences.

After a systematic literature analysis of research studies published on this topic, for a comprehensive recognition of the state of the art, key factors affecting the penetration depth of NIR and X radiations, as well as their interactions, will be investigated by application of multivariate design of experiments (MDOE). Moreover, applying proper sampling design techniques will ensure the collection/preparation of samples capable of guaranteeing maximum representativity and the development of analytical strategies characterised by an effective capacity to address the predetermined targets. During these initial phases, ad hoc samples, with a well-defined stratigraphy, will be designed and built employing a multi-material 3D printer, using polymers with distinct spectral signatures.

Multivariate unmixing strategies – including multivariate curve resolution (MCR) and super-resolution algorithms – will be applied for efficiently gathering 3D chemical information from hyperspectral data.

Confirmatory analyses will be performed to validate the analytical protocols developed by using scanning electron microscopy (SEM), gas chromatography-mass spectrometry (GC-MS) and ultra-high performance liquid chromatography tandem mass spectrometry (UHPLC–MS/MS).

Suitable tools for 3D graphics will be implemented for the conversion of deconvoluted NIR and XRF hyperspectral information into 3D chemical maps, including the development of a stand-alone app with a user-friendly GUI, which will be distributed to the project stakeholders for testing, and will demonstrate the way forward for establishing new opportunities in research and industrial sectors.

Acknowledgement:
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ANA-PO-154

Long-term and photostability of nabumetone/cyclodextrin solid mixtures

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Nabumetone (NAB) is a nonsteroidal anti-inflammatory prodrug, categorized as a class II drug according to the Biopharmaceutical Classification System. Very recently we have reported the results of spectroscopic, spectrometric and calorimetric studies on its complexes with β-cyclodextrins (β-CDs) in solution.[1] β-CDs form 1:1 inclusion complexes with NAB in water and simulated biorelevant media (Figure 1), and increase its solubility. In the continuation of our work, we have prepared and analyzed NAB-β-CDs systems in the solid state as well. Herein, we present the results of long-term and photostability of NAB solid mixtures with various cyclodextrins (CDs): β-cyclodextrin (β-CD), hydroxypropyl-β-CD (HP-β-CD), randomly methylated β-CD (RM-β-CD), and sulfobutylether sodium salt β-CD (SBE-β-CD).

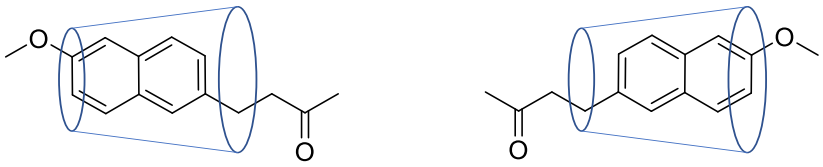

Figure 1: Two orientations of NAB in β-CD cavity.

The solid mixtures were kept under the following conditions: (*i*) 141.2 h under day light source (8.5 klux) + 40 h under UV source (5 W/m^2) to ensure that standard ICH Q1B photostability testing conditions were achieved; (*ii*) 25 °C and 60 % RH long-term storage condition according to ICH Q1A(R2). The samples were analyzed by previously developed and validated UHPLC-DAD stability-indicating method for NAB determination in the presence of its degradation products formed under the stress conditions. Chromatographic analysis was achieved on Agilent C18 column (2.1×50 mm, 1.8 µm) in gradient mode (15 min) using mobile phase consisting of 0.1 % formic acid in water and methanol with the flow rate set to 0.20 mL/min. NAB was detected at 231 nm. All prepared complexes and pure NAB appeared stable under tested conditions and no CD-mediated drug degradation was observed.

References:

[1] D. Klarić, M. Kelrajter, A. Čikoš, A. Budimir, N. Galić, *J. Mol. Liquids* 397 (2024) 124152.

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ANA-PO-155

Scanning electron microscopy for tear film analysis: identification, characterisation and quantification of particulate matter as a useful marker of urban air pollution.

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It is widely recognized today that outdoor air pollution can affect human health. Various chemical components that are present in ambient pollution may have an irritant effect on the mucous membranes of the body, particularly those of the respiratory tract. Much less attention has been focused on the adverse effect on the ocular surface, even though this structure is even more exposed to air pollution than the respiratory mucosa.

Tear analysis has emerged as a promising technique for non-invasive monitoring of various physiological and pathological conditions. Tears, often overlooked in clinical diagnostics, contain a diverse array of biomarkers reflective of systemic health, including environmental exposures[1]. Pollutants such as heavy metals and volatile organic compounds (VOCs) can be detected in tears, providing valuable insights into individual exposure levels and associated health risks[2]. However, challenges remain in standardizing tear collection protocols and refining analytical techniques for pollutant detection at trace levels.

Here, scanning electron microscopy (SEM) was employed for the first time to analyse and characterize particulate matter (PM) present in tear films. The final goal was to assess the extent of PM deposition on the ocular surface and its potential correlation with pollution levels in urban areas. Twenty healthy subjects were enrolled in the study after being exposed to urban traffic in Bologna. Tears were collected using a micropipette directly from the lower conjunctival sacs at different time points after the beginning of the exposure (0.5h, 1 h, 2h, 4h).

SEM analysis revealed the presence of various PM types on the surface of tear films collected. Particles were categorized based on size, morphology, and elemental composition. The average particle count per unit area was quantified, showing a range of particle densities across different samples. Results indicated a predominance of fine particles (PM2.5) adhering to the ocular surface, with occasional larger particles (PM10) observed. Energy-dispersive X-ray spectroscopy (EDS) was employed to perform elemental analysis of selected particles. Results identified common elements associated with PM pollution, such as carbon, oxygen, sulfur, nitrogen, and trace metals (e.g., iron, calcium).

In summary, SEM analysis of tear films from healthy subjects in the urban area of Bologna demonstrated significant deposition of PM. Statistical analysis revealed a positive correlation between PM levels in tear films and the exposure duration to urban environment.

References:

[1] M.A. Gutiérrez, D Giuliani, A.A. Porta, D. Andrinolo D, J Ophthalmic Vis Res 2019, 14(4), 419-427
[2] O. Girshevitz, N. Cohen-Sinai, A. Zahavi, Y. Vardizer, D. Fixler, N. Goldenberg-Cohen, J. Pers. Med. 2022, 12, 1633

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ANA-PO-156

Exploring the Mineral Composition of Niche Celery Varieties: A Multi-Elemental Analysis of Torricella Peligna Black and Trevi Black Cultivated in an Experimental Field

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The objective of this study was to evaluate the elemental composition of four distinct Italian celery varieties, with a special interest for two traditional cultivars, Torricella Peligna Black and Trevi Black, protected by the Slow Food Presidia. All samples were cultivated in an experimental field in Torricella Peligna (Abruzzo). Celery leaves were frozen, dried (85°C, 24 h), ground, mineralized and then analysed using Inductively Coupled Plasma-Mass Spectrometry. Accuracy and precision were assessed through spiking recovery analysis. 70 observations were available for the subsequent analysis. Covariance Selection-Linear Discriminant Analysis, Partial Least Squares-Linear Discriminant Analysis, and Soft Independent Modelling of Class Analogies, validated through double cross-validation, were employed to identify the most discriminating elements, with the aim of evaluating the potential of the multi-elemental profile to distinguish and authenticate these varieties from the common ones.

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ANA-PO-157

A study of emerging contaminants present in Antarctic matrices by means of high-performance liquid chromatography coupled with mass spectrometry

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Emerging contaminants (ECs) are chemical compounds not commonly present in the environment and whose dispersion may cause known or suspected damage to the environment and human health. Despite their potential adverse effects, these compounds have not yet undergone international regulation[1]. Recent scientific inquiries confirmed the presence of several categories of ECs in remote regions, including Antarctica. These compounds include pesticides, pharmaceuticals and personal care products, and hormones and are characterised by their poor degradability and pseudo-persistence[2,3]. Different approaches can be adopted to assess and monitor the impact of ECs on the Antarctic ecosystem. Filter-feeding organisms, such as bivalves, are often utilised in literature as biomonitoring species due to their capacity to accumulate pollutants through their feeding habits[4]. However, the inherent complexity of the sample poses a significant challenge in interpreting biomonitoring results. In response to these challenges, passive samplers are indicated as a valid alternative for environmental monitoring. These samplers offer advantages such as simplicity of deployment and the ability to provide integrated measurements over time, offering valuable information into temporal trends of EC levels in Antarctic waters[5].

In this study, a comprehensive assessment of Antarctic contamination was undertaken by evaluating two distinct approaches. The bioindicator species Adamussium colbecki was analysed alongside the Polar Organic Chemical Integrative Sampler (POCIS) deployed during the 2022-2023 Antarctic campaign. A. colbecki samples underwent a QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) pre-treatment procedure that was optimised using an experimental design technique. POCIS sorbents were eluted with a two-step elution by using methanol and a dichloromethane-isopropanol mixture. The resulting extracts were run dry and resuspended with methanol. The extracts obtained from the two methods were analysed using high-performance liquid chromatography-tandem mass spectrometry (HPLC-MS/MS).

References:

[1] N. Lowther, 2014, University of Canterbury Thesis Archive, 1-16.
[2] C. Mirasole, M. Di Carro, S. Tanwar, E. Magi, 2016, Journal of Mass Spectrometry, 814-820.
[3] S. Sauvé, M. Desrosiers, Chemistry Central Journal, 2014, 1-7.
[4] S. Pizzini, E. Marchiori, Piazza R., G. Cozzi, C. Barbante, 2015, Microchemical Journal, 184-191.
[5] N. Kamali, F. Abbas, M. Lehane, M. Griew, A. Furey, 2022, Molecules, 1-59.

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ANA-PO-158

Optimizing a sustainable approach: green extraction of anthocyanins from Apulian pigmented wheat landraces

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Among the most common staple cereals, bread (*Triticum aestivum* L.) and durum wheat (*Triticum durum* Desf.) are broadly employed to produce several wheat-based food items[1]. While conventional varieties of grains are scarce in anthocyanins, thus lacking a pillar in fighting the metabolic syndrome[2], pigmented ones were found to provide significant burdens of these secondary metabolites[3]. To meet the current market needs, Granomischio® offers a wide product lining of grain derivatives based on three wheat landraces harvested in Foggia (Apulia, Italy). The most promising genotypes have already received attention as potential primary commodities to produce nutraceutical supplements[4]. Although the use of acidified methanol with high amounts of HCl (MeOH/HCl) has led the way for the extraction of anthocyanins from pigmented grains, novel green approaches have extensively been explored to pursue food security[5]. At first, an analytical method relying on reversed-phase liquid chromatography in conjunction with UV–diode-array detector and electrospray ionization high-resolution mass spectrometry (RPLC-DAD/ESI-HRMS) was developed for the detection of three of the most abundant anthocyanins occurring in pigmented wheat, namely cyanidin-3-glucoside, peonidin-3-glucoside, and cyanidin-3-rhutinoside[6]. To find the most sustainable green extraction approach of anthocyanins from Apulian wheat landraces, we used a computer-aided plan called D-optimal design. This helped us identify key factors like acid content, solvent mix, solvent amount, and temperature. We also investigated whether using ultrasound waves during extraction could be beneficial. Next, we fine-tuned these factors to see if this new method could outperform the traditional one using MeOH/HCl. This communication will discuss the results, focusing on the trade-offs between different extraction strategies and how they can be used to maximize the value of these unique wheat varieties.

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References:

[1] Su Wen-Hao et al., Crit. Rev. Food Sci. Nutr., 2017, 5, 1039–1051.
[2] Dorothy Klimis-Zacas et al., J. Berry Res., 2016, 2, 225-236.
[3] Rachna Gupta et al., Trends Food Sci Technol., 2021, April, 2021, 240-252
[4] Anna Iannucci et al., Cereal Chem., 2022, 6, 1-14.
[5] Tan Jiaqi et al., J. Agric. Food Res., 2022, June, 100306.
[6] Praveen Saini et al., Crit. Rev. Food Sci. Nutr., 2021, 61, 3197-3210.

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ANA-PO-159

Unveiling the mechanism of action of additives in copper electrodeposition: A spectroscopical-computational approach

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Acid copper (AC) electroplating is a fundamental process both in technological and decorative fields. AC electroplating is a necessary step for Ni-free production cycles which are trending given the increased awareness of the toxicity of Ni and Ni^{2+} salts[1]. Commercial AC baths are made by $CuSO_4$, H_2SO_4, NaCl and a set of three organic additives (suppressor, brightener, and leveller) that are needed to obtain shiny and adherent deposits. Despite the widespread use of those in industrial processes, their mechanism of action and the role of NaCl during the deposition are not clear yet. An in-depth understanding of this topic is essential to achieve the environmental sustainability goals of reducing organics in wastewater and replacing toxic additives (e.g. thiourea) with eco-friendly alternatives such as L-cysteine[2]. This work aims to develop a protocol where analytical spectroscopy is intimately aided by microscopy and computational chemistry to characterize the mechanisms of action of additives during industrial electroplating processes. X-ray photoelectron spectroscopy (XPS) experiments were implemented to study the surface composition of the deposits, and to define the correct oxidation state and spin multiplicity of Cu clusters in simulations. Thanks to the XPS results and Raman experiments it has been possible to define the type of adsorption (chemical or physical) of species on top of the Cu surface. Moreover, the effect of additives on morphology (grain dimension and roughness) was investigated by Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). X-ray diffractometry (XRD) was employed to verify and quantify the magnitude of preferential orientation due to the additives and, linking XRD with AFM and SEM imaging, it was possible to unveil the influence of brighteners on the very first step of growth and to identify a seminal 2D structure[3]. All the hypotheses and doubts coming from empirical experiments were validated and dissipated thanks to a computational approach. Classical molecular dynamics, within the gaff2016 protocol, were performed to study how electrolytes behave under an electric field and if physisorption was possible. Finally, *ab-inito* calculations at CAM-B3LYP(D3BJ) level, employing a mixed 6-31G(d,p)-LANL2DZ basis set, where needed to define the chemisorption and explain the influence of additives on the shifting in preferential growth direction of copper nuclei.

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References:

[1] M. Vorobyova *et al.*, Materials 2023, 16(14), 4919
[2] B. Tadesse, M. Horne, J. Addai-Mensah, J Appl Electrochem 2013, 43, 1185–1195
[3] M. Song, G. Zhou, N. Lu, J. Lee, E. Nakouzi, H. Wang, D. Li, Science 2019, 367(6473), 40-45

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ALI-OR-001

Primary and Secondary Metabolites Associated to Sensory Perception in Honey

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In the present contribution we report our investigation on the relationship between chemical composition and taste, odour and flavour sensory descriptors in honey using O-PLS regression models.[1] Thirty multifloral honey from Trentino region (Italy), produced and collected in 2021, were characterised by NMR, GC-MS and sensory analysis (Check-all-that-apply).[2] The sensory panel was made up of 47 judges (Gender: 74% female; Average age: 49.3 years) registered in the Italian register of experts in sensory analysis of honey.[3]

Significant coefficients (after cross validation) of the regression models were calculated to establish the contribution of the single metabolite on each of the 68 sensory attributes used by the sensory panel.

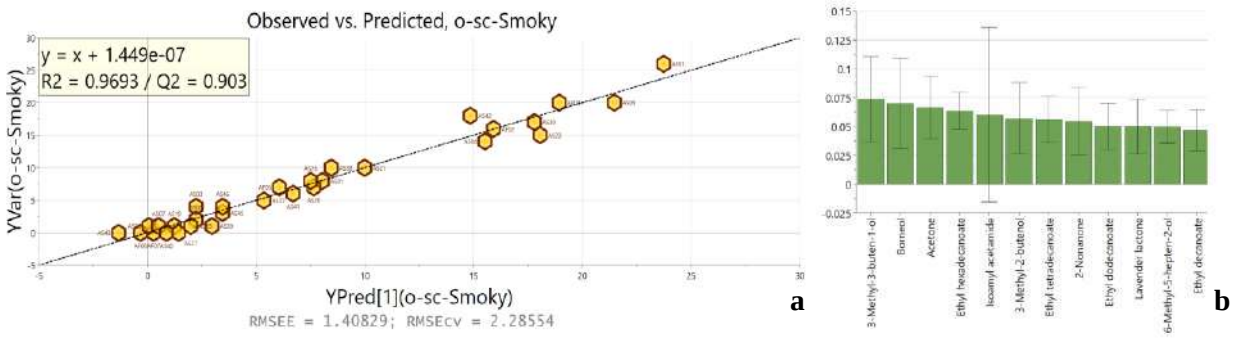

Figure 1: Odour "smoky" sensory descriptor: a) Scatter plot of the observed versus predicted values. b) Plot of the coefficients referring to scaled and centred data with confidence intervals derived from jack-knifing.

As an example, in Fig.1, is reported the regression model for the "smoky" odour attribute for which the five most contributing metabolites are 3-Methyl-3-buten-1-ol, Borneol, Acetone, Ethyl hexadecanoate, 3-Methyl-2-butenol.

References:

[1] E. Aprea, M.L. Corollaro, E. Betta, I. Endrizzi, M.L. Dematte, F. Biasioli, F. Gasperi, Food Research International 2012, 49, 667 – 686.
[2] J. Adams, A. Williams, B. Lancaster, M. Foley, 7th Pangborn Sensory Science Symposium, 2021, Minneapolis, USA, 12–16.
[3] https://www.crea.gov.it/web/agricoltura-e-ambiente/-/albo-nazionale-degli-esperti-in-analisi-sensoriale-del-miele

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A fermentation-based approach for the bioconversion of leftover food into astaxanthin by *Phaffia rhodozyme*

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Astaxanthin is a carotenoid with remarkable antioxidant properties, which is conventionally obtained through chemical synthesis or natural extraction[1]. However, both methods struggle to keep pace with the burgeoning market demand across various industrial sectors[2]. This study explores a fermentation-based approach for the bioconversion of leftover food (LF) into astaxanthin by *Phaffia rhodozyme*. The aim is to create a value-added product through a sustainable and cost-effective process. LF with a heterogeneous composition rich in carbohydrates, lipids, proteins, and minerals, was sourced from university canteens and it was used as fermentation medium for *P. rhodozyme* ATCC 74219. Previously the LF was pretreated via drying and grinding in order to obtain a fine powder, subsequently subjected to a comprehensive analysis, including proximate composition, elemental and fatty acid profiles, as well as reducing sugar content. For fermentation, 2.5 mL of *P. rhodozyme* inoculum was introduced into sterilized LF with pH adjusted to 5.0. Fermentation took place at 23 °C and 220 rpm agitation over a period of 115 hours, resulting in an astaxanthin yield of 132.6 mg· L^{-1} through direct fermentation (DF) in a lab-scale bioreactor. To enhance DF productivity, four substrate concentrations were tested, evaluating their impact on astaxanthin accumulation in *P. rhodozyme*. At the optimal 20% substrate concentration of LF, the mass balance at the end of fermentation yields 0.25% and 0.20% for carotenoids and ethanol, respectively. The purpose of the work was achieved through the implementation of an experimental design, based on three crucial steps: i) nutrient optimization (low-cost raw materials); ii) optimization of strain culture conditions; iii) optimization of fermentation variables with selection and inclusion of Barley extract as fermentation promoters.

References:

[1] A. Donoso, J. González-Durán, A. Muñoz, P. González, C. Agurto-Muñoz, Pharmacological Research 2021, 166, 479, 499.
[2] B. Stachowiak & P. Szulc, Molecules 2021, 26, 2666-2684.

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ALI-OR-003

Modulating the nutritional profile of the novel food *Acheta domesticus* by dietary supplementation with the eco-sustainable alga *Ascophyllum nodosum*

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The house cricket (*Acheta domesticus,* AD) is considered one of the most promising farmed insect species to be used as novel food, due to its attractive nutritional profile especially high in protein level [1]. However, being a terrestrial insect species, AD is poor in unsaturated fatty acids (UFAs), particularly the health promoting omega-3 long chain polyunsaturated fatty acids (n-3 LC PUFAs) such as docosahexaenoic acid (DHA, 22:6n-3) and eicosapentaenoic acid (EPA, 20:5n-3). One of the advantages of insects is their plasticity in response to varying rearing substrates [2]. As such, this study aimed to evaluate the use of the brown alga *Ascophyllum nodosum* (AN) (rich in n-3 PUFAs and omega-6 FAs [3]), as dietary for AD rearing, in different percentages (20% and 40% of the diet), to improve the nutritional quality of crickets. FA composition (GC-MS), proximate composition (AOAC method) and amino acid composition (HPLC) were determined. Results showed that the protein content of AD, as well as the amino acids profile, were not influenced by the experimental diets, with protein levels up to 55.9 g/100 g dry matter. The lipid content of AD significantly decreased ($p=0.0013$) with increasing seaweed inclusion in the diet, while a significant increase of UFAs ($p=0.0105$) (including EPA and DHA), and a significant decrease of SFAs ($p=0.0001$) was found compared to AD fed the control diet. Additionally, the assessment of the nutritional indices based on FA profile of crickets, in relation to cardiovascular disorders prevention in human, has been evaluated. In AD fed AN-enriched diets, Atherogenic and Thrombogenic indices significantly decreased ($p=0.0021$ and $p=0.0474$, respectively), while hypo-cholesterolemic to hyper-cholesterolemic ratio significantly increased ($p=0.0012$) compared to AD fed the control diet. These findings suggest that AN-enriched diets effectively improved the nutritional profile of crickets, leading to a reduced lipid content and an improvement in the quality of FAs in crickets, making them a valuable resource for human consumption.

References:

[1] X. Fernandez-Cassi, A. Supeanu, M. Vaga, A. Jansson, S. Boqvist, I. Vagsholm. Journal of Insects as Food and Feed 2019, 5 (2), 137-157.
[2] B. Ajdini, I. Biancarosa, G. Cardinaletti, S. Illuminati, A. Annibaldi, F. Girolametti, M. Fanelli, G. Pascon, M. Martinoli, F. Tulli, T. Pinto. Journal of Insects as Food and Feed 2024, 1, 1-18.
[3] GA. El-Shoubaky, AMY. Moustafa, EAE. Salem. Research Journal of Phytochemistry 2008, 2, 18-26.

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ALI-OR-004

Enzymatic protein hydrolysis of meat and poultry by-products: chemical characterization, process optimization and techno-functional properties.

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Protein hydrolysis is a well-known reaction with multiple applications in food production.[1] It is use for example to increase the water solubility of some proteins, to produce bioactive peptides with different bioactive properties (e.g. antioxidants, ACE-inhibitors, anti-tyrosinase, etc.),[2] to improve the digestibility of proteins and to obtain proteins with techno-functional properties. Compared to acid or basic catalyzed hydrolysis, the use of specific proteolytic enzymes allows working in mild conditions, avoiding the use of high temperatures or extreme pH which can cause unwanted side reactions, such as the racemization of amino acids.[3] Enzymatic protein hydrolysis can be applied directly to heterogeneous mixtures containing water and the food matrix to be hydrolyzed, combining the protein extraction and hydrolysis steps in a one-step process called enzyme-assisted protein extraction,[4] which produces an aqueous solution of peptides and free amino acids.

Enzyme-assisted protein extraction was then applied both to recover poultry industry by-products, such as bone and skin mixtures from poultry cuttings and mechanically separated meat residues, and to produce poultry hydrolysates with techno-functional and flavouring properties.

The protease from *Bacillus licheniformis* has been successfully used to recover proteins from poultry industry by-products, obtaining a protein hydrolysate with a high protein content (79-86%), a good amino acid profile (chemical amino acid score of 0.7-0.8) and good gastric digestibility (about 30% of hydrolysed peptide bonds). Regarding the production of poultry protein hydrolysates with techno-functional properties, pepsin provided the best hydrolysis yields (70.94 and 83.70 for mechanically separated meat and chicken breast, respectively) and technical-functional properties (solubility up to 95.5%, swelling up to 3.18 g/g, oil holding capacity up to 8.80 g/g, emulsifying properties up to 34.37%, foaming capacity up to 286.66%), with hydrolysis dependent on the raw material but still between 60 and 90 min.

Therefore, tailoring the process by choosing the right proteases and suitable hydrolysis conditions allows to recover the protein fraction of different poultry fractions, and to obtain hydrolysates with the desired techno-functional properties.

References:

[1] M. Nasri, Advances in Food and Nutrition Research 2017, 81, 109 – 159.
[2] D. E. Cruz-Casas, C. N. Aguilar, J. A. Ascacio-Valdés, R. Rodríguez-Herrera, M. L. Chávez-González, A. C. Flores-Gallegos, Food Chemistry: Molecular Sciences 2021, 3, 100047.
[3] F. D. Troncoso, D. A. Sánchez, M. L. Ferreira, Chemistry Open 2022, 11(3), e202200017.
[4] G. Franca-Oliveira, T. Fornari, B. Hernández-Ledesma, Processes 2021, 9(9), 1626.

ALI-OR-005

Potential antihypertensive effects of environmentally sustainable glucosinolate-extracts from radish microgreens

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The term biofactories refers to various biological platforms for the sustainable and inducible production of phytochemicals with potential nutraceutical applications. The main bio-factory models include microgreens, cell cultures, and cell suspensions. Specifically, microgreens are defined as "tender immature greens produced from seeds of vegetables and herbs having fully developed cotyledons with or without the emergence of a rudimentary pair of first true leaves"[1].

Glucosinolates (GSLs) are anionic sulfur-containing secondary metabolites found almost exclusively within the *Brassicaceae* plant family including, cabbage, rapeseed, and radish. Recently, these compounds have gained valuable attention for their role in the management of hypertension conditions, mainly related to their intrinsic capacity to be natural H_2S donors, a well-known vasodilating signalling molecule [2].

In this scenario, the increasing number of research demonstrating the health benefits of GSLs led to the need to improve their available concentration in existing cultivars. Thus, the main aim of the current work was the optimization of microgreen growth conditions of different radish cultivars, *Raphanus sativus L.* cv. Red Giant, Saxa, and White Tip, in order to maximize GSLs production useful for the formulation of nutraceuticals with antihypertensive potential. The seed germination was carried out using specific perforated trays, in darkness, at 23±1°C for 4 days. The sprouts obtained were transferred in a hydroponic culture supplied with nutrient solutions and harvested after 6, 9, or 12 days of cultivation. The determination of GSLs concentration at different growth-time samples was performed using an opportunely validated HPLC-HESI-MS-MS method. Our results indicated that the maximum GSLs amount was achieved in the Saxa samples after 9 days of cultivation (glucoraphanin 0.299 ± 0.008, glucoraphenin 34.802 ± 6.409, glucoraphasatin 65.629 ± 1.839, neoglucobrassicin 1.21± 0.02 mg/g of dw). Given these promising results, the ability of GSLs water extracts from 9 days-Saxa microgreens, to act as an H_2S donor in fluorescence-based assay and to induce vasorelaxant effects in a model of aortic rings were investigated. The data obtained showed that GSLs extract has shown the ability to release H_2S *in vitro* in a concentration-dependent manner, reaching the H_2S maximum release of 30 mM from 3 mg/ml of GSL extract. Finally, in terms of vasorelaxant activity, the GSL extract relaxed the pre-contracted aortic rings in a concentration-dependent manner, with the maximum effect achieved by treatment with 200 µg/ml of GSL extract (**** $p < 0.0001$, compared to the vehicle).

References:

[1] K. Demir, G. Sarıkamış, G.C. Seyrek. Food Chemistry 2023. 401, 134088.
[2] I. Bello, M. Smimmo, R.d'Emanuele di Villa Bianca. International Journal of Molecular Sciences 2023. 24, 6764.

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ALI-OR-006

Chemical and rheological profile of fermented animal milks and isolation and characterization of exopolysaccharides from kefir grains

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Kefir is an acidic, low-alcohol probiotic beverage made by inoculating whole, semi-skimmed, or skimmed milk with kefir grains, a complex mixture of microorganisms, including lactic acid bacteria (LAB) and acetic acid bacteria (AAB) and yeasts, that coexist in a synergistic relationship in a matrix of polysaccharides and proteins. During the fermentation process, the microflora of kefir grains produces an exopolysaccharide called Kefiran which has been chosen for a variety of applications due to their biological activity in vitro and in vivo[1]. The health-promoting and physicochemical properties of kefiran vary according to the type of milk and extraction method[2].

Six types of animal milks (cow, camel, buffalo, donkey, goat, and sheep) were used as raw materials for fermentation. Fermented samples showed a significant reduction of total sugar content (<0.05%) and a significant increase (**** $p < 0.0001$) of total phenolic content if compared to the starting milks. Both unsaturated and saturated fatty acids of fermented milks were found to be slightly higher than their unfermented counterpart, except for buffalo sample. Particularly important were the results for the content of conjugated linoleic acids (CLA) in fermented milks, which were found to be increased especially in the sheep sample if compared with the initial value (187.4 ± 6.0 mg/g *vs* 40.3±1.0 mg/g, **** $p < 0.0001$).

Three extraction methods were applied to isolate kefiran in order to identify the conditions leading to the highest yield. Exopolysaccharides were characterized by FT-IR, SEM, DSC, HPLC-RI, and rheological measurements. Yield, thermal properties, and morphological features of kefiran differed according to both the type of the milk and the extraction method. However, all kefiran were thermally stable, showing a degradation temperature ranging from 264 to 354°C. The resulting morphological and thermal differences could lead to different practical applications of kefirans in the fields of nutrition and pharmacology. In addition, biocompatibility tests were conducted, and the data highlighted both the non-cytotoxicity and the absence of haemolysis of the polymers, an essential characteristic of biomaterials to be used for tissue engineering applications[3].

References:

[1] T.G Barclay, C.M. Day, N. Petrovsky, S. Garg, Carbohydrate Polymers 2019, 221, 94-112.
[2] C. La Torre, A. Fazio, P. Caputo, A. Tursi, P. Formoso, E. Cione, Foods 2022, 11, 1098.
[3] H. Radhouani, S. Correia, C. Gonçalves, R. L. Reis, J. M. Oliveira, Polymers 2021, 13, 1342.

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ALI-OR-007

Lipophenols: bioactive compounds from edible oils

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Lipophenols are an emerging subclass of phenolic compounds, characterized by the presence of a lipid moiety. Tyrosyl oleate and hydroxytyrosyl oleate (TyOle and HtyOle, respectively, Figure 1A) have been identified in olive oil and by-products (pomace and olive mill waste waters), and represent a significant form in which the corresponding phenolics (tyrosol and hydroxytyrosol, respectively, Figure 1B) occur. Moreover, TyOle and HtyOle were found to display antioxidant, anti-inflammatory and anti-diabetic properties.[1-4]

In this communication, the occurrence of TyOle and HtyOle in other oil matrices (palm oil and grapeseed oil) is disclosed. Moreover, the identification of another member of this family, namely homovanillyl oleate (HvOle, Figure 1), as well as its antioxidant properties against DPPH and ABTS radicals, and by H_2O_2-treated HaCat human keratinocyte cell line is reported.

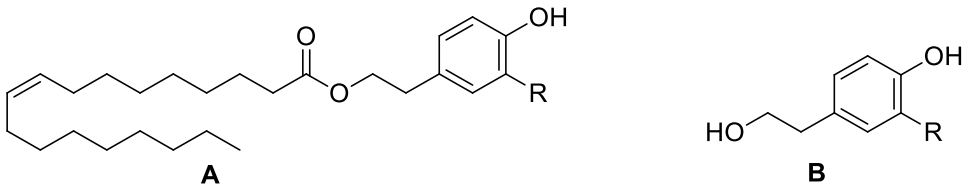

Figure 1: **A** Structure of lipophenols, namely tyrosyl oleate (TyOle, R=H), hydroxytyrosyl oleate (HtyOle, R=OH), and homovanillyl oleate (HvOle, R=OCH_3) and **B** of the corresponding phenolics, namely tyrosol (R=H), hydroxytyrosol (R=OH), and homovanillyl alcohol (R=OCH_3).

References:

[1] P. Plastina, C. Benincasa, E. Perri, A. Fazio, G. Augimeri, M. Poland, R. Witkamp, J. Meijerink, Food Chemistry 2019, 279, 105-113.
[2] C. Benincasa, C. La Torre, P. Plastina, A. Fazio, E. Perri, M.C. Caroleo, L. Gallelli, R. Cannataro, E. Cione, Antioxidants 2019, 8, 233.
[3] C. Benincasa, C. La Torre, A. Fazio, E. Perri, M.C. Caroleo, P. Plastina, E. Cione, Antioxidants 2021, 10(7), 1051.
[4] M.C. Caroleo, P. Plastina, A. Fazio, C. La Torre, F. Manetti, E. Cione, Pharmaceutics 2021, 13(7), 1085.

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ALI-OR-008

Green extraction techniques to obtain potential ready to use nutraceutical supplements from Apulian *Salicornia europaea* L.

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Nowadays, the extraction of antioxidant compounds, particularly polyphenols, from fresh plant materials is widely used to produce promising and efficient nutraceutical supplements for human and animal health. In this context, *Salicornia europaea* L., commonly known as glasswort or sea asparagus, is a halophyte plant native to coastal sites worldwide. *S. europaea* has applications in traditional Chinese medicine as an antioxidant and is consumed seasonally as an edible plant for its beneficial properties in the prevention of chronic diseases. Numerous studies have demonstrated the presence of bioactive compounds in *Salicornia* species, including vitamins (A and C), fatty acids, polyphenols and minerals[1]. Natural deep eutectic solvents (NADEs) have shown the greatest potential in the field of green chemistry being abundant, inexpensive, recyclable and attractive for food, cosmetic and pharmaceutical applications. To extract these highly valuable compounds in a green and eco-friendly approach, NADEs and ultrasound-assisted extraction (UAE), are innovative and promising tools nowadays. In this study, NADEs and UAEtechniques have been applied to *S. europaea* collected from the Apulian Adriatic coast. The plant material was dried in an oven at 40°C for 48 hours and ground to a particle size of 200 μm. A software-based prediction approach (BIOVIA COSMOtherm) was applied to optimize the acceptor of hydrogen bond (HBA) and donator of hydrogen bond (HBD) solvents for the polyphenol extraction from *S. europaea*. NADEs were synthesized at 50°C for 2 hours, with subsequent polyphenol extractions conducted in an ultrasonic bath at 30°C for 30 minutes[2,3]. The most promising extraction in terms of total polyphenol content (TPC) was obtained by using proline as the HBA and choline chloride as the HBD green solvents. With this method, polyphenols extracted from *S. europaea* through NADES could potentially be ready for use in food and pharmaceuticals without time-consuming and costly downstream purification steps.

References:

[1] F. Limongelli, P. Crupi, M.L. Clodoveo, F. Corbo, M. Muraglia, Molecules, 2022, 27, 7954.
[2] M. Panić, V. Gunjević, K. Radošević, M. Cvjetko Bubalo, K.K. Ganić, I.R. Redovniković, Molecules, 2021, *16*, 4722
[3] M. Panić, M. Stojković, K. Kraljić, D. Škevin, I.R. Redovniković, V.G. Srček, K. Radošević, Food chemistry, 2019, *283*, 628-636.

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ALI-OR-009

A metabolomist's point of view on the effects of soy-protein hydrolysate biostimulants on officinal plants: focus on *Calendula officinalis*

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Protein-hydrolysates are among the most widely used biostimulants in agriculture, although molecular mechanisms underlying their effects on plants are still unclear [1]. Moreover, limited information related to their use in the cultivation of officinal and culinary plants has been published so far. As already reported in literature [2], metabolomics represents a suitable strategy for investigating the biochemistry of plants and how this is affected by external stimuli.

In this work, *Calendula officinalis* plants were treated in greenhouse with a soy-protein hydrolysate (SPH) at different dosages, i.e. 0, 1, 2.5, 5, and 10 g/L, for 21 days, and with different application methods, namely soil drenching (SPH-S) and foliar spraying (SPH-F). The effects of treatments on flower count and plant yield were documented, and the underlying molecular mechanisms were assessed by UPLC-QToF-MS-based untargeted metabolomics. Results indicate that the SPH-S treatment can induce both flower and total plant biomasses, conversely to SPH-F. The effect on plant biomass was dose-dependent, while the highest effect on flower biomass was observed with the application of the lowest (1 and 2.5 g/L) SPH-S dosages. The application of SPH-S at 1 g/L resulted also the best treatment to induce the average flower count *per* plant (14.30 for SPH-S 1 g/L *vs.* 8.00 for control). Conversely, no significant effects were observed for SPH-F. Both SPH-S and SPH-F treatments induced changes of the flowers' metabolome: hexadecanoyl- (16:0) and linoleoyl- (18:2) lysophosphatidylethanolamines, known as regulators of plant growth, were induced, together with dipeptides, diglycerides, and saponins, while the amount of several flavonoids was decreased. Importantly, these effects were reversible, since floral metabolome resembled that of untreated plants after suspending SPH application. Carotenoids were significantly induced only by 10 g/L SPH in flowers collected 7 days after the suspension of treatment.

Overall, this work is the first to show the efficacy of SPH in inducing the growth of *C. officinalis*, indicating that these products can be efficiently used to enhance the biomass and phytochemical content of officinal and culinary plant species. Furthermore, metabolomics data contribute to partially elucidate the molecular mechanisms underlying the effects of SPH on plants. These results may be useful for researchers and practitioners to optimize the use of SPH in order to increase the productivity of officinal plants.

References:

[1] L. Bavaresco, et al. Scientia Horticulturae 2020, 270, 109413.
[2] S.W. Oh, et al. Frontiers in Plant Science 2023, 14, 1192235.

ALI-OR-010

Exploring the potential of lentil by-product extracts for managing IBD symptoms: investigating spasmolytic properties

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Introduction: Inflammatory Bowel Disease (IBD) poses a significant health challenge globally, with rising incidence rates and associated complications. Current therapeutic options often carry side effects, necessitating exploration into adjunctive non-pharmacological approaches. Diet plays a crucial role in IBD management, prompting interest in food-based interventions[1,2]. Lentils (*Lens culinaris*) have emerged as a source of bioactive compounds with potential health benefits[3-4]. However, the effects of lentil waste extracts remain relatively unexplored for their potential in IBD management. Building upon the study of spontaneous contractility, this research aims to investigate the potential spasmolytic effects of lentil hull extracts for a novel approach to IBD treatment.

Objective: This study aims to investigate the potential spasmolytic effects of lentil hull extracts for managing IBD symptoms, particularly diarrhea and abdominal cramps, which are prevalent manifestations of the condition.

Methods: Lentil hulls were subjected to conventional and microwave-assisted extraction methods using various solvents to obtain extracts enriched with bioactive compounds. Total phenolic content was determined using the Folin-Ciocalteu assay. In organ bath solutions experiments, spasmolytic activities were evaluated using guinea pig ileum and colon segments.

Results: Evaluation of spasmolytic activity revealed dose-dependent effects of the extracts on longitudinal and circular muscle contractions in guinea pig ileum and colon segments. Specifically, certain extracts demonstrated significant modulation of muscle tone, transit speed, pain perception, and bolus fragmentation, suggesting their potential utility in alleviating IBD symptoms. Notably, microwave-assisted extracts demonstrated superior activity compared to conventional extracts.

Conclusion: Lentil waste extracts exhibit promising spasmolytic effects, highlighting their potential as adjunctive therapies for managing IBD symptoms. Further studies are warranted to elucidate the underlying mechanisms and assess their efficacy in clinical settings. This research underscores the importance of exploring natural sources for novel therapeutic interventions in chronic inflammatory conditions like IBD.

References:

[1] M.M. de Castro, L.B. Pascoal, K.M. Steigleder, B.P. Siqueira, L.P. Corona, M.L.S. Ayrizono, M. Milanski, R.F. Leal. Role of diet and nutrition in inflammatory bowel disease. World J. Exp. Med. 2021, 11, 1–16.

[2] Reznikov, E.A.; Suskind, D.L. Current nutritional therapies in inflammatory bowel disease: improving clinical remission rates and sustainability of long-term dietary therapies. Nutrients 2023, 15, 668.

[3] Cavalluzzi MM, Lamonaca A, Rotondo NP, Miniero DV, Muraglia M, Gabriele P, Corbo F, De Palma A, Budriesi R, De Angelis E, Monaci L, Lentini G. Microwave-Assisted Extraction of Bioactive Compounds from Lentil Wastes: Antioxidant Activity Evaluation and Metabolomic Characterization. Molecules. 2022 Nov 2;27(21):7471.

[4] Peng, L.; Guo, F.; Pei, M.; Tsao, R.; Wang, X.; Jiang, L.; Sun, Y.; Xiong, H. Anti-inflammatory effect of lentil hull (Lens culinaris) extract via MAPK/NF-κB signaling pathways and effects of digestive products on intestinal barrier and inflammation in Caco-2 and Raw264.7 co-culture. J. Funct. Foods 2022, 92, 105044.

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ALI-OR-011

A multi-platform metabolomics approach for the characterization of novel food ingredients

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The current historical context is characterized by a marked attention to food and health. This is reflected in the search for high-quality food that is nutritionally favorable and organoleptically appealing. Consequently, more and more companies are incentivized to design and produce new foods or formulations. Indeed, the European Food Safety Authority (EFSA) has registered a significant increase in Novel Food proposals over the years, from 39 applications in the period 2000-2010 to an impressive 372 applications in the period 2010-2024 [1]. What is still missing, however, is the detailed chemical characterization of the new ingredients that are placed on the market. To date, there are no analytical techniques advanced enough to allow a comprehensive understanding of all the compounds that are contained within a food, especially in the case of food ingredients deriving from new sources (e.g., food by-products) or severe extraction processes. Food chemistry, in this sense, must strive to extrapolate as much detailed data as possible on the molecular structure of the compounds present, whether beneficial or potentially toxic.

Dietary fibers and oligosaccharides are nowadays found within foods or supplements and are passed off as functional compounds with alleged properties such as prebiotic, anti-cancer, etc. It is commonly recognized in the scientific literature that a very close relationship between the chemical structure and functional properties of the molecules exists [2], and it is equally evident that these molecules within dietary fiber ingredients are generally not characterized in such detail.

In this context, a multi-platform targeted and untargeted approach involving different combined techniques, namely GC-MS, LC-MS, NMR, and LC-IM-QTOF-MS, has been developed and applied to investigate the detailed composition of several potential hemicellulose-derived ingredients. The in-depth molecular characterization achieved for both oligosaccharides and lignocellulose degradation compounds highlighted that hemicellulose ingredients/supplements were very different in terms of both target molecules (i.e., xylo-oligosaccharides) and some contaminants resulting from matrix degradation, such as furans and phenols. It will be necessary in the future to further refine instruments and analytical capabilities to clarify these molecular structures, which may have a decisive impact on consumers' health.

References:

[1] EFSA website. Consulted online (27/03/2024). Available at: https://open.efsa.europa.eu/questions

[2] A. Fuso, W. Dejonghe, L. Cauwenberghs, G. Rosso, F. Rosso, I. Manera, A. Caligiani. *Journal of Functional Foods*, **2023**, 101, 105417.

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ALI-OR-012

Preparation and characterization of chitosan/tpp nanoparticles loaded with olive pomace phenolic compounds

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Olive pomace (OP), the polluting biomass deriving from the production of olive oil, contains the major part (>98%) of the phenols present in the olive fruit[1]. The OP most representative phenolic compounds, namely hydroxytyrosol (OH-Tyr), tyrosol (Tyr), and their precursors, are thought to have several health-promoting properties, in particular in the prevention of many non-communicable diseases[2]. In this study, OP phenolic compounds have been extracted and encapsulated into food-grade nanoparticles (NPs) by ionic gelation to increase their resistance to environmental and chemical stress. The reticulation of chitosan, a polysaccharide deriving from the deacetylation of chitin, with sodium tripolyphosphate, a GRAS salt, resulted in a monodisperse (PDI: 0.21 ± 0.01) population of cationic NPs (ζ-Potential: 32.77 ± 0.37 mV, size: 229.20 ± 80 nm), with an encapsulation efficiency (EE%), expressed as total phenolic content (TPC) and total OH-Tyr + Tyr content, higher than 60%. Two different antioxidant scavenging assays, ABTS and FRAP, confirmed the NPs Antioxidant Capacity (AOC). NPs were characterized using several spectroscopic approaches. The most effective lyoprotective conditions were evaluated in order to obtain a suspendable powder which was ultimately subjected to an *in-vitro* static digestion protocol (INFOGEST®) to assess the bioaccessibility of the main phenolic compounds.

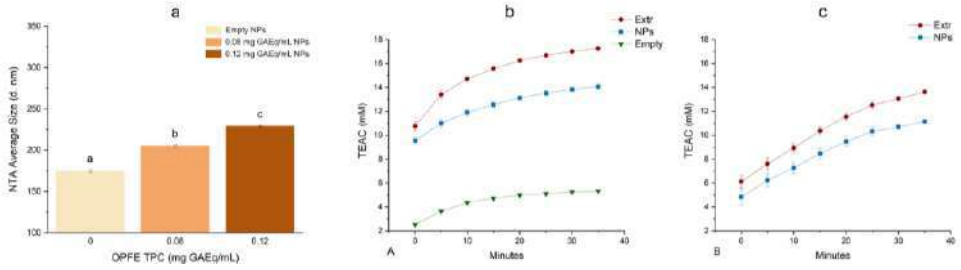

Figure 1: Effect of OP Fluid Extract concentration on the Nano Tracking Analysis (NTA) average size of NPs (a). AOC measured by ABTS (b) and FRAP (c) of extract, liqNPs and empty NPs (ABTS only). All data are expressed as mean ± standard error (SE) from triplicates. AOC data are expressed as mM Trolox Equivalent Antioxidant Capacity (TEAC).

References:

[1] Cecchi, L.; Migliorini, M.; Zanoni, B.; Breschi, C.; Mulinacci, N. An Effective HPLC-Based Approach for the Evaluation of the Content of Total Phenolic Compounds Transferred from Olives to Virgin Olive Oil during the Olive Milling Process. *J. Sci. Food Agric.* **2018**, *98* (10), 3636–3643.

[2] De Santis, S.; Cariello, M.; Piccinin, E.; Sabbà, C.; Moschetta, A. Extra Virgin Olive Oil: Lesson from Nutrigenomics. *Nutrients* **2019**, *11* (9), 1–17.

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ALI-OR-013

miRNAs as Biomolecular Markers for Food Safety, Quality and Traceability in Poultry Meat. A preliminary study

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The consumer requests and shift towards poultry meat consumption have pushed farmers to increase meat production, sometimes with no sufficient attention to meat quality and animal wellbeing. Nowadays, chicken growing rate in industrial farming increases considerably and a lower amount of time is required to obtain a mature chicken for meat production: from 120 days around 70 years ago to 30 days. Conversely, the feed conversion ratio (i.e., livestock production efficiency) was decreased from roughly 4.5 to less than 2.0, that means less than 2 kg of feed intake to let the animal gain 1 kg in muscle mass. This allowed the reduction of production costs, but some selected genetic variants were needed to permit such a fast growing rate. The dynamic process to obtain fast growing hybrid chickens produced important changes in poultry physiology and anatomy with strong consequences on animal wellbeing: muscle anomalies, stress-induced myopathies, white striping and wooden breast are the most common ones affecting animal health and organoleptic characteristics of meat. Ten years ago, slow growing broilers were introduced for improving the mentioned issues. In this preliminary study, two genetic variants (fast growing broiler, namely Ross308; slow growing broiler, namely Ranger Gold) were studied and compared for evidencing differences in biomarker expression that could be related with chicken diseases developed during farming and animal wellbeing. Expression and abundance of two chicken micro-RNAs (miRNAs), miR-21 and miR-126, have been analysed across different tissues (i.e., liver, lung, spleen, breast muscle, kidney) by quantitative reverse transcription polymerase chain reaction (RT-qPCR). Lung, spleen and muscle tissues revealed a higher expression and they have been further investigated in 13 animal biological samples. Results evidenced levels of miR-126 in lung tissue higher for Ranger Gold than Ross308: this could be explained in terms of higher respiratory capacity and higher oxidative metabolism for slow growing broilers, but it also has consequences in tracing hybrids. During sampling, some Ross308 broilers display diseases and anomalies, such as airsacculitis (bacterial inflammatory condition of air sacs), hepatic steatosis (intrahepatic fat deposition) and enlarged spleen. Fast growing broilers with both hepatic and respiratory diseases revealed up-regulation of miR-21 and miR-126 in breast muscle tissue. On the contrary, slow growing chickens exhibited lower levels of both miRNAs, even lower than healthy Ross308. Despite the limited extent of the sample set, these findings are quite promising and can suggest the use of specific miRNAs as biomarkers for the identification of bacterial or viral diseases in poultry breeds that can negatively influence the meat quality and the animal wellbeing.

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Valorization of grape pomace extracts against cranberry, elderberry, rose hip berry, goji berry and raisin extracts: Phytochemical profile and biological activity

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The valorization of food waste is gaining attention in the wine sector. Grape processing annually leads to the production of 9 million tons of grape pomace as waste[1].

The aim of this work is the valorization of grape pomace extracts obtained by decoction, ultrasound-assisted extraction and microwave-assisted extraction by investigating their phytochemical profile and biological activities which were compared to extracts of raisins and edible commercial berries.

For each extract, the total phenolic content was assessed preliminarily by colorimetric assay and the phytochemical profile was determined by HPLC-ESI-Q-TOF-MS. The highest amount of polyphenols was characterized in grape pomace extracts justifying their strong antioxidant activity, especially in DPPH, ABTS, CUPRAC and FRAP assays (Table 1). The inhibition against cholinesterase, amylase, glucosidase and tyrosinase was determined by *in vitro* assays. Grape pomace extracts present the best inhibitory effect against tyrosinase compared to the other extracts. Its inhibition is associated with the reduction of hyperpigmentation disorders[2].

This work underlines the potential value of grape pomace as a by-product rich in beneficial compounds prompting its further valorization and involvement in the production of nutraceuticals and cosmetics.

	Extraction methods	DPPH (mg TE/g)	ABTS (mg TE/g)	CUPRAC (mg TE/g)	FRAP (mg TE/g)	MCA (mg EDTAE/g)	PBD (mmol TE/g)
Grape pomace	Decoction	45.05±0.22^{a}	61.70±0.01^{a}	172.26±7.25^{a}	121.04±0.12^{a}	9.24±0.29^{ef}	1.89±0.09^{a}
	UAE	45.23±0.13^{a}	61.54±0.04^{a}	178.47±0.98^{a}	115.58±1.60^{b}	8.30±0.36^{efg}	1.97±0.06^{a}
	MAE	45.07±0.16^{a}	61.53±0.02^{a}	177.68±3.78^{a}	116.49±4.02^{b}	8.32±0.30^{efg}	1.86±0.05^{a}

Table 1: Antioxidant properties of grape pomace extracts. Values are reported as mean ± SD of three parallel measurements. TE: Trolox equivalent; EDTAE: EDTA equivalent. Different letters indicate significant differences between the tested extracts ($p<0.05$).

References:

[1] A. Schieber, F.C. Stintzing, R. Carle, Trends in Food Science & Technology 2001, 12, 401 – 413.
[2] L. Panzella, A. Napolitano, Cosmetics 2019, 6, 57.

ALI-OR-015

LIPIDOMICS OF SHEEP AND GOAT MILK BASED INFANT FORMULAS AFTER DYNAMIC IN VITRO DIGESTION

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In this work, we studied the lipid profile, after the dynamic in vitro gastrointestinal digestion, of 0-6 months infant formulas (IF) based on sheep and goat whole milk. Fatty acids methyl esters analysis indicates that the two formulates differed in the levels of polyunsaturated and short chain fatty acids. QTOF/MS analysis revealed distinct lipids profiles for goat and sheep IFs. This analysis also allowed us to monitor the lipolytic process through the quantitative analysis of complex lipids and their lypolysis products during digestion. Triacylglycerols digestibility decreased as a function of the fatty acid chain length, irrespectively of the unsaturation degree, and was found slightly higher in sheep IF. Additionally, lipid compounds in sheep IF were found more prone to hydrolysis than in goat IF during the gastric phase. Despite the differences observed between goat and sheep IFs, the overall digestion outcomes of complex lipids were found similar. Our results suggest that sheep whole milk can be considered as viable alternatives to cow milk when designing IF.

References:

1. Maryniak, N. Z., Sancho, A. I., Hansen, E. B., & Bøgh, K. L. (2022). Alternatives to cow's milk-based infant formulas in the prevention and management of cow's milk allergy. Foods, 11(7), 926. https://doi.org/10.3390/foods11070926
2. Lai, G., Caboni, P., Piras, C., Pes, M., Sitzia, M., Addis, M., ... & Scano, P. (2023). Development and Chemico-Physical Characterization of Ovine Milk-Based Ingredients for Infant Formulae. Applied Sciences, 13(1), 653. https://doi.org/10.3390/app13010653

ALI-OR-016

Green extraction of valuable proteins from unsorted fish-processing side streams: the Horizon 2020 - EcoeFISHent project

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Ecoefishent ("Demonstrable and replicable cluster implementing systemic solutions through multilevel circular value chains for eco-efficient valorisation of fishing and fish industries side-streams") project goal is to deploy sustainable and efficient use of fish-processing side streams by obtaining bio-actives for high value-added food supplements and cosmetic products, as well as compostable and biodegradable barrier layers for food packaging [1].

The project deals with the valorisation of unsorted non separated fishery side streams, avoiding the onerous sorting step of fish leftovers, and their transformation into high value bioactive compounds, mainly proteins and hydrolysed peptides such as gelatine (G), hydrolysed collagen peptides (HCPs), and non-collagenous peptides (NCs) [2]. The highly perishable unsorted biomasses, both tuna side streams (raw and cooked) and aquaculture products (seabreams and seabass), have been previously stabilized microbiologically, by a patented industrial dehydration process that enhances the logistics in their valorisation.

Then, a scalable extraction method represented by a single cascade flowchart, which exploits environmentally friendly techniques such as enzymatic-assisted extraction, has been applied for the upcycling of the protein fraction [3]. All the extracted proteins after their isolation/purification, and dehydration, were characterized in terms of proximate and ultimate analyses, biological activity, and functional properties, and in order to assess their potential applicability in different fields.

The extraction flowchart proposed allowed to obtain the following most promising compounds: 1.7 g of G, 3.2 g of HCPs, and 14.6 g of NCs per 100 g of dehydrated starting material. In particular, gelatine extracted has shown to have specific viscoelastic properties (5 mPa·s of viscosity and 14.3 °C of gelling temperature) and demonstrated encouraging technological and filming properties. HCPs demonstrated promising antioxidant activity and NCs demonstrated a good content of nutritionally valued proteins exploitable in dietary products and high-protein foods.

References:

[1] https://ecoefishent.eu/
[2] V. Orlandi, L. Orlandi, F. Turrini, G. De Negri Atanasio, F. Grasso, E. Grasselli, R. Boggia, Molecules 2023, 28, 7637 – 7654.
[3] F. Grasso, D. Méndez-Paz, R.Vázquez Sobrado, V. Orlandi, F. Turrini, G. De Negri Atanasio, E. Grasselli, M. Tiso, R. Boggia, Gels 2023, 9, 760 – 779

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ALI-OR-017

Preparation of natural compounds *via* flow biocatalysis

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Due to healthy lifestyle of modern society, the preference for bio-compounds derived from natural sources is rapidly expanding. On the other hand, according with both European and US regulation (EMA and FDA), processing natural starting material with biocatalytic approaches let the commercialization of the final product as natural too, thus increasing its market value.[1] In this scenario, the combination of biocatalysts (whole cells and cell-free enzymes) with flow facilities, represents an emerging technology to enhance reaction productivity and sustainability. Through immobilization techniques, the biocatalysts can be easily integrated in flow chemistry reactors, while their stability under operational conditions is dramatically improved.[2] Moreover, due to the catalyst recovery and reuse for several reaction cycles, cost-effective processes can be developed.

Valuable natural molecules such as aroma-compounds,[3] antioxidants,[4] as well as antimicrobials[5] have been successfully prepared merging the advantages of flow reactors with the specificity and benign conditions of biocatalysts. This strategy representing an alternative route for natural compound preparation and promoting a responsible care of natural resources, is particularly attractive for the food, pharma and cosmetic sectors.

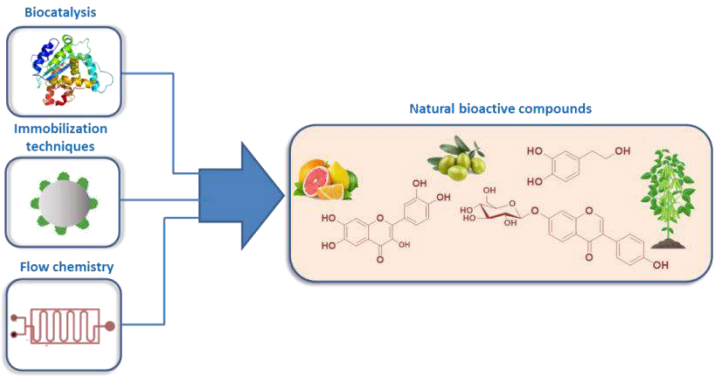

Figure 1: Merging biocatalysis, protein immobilization and flow facilities for natural compound preparation

References:
[1] G. Catinella et al. Food and Bioproducts Processing 2022, 121, 144-148.
[2] A. I. Benitez-Mateos et al. Reaction Chemistry & Engineering 2021, 6, 599-611.
[3] M. L: Contente et al. Journal of Flow Chemistry, 2020, 10, 235–240.
[4] A. Colacicco et al. Catalysis Science and Technology 2023,13, 4348-4352
[5] C. Pinna et al. Journal of Agricultural and Food Chemistry 2022, 70, 1, 223–228.

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ALI-OR -018

Comprehensive two-dimensional liquid chromatography for the characterization of the phenolic content in extra virgin olive oil and its by-products

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Extra virgin olive oil (EVOO) is associated with the beneficial effects of a Mediterranean diet due to an "ideal" lipidic fraction and microconstituents with antioxidant activity. Among micronutrients, phenolic compounds did show important beneficial effects for human health. The majority of the research studies on the phenol content are carried out by liquid chromatography combined to photodiode array and/or mass spectrometry detection; however, because of matrix complexity, one-dimensional liquid chromatography cannot be sometimes sufficient to obtain satisfactory results. As a consequence, in this contribution, comprehensive two-dimensional liquid chromatography, incorporating RP-Amide and C18 stationary phases, in the first and second dimension, respectively, both under reversed phase conditions, was investigated for the determination of the phenolic fraction in EVOO and its by-products. As far as detection is concerned, triple quadrupole mass spectrometry was employed under multi reaction monitoring mode offering superior selectivity and sensitivity. The reduction of matrix effects, when using comprehensive two-dimensional liquid chromatography with respect to conventional one-dimensional liquid chromatography, was assessed by comparing the slopes of calibration curves built from standard solutions and spiked olive oil samples.

Acknowledgments

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ALI-OR -019

Integrated omics approaches for comprehensive study of X-ray irradiated soft cheeses

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Food irradiation is an alternative technological process employed to preserve the hygienic quality of food and to extend its shelf life[1]. In this work, different types of dairy products were treated with X-rays and integrated omics approaches, a bottom-up proteomics and lipidomics, were used to evaluate their effect on protein and lipid fingerprints. Specifically, the matrices investigated were *mozzarella*, *robiola* and *primosale* as soft cheeses whereas *Camembert* and *Brie* as surface-ripened cheeses. Matrix-assisted laser desorption/ionization-time of flight mass spectrometry (MALDI-ToF-MS) and ultra-high-performance liquid chromatography coupled with quadrupole Orbitrap mass spectrometry (UHPLC-Q-Orbitrap-MS) were adopted to analyse the peptide mixtures coming from the proteolytic digestion of irradiated soft cheese using both trypsin and chymotrypsin enzymes[2]. For lipid fingerprint, a first step of lipid extraction using four different techniques, Folch procedure, extractions with accelerated solvent[3], microwave assisted solvent[4] and supercritical fluid, were developed by appropriate design of experiments and successively the extracts were analysed by UHPLC-Q-Orbitrap-MS. Multivariate statistics, namely principal component analysis, partial least squares-discriminant analysis and linear discriminant analysis, allowed the discrimination of irradiated versus non-irradiated samples and the selection of potential markers of treatment, useful in food traceability plans. The outcomes confirm integrated omics approaches as a powerful tool for deepening knowledge of food irradiation, also suitable as a model for food quality and safety control.

This work was supported by the Italian Ministry of Health who funded the Project code GR-2018-12367064.

Keywords: traceability, food quality, food safety, metabolomic.

References:

[1] R. Zianni, A. Mentana, M. Campaniello, A. Chiappinelli, M. Tomaiuolo, A.E. Chiaravalle, G. Marchesani. LWT, 2022, 153, 112466
[2] E.C.L. Rigante, C.D. Calvano, G. Ventura, R. Zianni, M. Campaniello, V. Nardelli, A. Mentana, T.R.I. Cataldi, LWT, 2024, 191, 115643.
[3] A. Mentana, R. Zianni, M. Campaniello, M. Tomaiuolo, A. Chiappinelli, M. Iammarino, V. Nardelli. Food Chemistry,2022, 133542.
[4] M. Campaniello, V. Nardelli, R. Zianni, M. Tomaiuolo, O. Miedico, O.; M. Iammarino, A. Mentana, A. Foods 2024, 13, 1033.

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ALI-OR-020

MS-IMAGING: IN SITU INVESTIGATION OF SECONDARY METABOLITES OF ORYZA SATIVA L. VARIETIES BEFORE AND AFTER COOKING

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Rice (*Oryza sativa* L.) is an important cereal in human nutrition due to its richness in vitamins, minerals, and bioactive compounds. The processing steps to which paddy rice is subjected after harvesting, while on the one hand making it edible improving its sensory quality and cooking, on the other hand, from a nutritional point of view could result in the depletion of many micronutrients and phytonutrients that are concentrated in the germ and bran [1]. An effective processing technique to reduce cooking time of rice is parboiling, a hydro-thermal treatment that allows the water-soluble components of the germ and outer parts to diffuse within the caryopsis [2].

The aim of the work to define the best procedure for the application of MALDI-MSI [3] to investigate the localization and migration of two different classes of rice micro-components after industrial processing and domestic cooking: steryl ferulates and anthocyanins [4], which are known to provide positive physiological effects on human health [5]. Spectra acquisitions with IMS were conducted on a MALDI-LTQ-Orbitrap XL and the ionic intensity of the signal associated with the different distribution of the analyte in the tissue was evaluated. The *Oryza sativa* L. varieties studied were 'Carnaroli' (white rice), 'Oro' (white parboiled rice), 'Nerone', (black pigmented rice), and 'Venere', (black pigmented parboiled rice). About domestic cooking methods, all rice varieties were analyzed raw, after boiling in water and after steaming.

The sample preparation steps were optimized to obtain reproducible results by MSI. As regards steryl ferulates, the study allowed to verify their localization in the different rises, highlighting a negligible migration of these compounds towards the endosperm in the parboiled rice. Regarding anthocyanins, it was found that steaming or boiling the pigmented rice provides a consistent migration of these compounds in the endosperm.

The obtained results provide a solid basis for the definition of future experimental designs for the study of rice secondary metabolites in raw and cooked rice and for monitoring the effects of parboiling.

References:

[1] Paiva F.F., et al. (2014). J. Food Comp. & Anal. 35, 10–17.
[2] Bhattacharya K. R. (2004). Rice chemistry and technology (3rd ed., pp. 329–404).
[3] Caprioli R.M., et al. (1997). Anal Chem. Dec 1;69 (23):4751-60.
[4] Ciulu, M., et al. (2018). Molecules, 23(11), 1–20.
[5] Goffman F. D., et al. (2004). J. Sci. Food &Agric., 84, 1235–1240

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ALI-OR-021

Insights into the Structure–Capacity of Food Antioxidant Compounds Assessed Using Coulometry

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Antioxidant compounds assumed with food and plant extracts play relevant health-promoting roles. The antioxidant capacity is a key parameter for determining food quality as it affects product stability during preparation and storage. For this reason, antioxidants are often used for food preservation. In biological systems (e.g., cells, tissues, fluids), endogenous and exogenous antioxidants rule key physiological processes. Considering their relevance, an extraordinarily large number of chemical methods have been proposed for the determination of antioxidant capacity and radical scavenging properties. In general, these methods correlate poorly with each other, so that none of them has found universal applicability. The Coulometrically Determined Antioxidants Capacity (CDAC, expressed as $mmol_{electrons}\ g_{sample}^{-1}$) has been recently developed by our group to estimate the antioxidant capacity of individual compounds or their mixtures[1,2]. The CDAC measurements consist of a constant-current coulometric titration, in which the titrating agent is Br_2 (standard potential E^0=+1.05 V) electrogenerated *in situ* from a KBr solution. The Br_2 excess generated at the endpoint is determined with a biamperometric system. CDAC determines the micromoles of electrons delivered for oxidizing the target analyte(s) with high accuracy. The method is accurate, rapid, cheap and does not require the use of standards. Herein, 48 individual antioxidant compounds commonly found in food have been analysed by CDAC method.[3] Expressing the CDAC on a molar ratio scale ($mol_{electrons}\ mol_{sample}^{-1}$, $CDAC_\chi$) the antioxidant capacity of several representative compounds ranks as it follows: tannic acid > malvidin-3-*O*-glucoside ≅ curcumin > quercetin > catechin ≅ ellagic acid > gallic acid > tyrosol > BHT ≅ hydroxytyrosol > chlorogenic acid ≅ ascorbic acid ≅ Trolox®. The correlation of the $CDAC_\chi$ values with the chemical structure of the molecules investigated in the present study, underlines that the aptitude of compounds to electron and hydrogen atom transfers estimated through the Bors criteria[4] is often ineffective to account for the observed antioxidant capacity. Other factors like side- and down-stream reactions, pH, geometrical structure, chemical environment, metal chelating ability, are involved in determining the $CDAC_\chi$ values. In this context, the electrochemical ratio (ER), defined as the CDAC of the sample relative to ascorbic acid, is proposed as a new dimensionless index to describe the antioxidant power of any food.

References:

[1] F. Siano, G. Picariello, E. Vasca, Food Chemistry 2021, 354, 129564
[2] F. Siano, G. Picariello, D. Castaldo, D. Cautela, T. Caruso, E. Vasca, Talanta 2023, 251, 123765
[3] F. Siano, A. S. Sammarco, O. Fierro, D. Castaldo, T. Caruso, G. Picariello, E. Vasca, Antioxidants 2023, 12
[4] W. Bors, W. Heller, C. Michel, M. Saran, Antioxidants in Therapy and Preventive Medicine Springer: Boston, MA, USA, 1990, 165-170

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ALI-OR-022

Effect of acorn harvesting time on the nutritional profile, polyphenols content, antioxidant activity and volatiles of different acorn flours.

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Abstract

Acorn flour resulted to be a promising alternative to the cereal flour for different applications thanks to its nutritional value, lack of gluten proteins and polyphenols content.

The aim of the study was to find possible differences in nutritional value, polyphenols, antioxidant properties and volatile profile of acorn flours obtained by acorns harvested at different times and to promote acorn flour as a rich source of nutrients and bioactive constituents. Indeed, two acorn flours have been studied: one was obtained from acorns harvested at the beginning of November 2023 (Spring 2023) and the other from those harvested in the late November 2023 (Fall 2023).

This study received funding from the European Union - Next-GenerationEU - National Recovery and Resilience Plan (NRRP) – MISSION 4 COMPONENT 2, INVESTMENT N. 1.1, CALL PRIN 2022 PNRR D.D. 1409 del 14-09-22 (CUP J53D23018470001). Results from nutritional analysis showed some differences, Flour Fall 2023 resulted to be richer in sugar content (glucose, fructose), total free aminoacids and most of the minerals (calcium, iron, phosphorous and magnesium) with respect to flour Spring 2023. An HPLC-MS/MS method was used for the determination of 38 polyphenols in flour samples (Mustafa et al., 2022) and their concentration resulted to be comparable between samples. However, the antioxidant activity, studied by DPPH free radical assay, Total Phenolic Content (TPC), Total Flavonoids Content (TFC) and Total Tannin Content (TTC), resulted to be different in acorn samples. In particular, TPC, TFC and TTP demonstrated a higher antioxidant activity in flour Spring 2023 with respect to flour Fall 2023. Finally, volatile profile was studied by HS-SPME-GC-MS and furanic compounds were quantified by HS-SPME-GC-MS (Acquaticci et al., 2024). This study demonstrated that acorn is a rich source of carbohydrates (50%), dietary fiber (25%), protein (10%) and macro-microelements such as potassium and calcium. Moreover, it has been assessed that flours obtained by acorns harvested at different times of the year showed differences in nutritional profile, antioxidant activity and volatiles. However, further studies are needed to understand if these differences will be maintained in food products to optimize the use of this flour to have a food product with the best possible properties.

REFERENCE

Mustafa, A. M., Angeloni, S., Abouelenein, D., Acquaticci, L., Xiao, J., Sagratini, G., Caprioli, G. (2022). A new HPLC-MS/MS method for the simultaneous determination of 36 polyphenols in blueberry, strawberry and their commercial products and determination of antioxidant activity. *Food Chemistry*, *367*, 130743.

Acquaticci, L., Schouten, M. A., Angeloni, S., Caprioli, G., Vittori, S., Romani, S. (2024). Influence of baking conditions and formulation on furanic derivatives, 3-methylbutanal and hexanal and other quality characteristics of lab-made and commercial biscuits. *Food Chemistry*, *437*, 137791.

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This study received funding from the European Union - Next-GenerationEU - National Recovery and Resilience Plan (NRRP) – MISSION 4 COMPONENT 2, INVESTMENT N. 1.1, CALL PRIN 2022 PNRR D.D. 1409 del 14-09-22– (AcorN: a forgotten resource to be rediscOVered and valorizEd in the production of good and heaLThY foods. "NOVELTY") CUP N. J53D23018470001.

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ALI-OR-023

Exploring the potential of ulvan from *Ulva lactuca* L.: extraction optimization by design of experiment, chemical characterization, and evaluation of *in vitro* prebiotic activity

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Ulva sp. is a green algae associated with the so-called "green tides", caused by water eutrophication. The main biomolecule of interest this green algae is the sulfated polysaccharide ulvan. It has gelling properties and has shown anticoagulant, anti-hyperlipidemic, and immunomodulatory activities in *in vitro* and *in vivo* models[1] . Its biological and chemo-physical properties are directly related to its chemical structure, which strongly depends on the extraction conditions[1] . Particularly, *Ulva lactuca L.* has been found to grow spontaneously in aquaculture tanks in Orbetello lagoon (OL), Tuscany, Italy, and can be considered a by-product of fish farming. Thus, this study firstly focused on the optimization of ulvan extraction from *U. lactuca L.* collected in OL and its chemical characterization, which is crucial for understanding the biological activities of the ulvans and to define their future possible uses.

To do so, a Response Surface Methodology was applied to investigate the effect of pH, extractant/sample ratio and time of extraction on yield, purity and sulfation degree of ulvan. Purity was evaluated by quantitative ^{1}H-NMR as rhamnose percentage on dialyzed polysaccharides. Sulfate and neutral/acidic sugars were quantified by turbidimetric assay and HPAEC-PAD respectively. Then, the optimized extraction conditions based on the maximization of yield and purity were chosen and applied to produce ulvan for in *in vitro* test of prebiotic activity. To evaluate it, the isolated polysaccharide was subjected to an *in vitro* enzymatic digestion following the INFOGEST 2.0 protocol. The undigested ulvan underwent colonic microbial fermentation using an *in vitro* static fermentation system[2] . Slurries were collected at different time points (0, 12, 24, 48h). pH, short chain fatty acids, and tryptophan-related metabolites were quantified and untargeted metabolomics was performed.

Therefore, this comprehensive approach, integrating extraction optimization, chemical characterization and colonic microbial fermentation will provide insights on ulvan's impact on the function of microbial communities and its potential future applicability for upcycling *Ulva* biomass towards the development of functional food with prebiotic effects.

References:

[1] J. T. Kidgell et al., Algal Research, 2019, 39, 101422
[2] S. Pérez-Burillo et al., Nature Protocols, 2021, 16, 3186-3209

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ALI-OR-024

Paracoccus sp LL1 a promising β-carotene cell factory

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Carotenoids are biomolecules naturally produced by plants, algae, fungi, and bacteria as secondary metabolites[1]. The international market size for carotenoids in 2022 was 2.0 billion dollars and it is expected to reach 2.7 billion dollars by 2027, at a compound annual growth rate of 5.7% for the forecast period of 2022 to 2027. Currently, scientific interest in microbial carotenoids production, to be implemented as natural dyes in food industry, has come into the mainstream because of their economic sustainability and cost-effectiveness[2].

The aim of this study was to provide a first qualitative and quantitative profile of both carotenoids and fatty acids produced by the bacterium *Paracoccus* sp LL1[3]. With this purpose, the best growth conditions were investigated in order to identify the carotenoids produced by the strain, beside the fatty acid profile characterization. *Paracoccus* sp. LL1 batch cultivation was carried out in 5 L fermenter, in a final working volume of 3.5 L of minimal medium supplemented with 20 g L^{-1} of glucose, using an inoculum size of 10% (v/v). Fermentation parameters were temperatures 24 °C, air flow 2.0 L min^{-1}, rpm 300, dissolved oxygen maintained at 20%, pH controlled at 7.5±0.2 by using 4 N HCl and 4 N NaOH.

The carotenoids produced by *Paracoccus* sp LL1 have been identified by HPLC/MS. It was possible to identify 12 different carotenoids. Among these β-carotene was detected in the highest amount, reaching up a concentration of 0.3 mg g^{-1} of dry matter, after 72 h fermentation. Whereas the main fatty acids detected by GC-MS/FID were represented by: C12:1n7-(E), C16:0, C18:0, C18:1n9-(Z) and C18:1n7-(Z).

The production of microbial carotenoids and in particular β-carotene from *Paracoccus* sp LL1 could represents a matter of great interest and economic value from food industrial perspectives.

References:

[1] GD. Lopez, G. Alvarez-Rivera, C. Carazzone, E. Ibanez, C. Leidy, and A. Cifuentes, Critical reviews in analytical chemistry 2023, 53, 1239–1262.
[2] S. Ram, M. Mitra, F. Shah, SR. Tirkey, S. Mishra, Journal of Functional Foods 2020, 67, 103867.
[3] SS. Sawant, BK. Salunke, BS. Kim, Bioresource Technology 2015, 194, 247–255.

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Application of Rapid Evaporative Ionization Mass Spectrometry: from clinical diagnosis to food traceability

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Rapid Evaporative Ionization Mass Spectrometry (REIMS) is a relatively recent MS technique, dating back to 15 years ago, which was explored in many application fields demonstrating high versatility in the detection of a wide range of chemicals, from small molecules (phenols, amino acids, di- and tripeptides, organic acids, sugars) to larger biomolecules, i.e. phospholipids and triacylglycerols. In particular, it was coupled with different sampling devices and used in direct-MS approaches, without the need for laborious and time-consuming sample preparation procedures and chromatographic separations, according to the definition of Ambient MS which refers to the ionization of unprocessed or minimally modified samples in their native environment.

This innovative technique combines two complementary analytical approaches, that can be defined as a metabolomic profiling and a metabolic fingerprinting. The first deals with a complete and accurate characterization of the sample from both qualitative and semi-quantitative point of view. The second is a fingerprinting approach that aims to obtain characteristic profiles of various samples. In other terms, REIMS was successfully used to achieve a comprehensive sample profiling according to a metabolomics untargeted analysis. Moreover, when a multitude of samples were available, the combination with chemometric tools allowed a rapid differentiation of the samples and the identification of discriminant features.

The present talk aims to provide examples of the applicability of REIMS in two main fields, namely clinical diagnostics, covering both veterinary and human medicine areas, and food analysis, aiming both at the preservation of both food security and at the safeguard of food safety and quality.

More in details, the application to differentiation of brain tumors will be presented to demonstrate the potentiality of REIMS in the accurate identification of tumor grade and type, which can be exploited for an early cancer diagnosis. In the agri-food sector, the applicability against food fraud will be assessed through the building of statistical models aiming at differentiating between different fish species, spices and extra virgin olive oils in order to ensure to consumers safe and nutritious foods, as well as to protect the economy of local producers and the entire ecosystem.

DIVISIONE DI CHIMICA DEGLI ALIMENTI

COMUNICAZIONI POSTER

ALI-PO-001

Sustainability in Food Safety: Deep Eutectic Solvents for Aflatoxin Extraction in Pistachios

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Aflatoxins, identified as carcinogenic mycotoxins belonging to Group 1 by the International Agency for Research on Cancer, pose a substantial risk to global food safety. These contaminants are present in diverse food sources such as wheat, rice, corn, milk, spices, and nuts. To address health concerns linked to aflatoxin exposure, global regulatory bodies have set maximum limits for aflatoxins in food products, necessitating thorough pre-trade analyses by producers. Existing official methods for aflatoxin analysis rely on organic mixtures, generating considerable waste[1]. In response to the increasing emphasis on sustainable analytical practices, especially in food chemistry and safety, this study suggests an innovative and environmentally friendly approach using Deep Eutectic Solvents (DES) for the extraction and quantification of aflatoxins from pistachios—an economically valuable commodity prone to contamination in hot and arid regions. DES, a recent class of alternative solvents, comprises a binary mixture with a hydrogen bond donor and acceptor in specific molar ratios, allowing their use at room temperature. Numerous DESs have exhibited non-toxicity, biodegradability, and effective extraction capabilities for various target compounds[2]. The extraction process was optimized using a Design of Experiment. Considering the complex nature of extracts from aflatoxin-contaminated pistachios, a necessary clean-up and concentration step involved dilution with water and passage through a C-18 solid phase extraction cartridge. The trapped aflatoxins were subsequently eluted with a minimal amount of methanol and analyzed using ultra-high performance liquid chromatography coupled to a fluorometer detector, equipped with a partially porous C18 column. This study illustrates the feasibility of utilizing DES as extraction media for aflatoxins in a complex matrix, diminishing dependence on conventional solvents and minimizing process waste. The developed method demonstrated robustness and reliability, achieving an inter-day repeatability lower than 6.4% (CV%) for each analyte, with limits of quantification below 0.71 ng/g. Recoveries for individual aflatoxins were as follows: 97.5% for AFB_1, 98.5% for AFB_2, 105.2% for AFG_1, and 92.9% for AFG_2. Additionally, the environmental sustainability of the method was quantified and evaluated using two distinct metrics. This inventive approach aligns with the ongoing trend towards more environmentally conscious analytical practices in the field of food safety.

References:

[1] A. Schincaglia et al., Foods 2023, vol. 12, no. 3
[2] M. A. R. Martins et al., J Solution Chem 2019, vol. 48, no. 7, pp. 962–982

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ALI-PO-002

Combination of HS-SPME-GC-MS analysis of terpenes and pentene dimers and chemometrics for characterization and clustering of Italian monovarietal extra virgin olive oils

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Terpenes and pentene dimers are two less-studied classes of volatile organic compounds (VOCs), associated with characteristic sensorial attributes of extra virgin olive oils (EVOOs). This 3-years study aimed to characterize the mono- and sesquiterpene and pentene dimer profiles of monovarietal EVOOs from 14 Italian cultivars for their quality control and authentication. Quantitation of both classes of compounds was achieved with a recently validated HS-SPME-GC-MS method. A total of 225 monovarietal EVOOs collected over three harvest seasons were analyzed, and the quantitative data were used for the characterization of the cultivars. The cultivars were also classified in groups based on their terpene and pentene dimer profiles. Sesquiterpenes were the molecules that most differentiated the groups, ranging from a total content of 3.908 mg/kg for the Moraiolo variety to 38.215 mg/kg for the Nocellara variety. The chemical structure (e.g., acyclic, monocyclic, polycyclic) of the prevalent sesquiterpenes also played a role in the characterization of the cultivars. Pentene dimers (1.336-3.860 mg/kg) and monoterpenes (0.430-1.794 mg/kg) showed lower variability among cultivars and much lower content overall. Statistical methods such as Kruskall-Wallis test-PCA-LDA-AHC were applied to the experimental data and allowed dividing the cultivars into 4 clusters (cluster 1: Ascolana Tenera, Casaliva, Leccio del Corno, Moraiolo, Pendolino, Frantoio, Leccino; cluster 2: Coratina, Picholine, Tonda Iblea, Nocellara; Cluster 3: Bosana, Peranzana; cluster 4: Itrana). A predictive model to classify the monovarietal oils in the clusters was built and achieved a 94.3 % correct classification when used on the training group samples. The model was also tested on 33 additional monovarietal EVOOs, correctly classifying 91% of them.

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ALI-PO-003

RES2OX - Investigating Specialized Metabolism as an integral factor to improve oxidative stress resilience in native plants exposed to metalloid naturally contaminated soils

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Global climate change (GCC) has altered the frequency of climate change, determining much more severe environmental disruptions than occurred in the past. The presence of abiotic stresses, such as drought, heat, salt, or heavy metals and metalloids, like arsenic (As), exacerbates GCC effects. Flavonoids are a representative group of secondary metabolites with various functions in plants, protecting them from abiotic and biotic stresses through antioxidant activity[1]. However, flavonoid function remains to be determined experimentally in naturally tolerant wild plants living in stressful soils. Soils developed on the volcanic substrate, as a considerable part of the Campanian region and Etna surroundings, are rich in neo-formed amorphous alumino-silicates and organo-mineral compounds and have a high binding capacity for trace metals, such as As. The Brassicaceae family comprises several plant species with agronomic and economic significance, such as *Brassica rapa*, which was reported to show significant tolerance to As-rich soils[2]. However, the role of flavonoids in the oxidative stress tolerance of *B. rapa* remains to be addressed, although the tolerance mechanisms, as adaptive traits, evolved in this species can become a knowledge milestone for future phytoremediation. In the present project, through untargeted transcriptome and metabolome approaches, we aim to investigate the role of flavonoids as ROS scavengers within the tolerance strategy of wild *B. rapa* naturally growing in soils affected by arsenic, assessed through geochemical approaches, by performing transcriptome and metabolome profiling analyses.

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It includes three research partners from the National Research Council of Italy (Principal Investigator), the University of Messina, and the University of Sannio. CUP J53D23014350001- ID. P2022HAMX9

References:

[1] G. Agati, C. Brunetti, A. Fini, A. Gori, L. Guidi, L., M. Landi, M. Tattini, Antioxidants 2020, *9*(11), 1098-1116.
[2] A. Roychoudhury, S. Krishnamoorthi, R. Paul, Genetics and Genomic Perspectives 2020, 1, 159-186.

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ALI-PO-005

Vitamin D_3 enrichment from fish waste: green extraction optimization and nutraceutical development

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In recent years, vitamin D has become increasingly important for human health due to its crucial role in maintaining bone and neuromuscular system homeostasis[1]. However, vitamin D deficiency is nowadays a concerning issue, with approximately 40% of the population estimated to have insufficient levels[2]. The ability of fish to store large quantities of Vitamin D_3 in their tissues, makes them an excellent dietary source of Vitamin D_3 for humans. Considering the activities related to the fishing sector, including fishery, aquaculture and the fish processing industry, significant amounts of fish waste are daily produced, leading to a significant environmental impact[3]. These precious wastes are often discarded because they do not meet market specifications, but they can serve as an excellent natural substrate for producing Vitamin D_3-rich extracts.

This research is part of the "VITADWASTE—Innovative and sustainable processes for the development of Vitamin D nutraceutical from fish waste: extraction, formulation and clinical study for the evaluation of its bioavailability and clinical equivalence" project, a PRIN (Research Projects of Significant National Interest) funded by Italian Ministry of University Education and Research (MIUR).

The final goal is to use fish production waste as a substrate for the extraction, enrichment, characterization and formulation of Vitamin D_3 nutraceuticals. An innovative approach is being tested to convert pure waste into a valuable resource for the pharmaceutical and food industries in accordance with the principles of the circular bioeconomy. For this purpose, a green and non-conventional technique, such as Supercritical Fluid Extraction (SFE), has been tested to obtain vitamin D_3-rich extracts. Extraction parameters were optimized using the Design of Experiment tool of XLSTAT software (2023.1.4.1408) in Box-Behnken design mode. Preliminary data showed the significant potential of supercritical carbon dioxide in extracting the lipophilic fraction from fish waste. The quantification of vitamin D_3 and its precursor, 7-dehydrocholesterol, which is highly concentrated in fish, was performed using a high-performance liquid chromatography coupled with a diode array detector, through a specifically developed method. After the optimization, a formulation study based on microencapsulation followed by a bio-accessibility study will be conducted to obtain a nutraceutical to be tested in pharmacokinetics and bioequivalence in comparison with a standard Vitamin D supplement.

[1] I.V. Di Molfetta, L. Bordoni, R. Gabbianelli, G. Sagratini & L. Alessandroni, Nutrients 2024, 16, 221-237.
[2] K. Amrein, M. Scherkl, M. Hoffmann, […] O. Malle, European journal of clinical nutrition 2020, 74, 1498-513.
[3] D. Coppola, C. Lauritano, F. Palma Esposito, G. Riccio, C. Rizzo & D. de Pascale, Marine drugs 2021, 19, 116-155.

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Phenolic fraction from palm oil and grape seed oil

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Palm oil (PO) derives from the palm tree fruit (*Elaeis guineensis*) and it is the most widely produced and consumed vegetable oil in the world. The palm tree accounts for the smallest percentage (5.5%) of all the cultivated land for oils and fats globally, but produces the largest percentage (32%) of total output. It is strongly debated due to environmental and nutritional issues, as it has a 1:1 ratio of saturated and unsaturated fatty acids. However, there are a number of studies in literature that do not support some of these assumptions.[1] Grapeseed oil (GSO) is extracted from grape seeds. The percentage of extractable oil varies according to the cultivar. It is particularly known for its beneficial properties, attributable to its high content of polyunsaturated fats and antioxidant compounds.[2] Herein, the phenolic fractions extracted from PO and GSO samples were investigated and their characterization is reported.

The extraction of the phenolic fraction from POs and GSOs was achieved in an ultrasonic bath by using a methanol/water solution (80/20, *v/v*) as the extraction solvent. Total phenolic content (TPC) was evaluated by using *Folin-Ciocalteu* method, and the results are expressed as mg GAE (gallic acid equivalents) / 100 g oil. The analyses for the determination of phenolics were carried out using an HPLC system, equipped with a Discovery C18 chromatographic column, coupled to an MSD API 4000 Q-Trap model mass spectrometer.

A higher amount of phenolics was observed in POs than in GSOs. In fact, TPC values were in the range 8.74 – 30.54 mg GAE / 100 g oil for PO samples and 0.21 – 0.90 mg GAE / 100 g oil for GSO samples.

Among the individual phenolics, simple phenols, phenolic acids and flavonoids were identified and quantified in both series of samples. The most abundant were: hydroxytyrosol, whose amount ranged 13.80 – 42.8 mg / kg oil for POs and 0.9 – 1.3 mg / kg oil for GSOs, while tyrosol ranged 2.74 – 8.12 mg / kg oil for POs and 1.25 – 1.4 mg / kg oil for GSOs; caffeic acid, whose amount ranged 11.08 – 45.58 mg / kg oil for POs and 1.013 – 1.3 mg / kg oil for GSOs (and it was lower than LOD in same GSO samples); apigenine, whose amount ranged 7.68 – 43.5 mg / kg oil for POs, while it was never found in GSOs; *m*-coumaric acid, whose amount ranged 7.82 – 45.20 mg / kg oil for POs (and it was lower than LOD in many PO samples) and 5 – 11 mg / kg oil for GSOs.

References:

[1] S.R. Ismail, S.K. Maarof, S. Siedar Ali, A. Ali, PLoS ONE 2018, 13(2), e0193533.
[2] M.E. Martin, E. Grao-Cruces, M.C. Millan-Linares, S. Montserrat-de la Paz, Foods 2020, 9, 1360.

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ALI-PO-007

The added value of natural flavourings: characterization of bioactive compounds in Calabrian chili pepper flavourings obtained with different extraction techniques

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Flavourings are defined as all those substances with a high impact on food flavour, while the term "natural flavourings" specifically refers to flavouring preparations of which at least 95% is obtained from a material of plant, animal or microbiological origin, by appropriate physical, enzymatic or microbiological processes, as described by the European Regulation 1334/2008. In particular, the aim of the present work is to compare natural flavourings obtained from Calabrian chili peppers by two extractive techniques and different parameters, both in terms of their volatile molecules, linked to specific sensorial properties, and through the characterization of their important bioactive compounds[1]. This research is part of a broader project aimed at the valorisation of natural flavourings from Calabrian chili pepper variety, considering the initiated procedure to obtain the PGI mark, and at the reuse of chili peppers, that are not suitable for a direct sale, for flavouring preparations, with a view to a circular economy. In this work Soxhlet extraction and Ultrasound Assisted Extraction (UAE) techniques were compared especially in terms of bioactive compounds recovery. Thus, hydroalcoholic solvents in different percentages were used, since they are environmentally friendly and permitted in food flavouring production. The extracts were then analysed in terms of pungency, related to the concentration of the two main capsaicinoids (capsaicin and dihydrocapsaicin), vitamin C, vitamin E, polyphenols, and carotenoids[2,3]. Analyses were performed using different methods and instruments such as HPLC-DAD and UHPLC-MS/MS. The volatile molecules were analysed by HS-SPME-GC-MS and compared to that of the original matrix. An accurate statistical analysis was then applied to compare all the obtained data. The most impactful parameter turned out to be the ethanol/water percentage of the extraction solvent, since, for example, capsaicinoids and vitamin E were more present in chili extracts from anhydrous ethanol, while polyphenols, vitamin C and antioxidant activity were more related to extractions with a higher water percentage, as expected. In particular, both for Soxhlet and UAE ethanol 70% was a good compromise, since it assured the most heterogeneous chemical composition of volatile extracted compounds, with a high similarity to the original matrix. Besides, in both the involved techniques, ethanol 70% extracted a high concentration of the analysed bioactive molecules, compared with the literature [4].

References:

[1] Y. Wang, Z. Yahan, F. Jia, Current Opinion in Pharmacology, 2021, 61, 1-5.
[2] Z. Nagy, H. Daood, Z. Ambrózy, L. Helyes, Journal of analytical methods in chemistry, 2015, 102125.
[3] L. M. J. de Carvalho, P. Barros Gomes et al, Food Research International, 2012, 47, 337-340.
[4] M. A. Salamatullah, K. Hayat et al, Evidence-based complementary and alternative medicine: eCAM, 2022, 7372101.

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ALI-PO-008

In-depth study of coffee's acidity among eight brewing methods: chemical, sensory and statistical evaluation

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Acidity in coffee is a crucial sensory characteristic mainly influenced by the roasting level and organic acid composition.[1,2] This research offers a comprehensive analysis of how eight coffee brewing methods (AeroPress, Chemex, Clever, FrenchPress, Moka, PureBrew, Ibrik and V60) affect the acidity profiles of both specialty and mainstream coffees across different types of coffee. For the first time, a systematic approach with chemical analysis and sensory evaluation has been applied to explore the relationship quantitatively and qualitatively between brewing methods and coffee acidity. Employing an innovative method, the study correlated the chemical composition comprising organic acids, chlorogenic acids, and caffeine [3], with sensory attributes like sourness and mouthfeel, alongside physicochemical acidity indicators such as titratable acidity, pH, and Total Dissolved Solids (TDS). Statistical analyses demonstrated that chlorogenic acids significantly affected the coffee's pH and titratable acidity (**Figure 1**), whereas the sensory perception of sourness was more closely correlated with the concentration of organic acids. Notably, non-filtered brewing methods like Ibrik and Moka showcased a higher total acids content, with Ibrik coffee registering the highest acid levels, reaching at 2500 mg/L for certain organic acids such as acetic and citric. In contrast, the Chemex method, which employs a specific paper filter, yielded the lowest acid extraction, underscoring the impact of filter type on acidity.

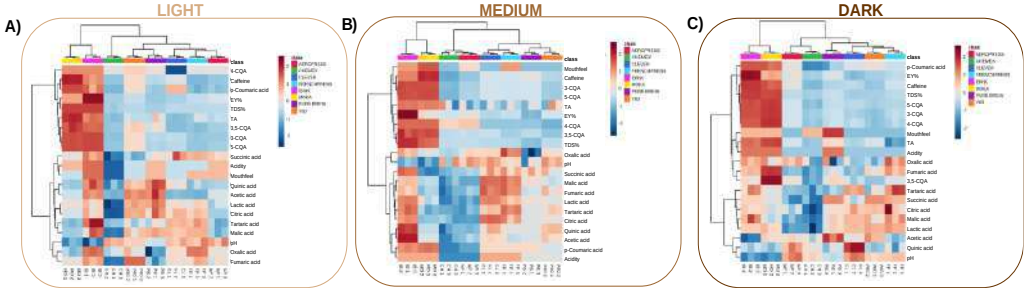

Figure 1. Hierarchical clustering and heatmaps of the three coffee varieties throughout the analyzed extraction methods.

These findings identified organic acids as likely predictors of perceived coffee acidity, providing new insights into how brewing techniques influence the sensory and chemical profiles of coffee. The study significantly advances our understanding of coffee brewing science and sets the stage for further research to improve coffee quality and consumer satisfaction with respect to acidity.

References:

[1] C. Rune, D. Giacalone, I. Steen, L. Duelund, M. Münchow & M. P. Clausen, 2023, 6, 100485.
[2] M. E. Batali, A. R. Cotter, S. C. Frost, W. D. Ristenpart, & J. X. Guinard, 2021, 1(4), 559-569.
[3] A. Santanatoglia, S. Angeloni, M. Fiorito, L. […] Caprioli, G., 2024, 125, 105732.

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ALI-PO-009

Fortified food: chemical characterization of pressed ovine cheese added with different percentages of *Moringa oleifera* powder

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Moringa oleifera is a plant distributed in many tropical and subtropical countries and represents a precious source of bioactive molecules with numerous health benefits [1,2]. The experimental plan involved the production of a control cheese and two experimental fortified cheeses, obtained by adding commercial Moringa powder to the curd at a percentage of 1% and 2% (w/w). The samples (Moringa powder, freeze-dried ovine's milk, freeze-dried control and 1% - 2% fortified cheeses) were subjected to chemical characterizations on the lipid, phenolic, microbiological and sensorial profile. The microbiological analyses highlighted the absence of the main pathogens of dairy interest and the dominance of *Lactococcus lactis* added as starter cultures. Analyses carried out on samples, showed promising values of antioxidant activity, with a range of values equal to 0.82 – 1.35 mmol TEAC/100g for the ABTS test and 0.99 – 1.21 mmol TEAC/100g for the DPPH test, highly superior to cheese control (0.11 – 0.06 mmol TEAC/100g, respectively). Interesting values regarding the total phenolic content (TPC), equal to 2.01 and 2.72 mgGAE/g for the 1% and 2% fortified cheese, respectively, and higher than the control (1.19 mgGAE/g), were highlighted. GC/MS analyses did not reveal a particular increase in unsaturated fatty acids compared to the control cheese. The UHPLC-ESI MS/MS analyses involved the search for phenolic compounds in the freeze-dried cheese samples; cheese fortified with 2% Moringa powder was richer in polyphenols than the control; in particular, chlorogenic (23.62 mg/100g), caffeic (3.07 mg/100g), ferulic acid (14.38 mg/100g) and quercitrin (34.79 mg/100 g) were higher than cheese produced only with ovine's milk, which had lower concentrations of chlorogenic acid (0.51 mg/100g), caffeic acid (1.15 mg/100g), ferulic acid (0.254 mg/100g). Quercitrin was not detected in control cheese. The addition of Moringa powder did not negatively impact the judges' overall level of appreciation. This fortification therefore represents an optimal strategy to enhance Sicilian sheep's milk through the production of innovative dairy products, rich in bioactive molecules and with a longer shelf-life thanks to the presence of antioxidant compounds.

References:

[1] F.Anwar, S. Latif, M. Ashraf, AH. Gilani, Phytother Res 2007, 21(1):17-25.

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ALI-PO -010

Chemical properties of hemp (*Cannabis sativa* L.) microgreens extract obtained with Natural Deep Eutectic Solvents (NADES)

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Bioactive compounds have been regarded as desirable substances that naturally exist in plant and food items, which can promote benefits for human health thanks to biological properties including antioxidant, antimicrobial and anti-inflammatory. Natural Deep Eutectic Solvents (NADES) are used as solvent for bioactive compound recovery from different sources, such as agri-food residues and plant materials. Compared to common solvents, NADES present higher extractive capacities and are cheaper, readily prepared, safer for the environment, more biodegradable, and more sustainable alternative.[1]

Cannabis sativa L. is a versatile crop, whose industrial varieties can be cultivated in Europe provided they respect the 0.3 % Δ9-tetra-hydrocannabinol (THC) threshold set by the EU legislation. Consumption of food items containing hemp (such as seeds, oil extracts, and defatted flours) is rising up, particularly in Western countries, thanks to the its unique composition and significant nutritional and biological properties.[2] The production of an alternative to the mature plant, such as microgreen, young seedlings of plants grown from seeds, is becoming a great opportunity because they are harvested in two weeks since germination and the chemical composition is very attractive due to their richness in both phytochemical compounds and micro/macro elements.[3]

This work aimed to evaluate a green-extraction method based on the use of NADES to extract phytochemical compounds from hemp microgreens. Thus, the method was compared with a conventional one, performed with an ethanolic solution. Before selecting the NADES with the higher extraction yield, different eutectic solvents were tested. The extracts were characterized in terms of total polyphenolic content (TPC) and antioxidant activity (AO), applying FOLIN-CIOCALTEAU, DPPH and FRAP assays, respectively. Moreover, the molecular profile was obtained through UHPLC-MS/MS.

To the best of our knowledge this study investigates for the first time these types of plant materials applying a NADES extraction method.

References:

[1] R.F. Gonzalez-Laredo, V.I. Sayago-Monreal, M.R. Moreno-Jiménez, N.E. Rocha-Guzman, J.A. Gallegos-Infante, L.F. Landeros-Macias, M. Rosales-Castro, International J. of Food Science and Technology 2023, 58, 6660 – 6673.

[2] J. Vitorović, N. Joković, N. Radulović, T. Mihajilov-Krstev, V.J. Cvetković, N. Jovanović, T. Mitrović, A. Aleksić, N. Stanković, N. Bernstein. Antioxidants. 2021; 10(6):830.

[3] G. Corrado, A. Pannico, A. Zarrelli, M. Kyriacou, S. De Pascale, Y. Rouphael, Journal of Food Composition and Analysis 2022, 114, 104750.

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ALI-PO -011

Effects of feed supplementation of ewes with silages of prickly pear by-products (*Opuntia ficus-indica*) on the chemical-nutritional characteristics of their dairy products

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Industrial and technological growth has led to an increase in waste and by-products, which requires green and circular economy approaches. The waste resulting from *Opuntia ficus-indica* can exceed 40% up to 55% of the total weight of the fruit. These by-products lend themselves well to ensiling[1] and are rich in bioactive substances such as proteins, vitamins, minerals, carbohydrates and polyphenols, and have multiple physiological activities such as antioxidant, anti-inflammatory and antimicrobial[2]. The aim of this study was to determine the chemical-nutritional characteristics of prickly pears by-products silages (PPS) (peels+12% of wheat bran and prickly pears peels, pulp, seeds + 12% of wheat bran), bulk milk and cheese samples from ewes fed with these PPS, in order to evaluate their effects on cheese quality. Milk, cheese and PPS samples were subjected to qualitative-quantitative chemical characterizations on the lipidic and phenolic fraction. Cheeses samples were subjected to triangular test. PPS, milk and cheese samples were freeze-dried before analysis. All the samples were analysed for their antioxidant activity by DPPH and ABTS tests, total phenolic content (TPC) by Folin-Ciocalteau test, phenolic profile by UHPLC-ESI/MS-MS analysis and fatty acid profile by GC- MS method. PPS showed considerable antioxidant activity, especially the PPS peels, which was reflected in the milk and cheese samples of the ewes fed with this by-product. In particular, cheese samples showed higher anti-radical values (0.375-0.710 mmol TEAC/100 g) respect to the control (0.122 mmol TEAC/100 g). Analyses carried out on TPC showed a higher value in milk and cheese samples (2.04-3.41 mg GAE/g), respect to the control samples (0.24 mg GAE/g). Supplementation of PPS in the sheep's diet, however, did not significantly influence the fatty acid profile of milk and cheese samples and the sensorial test ($P>0.10$). Therefore, the feed supplementation with PPS represents an optimal strategy to enhance Sicilian sheep's cheeses, through the production of innovative dairy products enriched with bioactive molecules and with a longer shelf-life, due to the presence of natural antioxidants without altering their sensorial aspects.

References:

[1] R. Gannuscio, A. Vastolo, G. Maniaci, C. Lucia, S. Calabrò, M. Todaro, M.I. Cutrignelli, Italian Journal of Animal Science 2024, *23*(1), 492-503.
[2] D. Gopi, K. Kanimozhi, L. Kavitha, Spectrochim. Acta Part A Mol. Biomol. Spectrosc 2015, 141, 135–143.

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ALI-PO -012

Transferase and lipase catalysed synthesis of *N*-fatty acylalkanolamine derivatives

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Unlike lipases and esterases, the acyltransferase from *Mycobacterium smegmatis* (MsAcT) is able to catalyze acylation reactions of primary alcohols and amines in aqueous solutions at room temperature and with a high acyltransferase/hydrolase ratio.[1] Since nothing has been reported in literature on the use of MsAcT with amino alcohols, a screening with a collection of difunctionalized compounds was conducted for the development of a biocatalytic chemo-selective acylation tool.

In order to optimize reaction conditions, batch biotransformations were initially carried out with different substrates including amino alcohols, secondary alcohols and amines, using EtOAc as acyl donor. The enzymatic acylation of model amino alcohol substrates has been carried out to evaluate the chemo-, regio- and stereo-selectivity of the glyoxyl-immobilized MsAcT with the advantage of simplifying the downstream process by eliminating the work up step.[1] In all the cases studied, using EtOAc as acyl donor, a preference towards *N*-acetylation over the *O*-acetylation has been observed.

Finally, MsAcT has been tested for the synthesis of *N*-fatty acylalkanolamines starting from the ethyl esters of linoleic, arachidonic and oleic acids with various alkanolamines. MsAcT has been compared with *Candida antarctica B* (CAL B) lipase immobilized on an acrylic resin (Fig.1), the latter showing higher yields in the amidation steps.[2] Therefore, CAL B was applied as a biocatalyst in flow reactors for the development of a sustainable and continuous enzymatic preparation of the endocannabinoid anandamide (**1**) and a small collection of analogues.[3]

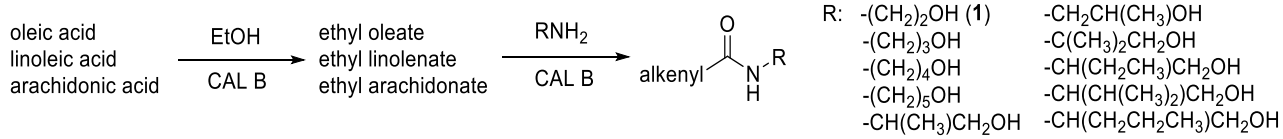

Figure 1: Scheme representing the CAL B-mediated reaction for the preparation of anandamide analogues.

References:

[1] P. Cannazza, S. Donzella, A. Pellis, M. L. Contente, *Biotechnology Advances*, **2022**, *59*, 107985.
[2] R. N. Lima, C. S. dos Anjos, E. V. M. Orozco, A. L.M. Porto, *Molecular Catalysis*, **2019**, *466*, 75-105.
[3] P. G. Quintana, G. G. Liñares, S. N. Chanquia, R. M. Gorojod, M. L. Kotler, A. Baldessari, *European Journal of Organic Chemistry*, **2016**, *3*, 518-528.

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ALI-PO-013

Application of phenolic compounds from olive pomace in delaying flaxseed oil oxidation in model emulsions

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Olive pomace (OP) represents the main by-product of olive oil production[1]. OP contains approximately 98% of olive phenolic compounds which are represented mostly by hydroxytyrosol (OH-tyr) and tyrosol (tyr), along with their precursors[2], whose antioxidant activity has been largely documented. Besides their health-promoting properties, these phenolic compounds could also be used as natural antioxidants. Hence, this research aimed at evaluating the capacity of OP antioxidant compounds to mitigate lipid oxidation of highly labile compounds like omega-3 fatty acids. A response surface methodology (RSM) was conducted to investigate the effect of three independent variables (temperature, 4-95 °C; time, 30-120 min; ethanol concentration, 0-50%) on the green extraction of free and total OH-tyr and tyr, measured by HPLC-DAD, and the radical scavenging capacity (RSC) assessed by DPPH assay. The conditions allowing for the higher yield of OH-tyr and tyr and RSC were 95°C, 40% ethanol and 30 minutes. The best-perfoming extract was incorporated at different concentrations into flaxseed oil model emulsions and incubated for 60 days at 40°C to induce oxidation. Primary and secondary oxidation products were assessed by peroxide value (PV) and thiobarbituric acid reactive substances (TBARS) tests, respectively. The degradation of OH-tyr and tyr was also monitored by HPLC. OP extract at the maximum concentration used (400 μM) provided a reduction of PV and TBARS of 97.8% and 78.0% respectively in the emulsions after 60 days. The 82.5% reduction of OH-tyr during the incubation time further proved its antioxidant capacity, differently from tyr that remained substantially stable. These results demonstrate the efficacy of OP OH-tyr in retarding the lipid oxidation of flaxseed oil, providing a valuable tool for future technological applications.

References:

[1] C. M. Sánchez-Arévalo, A. Iborra-Clar, M. C. Vincent-Vela, and S. Álvarez-Blanco, "Solvent-resistant ultrafiltration to recover bioactive compounds from wet olive pomace extracts," LWT-Food Science and Technology, 2023, p. 115167-115181.

[2] J. Madureira, M. Dias, J. Pinela, R. Calhelha, L. Barros, C. Santos-Buelga, F. Margaça, I. Ferreira, et al., "The use of gamma radiation for extractability improvement of bioactive compounds in olive oil wastes," Science of The Total Environment, 2020, vol. 727, p. 138706-138717.

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ALI-PO -014

Flow-biocatalytic production of aglycones from glycosides found in citrus residues

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As the global population is approaching 8 billion and lifestyles and dietary habits change, a significant rise in agri-food industrial waste is expected, posing both environmental and economic challenges. Many of these residues demonstrated to contain a plethora of bioactive compounds.

The recovery and processing of such molecules to generate value-added products for applications in the pharmaceutical, cosmetic, and food industries can represent a promising strategy for saving relevant resources and reducing bio-waste[1]. In this context, biocatalysis can offer important advantages over traditional synthetic methods in terms of efficiency and selectivity.

Extremophilic glycosidases, capable of cleaving glycosidic bonds, are essential tools due to their ability to withstand harsh reaction conditions. We particularly focused on rutin (RT) and hesperidin (HES), glycosides commonly found in citrus fruits and residues (Figure 1). By using a commercially available α-rhamnosidase (RN) and a homemade halo-thermophilic β-glycosidase (HOR), we aimed at obtaining their aglycones, hesperetin (HP) and quercetin (Q), which exhibit higherx bioavailability and membrane permeability. By developing a continuous process using flow reactors and enzyme immobilization techniques, we enhanced reaction yields and sustainability. Co-immobilizing both enzymes on the same matrix and employing a biphasic system with an unconventional green solvent, 2,2,5,5-tetramethyloxolane (TMO)[2], further reduced costs and addressed substrate solubility issues. By recovering and reusing all materials involved in the flow biotransformation, this approach can be claimed as a zero-waste procedure[3].

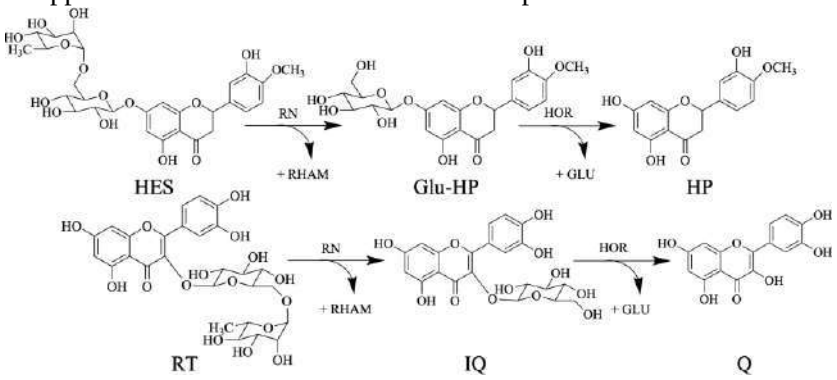

Figure 1: Obtainment of quercetin and hesperetin as aglycones from the corresponding natural glycosides.

References:

[1] D. Tonini, P.F. Albizzati, T.F. Astrup, Waste Management 2018, 76, 744–766.
[2] A. Pellis, *et. al.* Green Chemistry 2019, 21, 1686–1694
[3] A. Colacicco, *et al.* Catalysis Science and Technology 2023, 13, 4348-4352

ALI-PO-015

Comparison of metabolic profile, anti-oxidant, and hypoglycaemic effects between fresh and fermented Voghiera black garlic (*Allium sativum* L.) extracts

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Diet is currently one of the most important exogenous factors in the prevention of chronic diseases. The increasing incidence of non-communicable diseases is driving the search for and use of functional foods that can actively contribute to the prevention of human disease [1].

Allium sativum L. is a plant known as a medicinal food since ancient times. To date, several beneficial properties have been demonstrated, such as anti-cancer, antibacterial, antiviral, anti-hypertensive, cardioprotective, hypolipidaemic and anti-diabetic effects, mainly associated with various organosulphur compounds [1,2]. However, the consumption of garlic is uncommon in Europe and America due to its pungent smell and taste, which is not very pleasant. To overcome this problem, it is common practice, especially in Asia, to ferment garlic at high humidity and temperature (around 70°C) for different days (30-40gg). Fermented black garlic becomes sweet and aromatic with a syrupy, gelatinous consistency. In addition, the fermentation process also seems to improve the beneficial properties, probably due to non-enzymatic browning reactions (phenol oxidation, Maillard reaction and degradation of organo-sulphur compounds) and enzymatic ones. Studies have shown that fermentation modifies the chemical composition of garlic, resulting in greater antioxidant power (mainly related to the formation of S-allylcysteine, Amadori products and melanoidins) and improved hypoglycaemic capacity [3].

In the present study, DOP garlic from Voghiera was fermented and several samples were taken throughout the process (30 days) to assess the changes in its chemical composition. For this purpose, the samples were extracted by hydroalcoholic sonication and, after purification, analysed by mass spectrometry. In addition, the antioxidant and hypoglycaemic properties were assessed using various spectrophotometric assays (ABTS, ORAC, DPPH, alpha-amylase and glucosidase), highlighting in particular an improvement in antioxidant capacity as the fermentation process progressed.

Finally, the chemical composition and bioactivities tested were correlated to identify the most bioactive classes of molecules.

References:

[1] Afzaal, M., Saeed, F., Rasheed, R., Hussain, M., Aamir, M., Hussain, S., ... & Anjum, F. M. International Journal of Food Properties (2021), 24(1), 1387-1402.
[2] Ryu, J. H., & Kang, D. Molecules (2017), 22(6), 919.
[3] Ríos-Ríos, K. L., Montilla, A., Olano, A., & Villamiel, M. Trends in food science & technology (2019), 88, 459-467.

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Comprehensive lipidomic analysis of functional foods and nutritional implications

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In the last decades, lipidomics has emerged as a cutting-edge approach among omics- techniques, since lipids revealed to be essential molecules in the regulation of metabolic pathways. To this regard, the content of essential fatty acids (EFAs), as well as nutritional indices such as the levels of omega-3 and omega-6 FAs and their ratio are essential parameters to evaluate the beneficial properties of food products. In addition, the investigation of complex lipids in their native forms is proved to be crucial to obtain additional information about lipids role and on FA arrangement into each species.

For this reason, the present talk aims at a detailed elucidation of intact lipids in different functional foods, including marine organisms such as algae and the wastes of the fish industry, according to current trends in food science, such as the valorization of unconventional and sustainable food products and the minimization of food wastes and the promotion of recycle strategies (circular economy models).

From an analytical point of view, two parallel and complementary approaches are commonly used in the lipidomic field: gas chromatography-mass spectrometry (GC-MS) and high-performance liquid chromatography-mass spectrometry (HPLC-MS). The former is essential for the detailed characterization of the total FA composition, being able to reliably identify the position of the double bonds along the carbon chain (omega nomenclature) and/or the configuration of the double bond (cis/trans), while the latter is employed for the elucidation of intact lipids (e.g., triglycerides, diglycerides, phospholipids, free FAs) as they are originally present in the sample, thus adding important information about storage conditions and how they will be metabolized. In both cases, particular emphasis is paid on the miniaturization and automation of the entire analytical workflow by using robotic workstations able to perform the sample preparation in a fully automated manner and online with the chromatographic system.

In a second stage of a lipidomic workflow, biological samples could be analysed to investigate on nutritional aspects directly related to lipid metabolism. To this regard, lipid profiles of human blood can be obtained by using the same analytical platforms described above and can be correlated with different dietary regimes.

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A method using dilute-and-inject liquid-gas chromatography-tandem mass spectrometry for the determination of sixteen polycyclic aromatic hydrocarbons in extra-virgin olive oil

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This study presents a method based on dilute-and-inject liquid-gas chromatography-tandem mass spectrometry for the rapid determination of 16 polycyclic aromatic hydrocarbons (PAHs) in extra-virgin olive oil (EVOO). The sample preparation process was simple, involving only a dilution step, thereby eliminating the need for extraction, clean-up procedures, and reducing organic solvent usage significantly. A comparison between selected-ion-monitoring and pseudo multiple-reaction-monitoring (p-MRM) acquisition modes was conducted to assess specificity and analyte detectability. The results favored the p-MRM mode for its superior performance and was thus adopted for acquisition.

The method exhibited linearity within the concentration range of 1-200 µg kg^{-1} (and 5-200 µg kg^{-1} in three instances). Accuracy, tested at 2 µg kg^{-1} and 20 µg kg^{-1} concentration levels, fell within the range of 86.9-109.6%, with a relative standard deviation of less than 10%. Precision within the same concentration levels showed intra-day and inter-day variations ranging from 1.2% to 8.8% and 3.2% to 10.8%, respectively.

All PAHs showed a negative matrix effect. Among ten samples, three EVOOs exhibited traces of three out of the sixteen PAHs, albeit at low parts per billion levels.

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ALI-PO-018

Characterization of phenolic compounds in olive leaves of three different *Olea europaea* cultivars by HPLC-PDA/MS

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Olive oil production has expanded, resulting in a significant amount of solid and liquid by-products. From an economic and environmental perspective, the accumulation and management of residues represents a significant challenge. However, the valorisation of these by-products to recover and/or bio-transform their organic content is a significant potential, transforming the waste treatment process into one that produces high value products. In particular, olive leaves are one of the most important agricultural biomasses obtained from the pruning of olive trees, which can be considered as an available industrial by-product. They are known to be a rich source of various phytochemicals, including phenolic compounds, with high potential for their antioxidant properties.

The aim of this study was to characterise the main bioactive compounds from olive leaves of three different *Olea europaea* cultivars. Olive leaves are subject to solid-liquid extraction and then the analyses were carried out by high-performance liquid chromatography combined with photodiode array and mass spectrometry detection. The present analytical method has already successfully been employed by our research group in the drupes and olive oil and and wastes[1]. Method validation was performed in terms of limit of detection (LoD), limit of quantification (LoQ), linearity range, reproducibility and repeatability. Recovery of the method was performed achieving good results.

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References:

[1] M. Russo, I.L. Bonaccorsi, F. Cacciola, L. Dugo, L. De Gara, P. Dugo, L. Mondello, Natural Product Research 2021, Volume 35:21, 4182-4187

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ALI-PO -019

Determination of oxygen heterocyclic compounds content in cinnamon- and Citrus-flavoured foods using High Performance Liquid Chromatography-Tandem Mass Spectrometry

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A great number of plants, principally belonging to Apiaceae and Rutaceae families, contain high levels of oxygen heterocyclic compounds (OHCs), namely coumarins, furocoumarins and polymethoxyflavones[1]. These compounds are mainly present in *Citrus* fruits, cinnamon, carrot, parsnip, fennel, celery, parsley and turnip which are commonly used in several plant-based foods. Due to their numerous biological effects, coumarin and its derivatives are widely exploited as therapeutic agents but also as flavouring agents in foods[2]. The most important properties of these molecules are the antioxidant and anti-inflammatory effects[1]. Taking into account their significant role in several fields, special attention must be paid to the noteworthy drawback of their hepatotoxicity and skin phototoxicity. Among all the OHCs, the content of coumarin is the only one strictly regulated in foods. The Decision No 1334/2008 of the European Parliament and Council forbids the addition of coumarin to food as an additive, while the Annex III allows the maximum presence of 50 mg kg^{-1} for traditional bakery products and 5 mg kg^{-1} for desserts of coumarin in foods containing cinnamon as a flavor[3].

The aim of this research was to investigate the amount of coumarin and 35 OHCs in more than 30 foods flavoured with cinnamon and *Citrus* products to monitor the daily intake of coumarin by food. For this purpose, liquid chromatography coupled with triple-quadrupole mass spectrometry detector (RP-HPLC-QqQ/MS) was the approach of choice to determine the amount of OHCs in the samples of our interest and verify if coumarin content was in accordance with the limit of 0.1 mg kg^{-1} body weight as a tolerable daily intake imposed by EFSA[4]. Before the RP-HPLC-QqQ/MS analysis, each sample was subjected to solid-liquid extraction. The extraction method was validated in terms of recovery, varying the type and volume of solvent used, the extraction time and temperature, leaded by the objective of a more environmental friendly way to operate.

References:

[1] M. Loncar, M. Jakovljević, D. Šubarić, M. Pavlić, V. Buzjak Služek, I. Cindrić, M. Molnar, Foods 2020, 9, 645.
[2] S. C. Heghes, O. Vostinaru, C. Mogosan, D. Miere, C. A. Iuga, L. Filip, Frontiers in Pharmacology 2022, 13.
[3] European Commission. Regulation (EC) No 1334/2008 on flavourings and certain food ingredients. Official Journal of European Union 2008.
[4] European Food Safety Authority (EFSA). Coumarin in flavourings and other food ingredients with flavouring properties - Scientific opinion of the panel on food additives, flavourings, processing aids and materials in contact with food (AFC). EFSA J. 2004, 6.

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ALI-PO -020

Chemical characterization of unconventional seed oil with a focus on lipid components and volatile profile

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The Food and Agriculture Organisation of the United Nations has estimated that in order to cope with the continuous increase in world population, agricultural production should be increased by a 60% factor. For this reason, search for alternative food sources that can replace or complement existing ones are becoming widespread. In this context, seed oils are gaining an important role in food and nutraceutical market, as they are widely used both for direct consumption and as nutraceuticals for the high content in polyunsaturated fatty acids (PUFA). The present research focused on the investigation of unconventional eight cold pressed seed oils: blackcurrant, carrot, plum, pomegranate, radish, raspberry, rosehip, strawberry. The aim of the study was to demonstrate their beneficial properties related to the FA composition and/or volatile profile. Specifically, FAs were identified and quantified as FA methyl esters, obtained via a cold derivatization procedure[1], by using gas chromatography (GC) coupled with mass spectrometry (MS) and flame ionization detector (FID), respectively. The volatile fraction was elucidated by means of headspace solid-phase-microextraction (HS-SPME) coupled with GC-MS[2]. All the oils showed a content of UFAs, mainly consisting of oleic, linoleic and α-linolenic acid in the range 80-90%, potentially contributing to the prevention of cardiovascular diseases. Isomers of linolenic acid were also detected in significant amounts, such as α-linolenic and punicic acid in blackcurrant and pomegranate seed oils, respectively. Particularly, punicic acid is a conjugated isomers of linolenic acid, with possible antioxidant, anti-cancer, anti-obesity and anti-inflammatory activities.

Regarding the volatile compounds, aldehydes were the dominant molecules identified in plum, pomegranate and strawberry seed oils, while terpenes such as α-pinene, δ-3-carene and carotol were the main volatiles in blackcurrant, carrot and rosehip seed oils.

The results confirmed that these oils could be introduced into the food market for direct consumption or as nutraceutical products for the prevention of specific health conditions.

References:

[1] M. Oteri, G. Bartolomeo, F. Rigano, J. Aspromonte, E. Trovato, G. Purcaro, P. Dugo, L. Mondello, M. Beccaria, Foods 2023, 12, 23.
[2] T. Lechhab, W. Lechhab, E. Trovato, F. Salmoun, L. Mondello, F. Cacciola, Horticulturae 2022, 8, 925.

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ALI-PO -021

Analytical evaluation of bioactive compounds in olive oil by-products

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The production of by-products from farming and food manufacturing poses a significant challenge to global environmental and food emergencies. Olive oil production employs a technological process that relies on physical operations without chemicals. However, the extraction process requires a large amount of water and produces a significant amount of solid waste and harmful liquids, which raises significant environmental concerns. Improper disposal of by-products of the olive oil mill industry can lead to environmental pollution and harm ecosystems. Olive mill wastewater (OMWW) is known for its dark color and high concentrations of organic carbon, potassium, nitrogen, phosphorus, calcium, magnesium, and iron, particularly phenols and polyphenols. Olive pomace (OP) is a solid waste consisting mainly of water, seed, and pulp with a high organic matter and carbon content, rich in potassium, low in phosphorus, with intermediate nitrogen levels. It may also contain phenolic and lipid compounds. Both matrices have a high pollution index due to their acidic nature and high concentrations of salts and phenolic compounds, making them potentially harmful by-products for the environment. Identifying and measuring bioactive compounds in complex matrices such as OMWW and OP after extraction and recovery is a challenging task. Accuracy and reliability are essential to promote new practical destinations for olive oil by-products, resulting in environmental and financial benefits.

In this study, a sensitive and robust analytical method for the quali-quantitative characterization of bioactive compounds (polyphenols and lipophenols) in samples of OMWW and OP based on high-performance liquid chromatography coupled with diode array detector and mass spectrometry with electrospray ionization interface (HPLC-PDA-ESI-MS) has been proposed and validated, by studying parameters such as repeatability, limit of detection (LOD), limit of quantitation (LOQ), linearity range, and recovery by analyzing standard phenolic and flavonoid compounds.

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ALI-PO-023

Preliminary investigations about protein insects bioaccessibility

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Edible insects are becoming a new protein source in order to feed a growing number of consumers, at the same time keeping environmental friendliness first[1]. Recently, after the positive safety evaluation by the European Food Safety Authority (EFSA) and their inclusion in the group of Novel Foods, it is mandatory to investigate their nutritional and toxicological profile that are generated during their intake. In this contest, the Italian National Recovery and Resilience Plan financially supported "OnFoods" which is a foundation including twenty-six public and private organizations taking sustainability, working on safety, security, and health actions. The University of Pavia is part of this foundation, and our research group aims to study the bioaccessibility, absorption, metabolism, and safety of selected components of novel foods, including *Locusta migratoria*, *Acheta domesticus*, and *Tenebrio molitor* proteins. Firstly, the proteins digestibility and amino acids bioaccessibility have been investigated using adapted Infogest 2.0 digestion protocol, a simulated *in-vitro* digestion process [2]. Digested fractions are being processed, according to protein precipitation and hydrolysis procedures under acid and basic conditions, to recovery macronutrients for subsequent investigations (e.i. protein content and digestible essential amino acid scores) [3,4]. In addition, changes occurring as a result of the digestion process will be monitored through Caco-2 cells biocompatibility tests. These preliminary investigations on insects underlines their potential nutritional value; in fact, they might be considered auspicious choices to overcome the future demands of new functional sources.

References:

[1] E. Ververis, G. Boué, Journal of Food Composition and Analysis 2022, 114, 104859.
[2] A. Brodkorb, L.Egger, Nature Protocol 2019, 14, 991-1014.
[3] L. Hammer, D. Moretti, Frontiers in Nutrition 2023, 10, 1150581.
[4] R. Sousa, I. Recio, Food Chemistry 2023, 404, 134720.

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ALI-PO-024

Biodiversity valorization through investigation of anti-glycative activity *of Diospyros kaki, Succisa pratensis, Aloysia citriodora*

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Italy has one of the most significant biodiversity heritages in Europe, both in terms of the total number of plants and the high rate of endemism. Therefore, it is important to preserve and enhance it as a source of goods and resources to ensure the maintenance of healthy ecosystems and coexistence between humans and nature, which is sustainable in the long term and resilient to ongoing climate change. In this contest, the Italian National Recovery and Resilience Plan financially supported "National Biodiversity Future Center", dedicated to frontier research involving Italian institutions and companies, including the University of Pavia, which aims to monitor, preserve, restore, and enhance biodiversity. Therefore, our research group aims to investigate and identify biologically active edible plant species, focusing on their potential anti-glycative properties.

Glycation is a non-enzymatic reaction between a reducing sugar and the side-chain amino groups of protein lysine or arginine residues, followed by further rearrangements, leading to the formation of advanced glycation end-products (AGEs). In *vivo* AGEs accumulation is associated with many chronic disorders such as diabetes, retinopathy, nephropathy, cardiovascular, and neurodegenerative diseases.[1] In particular, the aim of the present study is to investigate the anti-glycative activity of *Diospyros kaki*, *Succisa pratensis*, and *Aloysia citriodora*, included in the Belfrit list, in order to identify and develop a new food ingredient with anti-glycative properties. Several in *vitro* assays were carried out to evaluate the ability to interfere with the glycation process at the initial, intermediate, and final stages of the reaction. In particular, model systems consisting of glycating agent, such as MGO, and a protein, such as bovine serum albumin (BSA), has been set up at physiological conditions (37 °C, pH 7.4) to evaluate the intermediate stage of glycation process.[2] With the help of NBT (blue nitrotetrazolium chloride), the capacity of the extracts to inhibit the formation of Amadori products (the initial products of the glycation process) has been evaluated.[2] In addition, MGO and GO trapping ability of the extracts has been investigated.[2] Then, the antiglycative activity at the final stage of the reaction was further investigated by several in *vitro* assays such as BSA-Glucose[3], BSA-Fructose[3], phthalaldehyde test[4], and thiol group test[5]. Overall, all three edible extracts had high anti-glycative properties at the intermediate stage of the reaction, efficiently inhibiting the formation of AGEs in the presence of MGO, which is also highly trapped. In addition, they inhibited the glycation reaction at the final stage of the reaction in presence of fructose and glucose, also increasing the percentage of free lysine amino groups; conversely, they had low anti-glycative properties at the initial stage of the reaction.

References:

[1] G. Vistoli, D. De Maddis, Free Radical Research 2013, 47, 3–27.
[2] M. Maietta, R. Colombo, Food Function 2018, 9, 1545–1556.
[3] L. Ferron, R. Colombo, Molecules 2020, 25, 1958.
[4] Y. Deng, X. Wang, Journal of Bioresources and Bioproducts 2023, 8, 187-197
[5] S.E. Fayle, J.P. Healy, Electrophoresis 2001, 22, 1518–1525.

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ALI-PO -025

Enzyme-Assisted Extraction of Antioxidants from Vegetable Wastes: Optimization by Surface Response Methodology.

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Circular economy and recovery of mixtures of bioactive compounds from agri-food wastes and by-products is a well-known goal within UN Agenda 2030[1] for sustainable development. Many different strategies have been developed to achieve this task with attention also to other topics and targets, mainly that one known as Green Chemistry. Thus, aqueous buffers and solutions and strategies for enhancing the extraction of antioxidant compounds from vegetable matrices (i.e., microwaves, ultrasounds, pressurised liquid extraction, supercritical fluids, enzymes, or their practicable combinations)[2].

In this work, an enzyme mixture, made of mainly Pectolytic and Cellulolytic enzymes (known as Viscozyme[3]), was applied for the degradation of asparagus hard-stem (*Asparagus officinalis L.*) and red grape pomace (*Vitis vinifera L.*) samples and improve the extraction of phenolic substances. Asparagus hard-stem is the non-edible terminal part discarded after packaging asparagus edible stems with a given commercially defined length; red grape pomace is the most common by-product after grape pressing for must extraction and grape pomace is a mix between grape skin, seeds and green stem and it is also known as “marc”. Amount of enzymatic mixture (% w/w), incubation temperature and incubation time (hours) were the experimental variables studied for extraction optimization. Measured parameters in extracts were the antioxidant capacity (i.e., mM TE, trolox equivalents, by DPPH assay), total polyphenols content, TPC (i.e., mg CE, catechin equivalents, per g of dry sample, by Folin-Ciocalteu assay), total flavonoids content, TFC (i.e., mg CE, catechin equivalents, per g of dry sample, by $AlCl_3$ assay) and condensed tannins content, CTC (i.e., mg CE, catechin equivalents, per g of dry sample, by vanillin assay). A two-factors central composite design approach was used for finding the best extraction conditions and experimental data were fitted to a second order polynomial model with interactions between the independent variables. Results evidenced that the amount of antioxidants that can be recovered is quite different from the two waste matrices and optimum ranges for enzyme mixture quantity, temperature and incubation time can be identified in each case.

References

[1] https://www.unssc.org/courses/circular-economy-and-2030-agenda-1
[2] M. Waseem et al., Food Frontiers, 2023, 4:1681–1701, DOI:10.1002/fft2.296

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ALI-PO -026

In-depth metabolite characterization of complex food samples using different separation properties in comprehensive two-dimensional liquid chromatography

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Attaining comprehensive characterisation of complex food samples often requires the employment of advanced chromatographic platforms.

In this context, comprehensive two-dimensional liquid chromatography is one of the most widely used approaches to achieve high-quality data acquisition for unequivocal identification.

The characterization of polar compounds in food analysis is typically carried out by reversed-phase liquid chromatography (RP) and hydrophilic interaction liquid chromatography (HILIC) separation mode. The aim of this contribute is to compare different platforms (HILIC × RP, RP × HILIC, RP × RP) for the analysis of complex polyphenols samples.

Their performance was evaluated in terms of peak capacity, orthogonality and maximum number of identified compounds.

In particular, one of the most complex phenolic compounds mixtures is represented by herbal liqueurs, typically produced by macerating several herbs, roots, flowers, bark, and/or citrus peels in alcohol, either neutral spirits or wine, mixing the filtrate with sugar syrup, and allowing the mixture to age in barrels or bottles. The huge varieties of botanical families used in their production, make herbal liqueurs a perfect matrix to evaluate the different comprehensive set-ups, mentioned above, on several phenolic matrices at the same time. Moreover, hyphenation with PDA and MS/MS detectors and chemometric approaches allowed discriminating between the several isomers presents in the different botanical families.

ALI-PO -027

Sumac as promising nutraceutical source: investigation on phenolic profiles of Sicilian fruits and leaves

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Rhus coriaria L. (Anacardiaceae), commonly known as sumac, it is a typical plant of Mediterranean and Middle Eastern areas, whose ground fruits are nowadays mainly used as spice or for flavouring and garnishing food. However, has been also used, since ancient times, in traditional medicine for treating many diseases such as haemorrhoids, wound healing, diarrhea, ulcers, and eye inflammation.

Actually, sumac fruits and leaves are rich in antioxidant compounds, including several gallic acid derivatives and flavonoids, from which treatment of common oxidative stress diseases could benefit. However, while many studies are focused on fruits, really few were conducted on leaves composition; moreover, most of them about Middle Eastern area samples.

For this reason, conventional and advanced liquid chromatography techniques coupled with photodiode array and mass spectrometer detectors were employed to investigate the phenolic profile of *Rhus coriaria* L. fruits and leaves, coming from different Sicilian areas. More than 80 phenolic compounds, mainly represented by gallic acid and its derivatives were positively identified, with important qualitative difference between fruits and leaves extracts. The present work confirmed the nutraceutical value of this plant, highlighting sumac leaves as a rich source of gallic acid.

Acknowledgments

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ALI-PO -028

HS-GC-IMS screening method to support the virgin olive oils panel test: an inter-laboratory study

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For extra virgin olive oils, it is crucial to ensure the authenticity of the declared and labelled commercial category. Olive oil companies, as well as quality control public and private laboratories, are often requested to rapidly assess the quality and purity of extra virgin olive oils. In this framework, a screening method based on gas chromatography coupled with ion mobility spectrometry (HS-GC-IMS) for the analysis of volatile compounds can be useful to support the virgin olive oils sensory analysis (Panel test). This instrumental approach can contribute to improve the overall efficiency of official quality and purity controls in the olive oil sector, thus protecting the consumer from the related common fraudulent practices.

In this research, around 80 commercial virgin olive oils were sensory assessed by five Italian panels, then classified, through the adoption of a decision tree based on the agreement among them, in a commercial category. Moreover, the volatile fraction of these oils was analysed in five laboratories by HS-GC-IMS. The results were elaborated towards the possible definition of a joint calibration based on a common dataset. In particular, the commercial categories of each oil were predicted based on volatile compounds data using PLS-DA models, with a focus on borderline samples between the extra virgin and virgin commercial categories.

This inter-laboratory study showed satisfactory results for such a prediction of the commercial category since most of the samples were correctly classified in the same quality grade with respect to the robust sensory classification.

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ALI-PO-029

Direct Analysis in Real Time: untargeted *vs* targeted approaches for the preservation of high-quality Italian Extra Virgin Olive Oil

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One of the most significant sources of "healthy" fats and bioactive compounds in the Mediterranean diet is extra virgin olive oil (EVOO). Due to its unique nutritional and sensory characteristics and high commercial value, it remains a primary target for fraudulent activities. Within this context, the present study aimed to establish a fast and reliable method to differentiate and valorize top-quality Italian EVOOs, thus preserving the national product against mislabeling practices. A cost-effective and user-friendly approach has been developed using an ambient mass spectrometry (AMS) ion source, specifically Direct Analysis in Real Time (DART) coupled with a compact single quadrupole MS analyzer, to characterize major and minor compounds in EVOOs. An untargeted approach based on the analysis of EVOOs in their native form and a targeted method involving a solid phase microextraction (SPME) of phenolic compounds prior of the analysis, were explored and evaluated in terms of rapidity of the analysis, cost-effectiveness, "greenness profile" and type of delivered information. Moreover, MS spectra were used to create a spectral database and statistical models useful to clusterize and classify EVOOs according to geographical origin and cultivar, as main factors determining their nutritional and sensory profiles. Targeted and untargeted strategies were also compared in terms of sample clusterization into the chemometric space and prediction capability of the statistical models as well as correctness of the real-time and playback identification of "unknown" samples. The targeted method provided the model with the highest correctness score, higher than 90%, despite the high intra-class variability (more than one olive cultivar, in different ratio, can be used for the production of the same PDO EVOO or the same PDO EVOO can come from different close territories) and low inter-class variance (all Italian top-quality EVOOs).

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ALI-PO -030

Metabolomic Profiling of Herbs and Spices by using Ambient Mass Spectrometry Combined with Chemometric approaches: A Powerful Tool for Fraud Detection and Prevention.

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Fraudulent activities in food field are carried out principally for economic purposes and generated to improve perceived quality. In this contest, aromatic herbs and spices represent the most susceptible food matrices to those deceitful and illegal practices. The long and complex supply chain, the increasing in demand and prices make them vulnerable to economically motivated adulteration [5], which define the onset of issues related to the product quality and safety. Moreover, apart from their commercial value, herbs and spices or their extracts (or essential oils), contain functional compounds well-recognized for their biological activities, in particular phytochemicals (phenol compounds, terpenes and alkaloids), recognized for the anti-inflammatory and antioxidants properties. The authenticity and traceability of those samples are commonly evaluated according to ISO standards by using conventional analytical methods, that although provide high reproducibility and sensitivity, are time-consuming approaches in terms of sample preparation and analysis time. In order to deal such drawbacks and introduce more competitive approaches against food fraud, in the last decade fast fingerprinting methods have been employed for the reliable identification of "precious" foodstuffs. Ambient Mass Spectrometry (AMS) has attracted interest for the absent or minimal sample preparation, in line with green chemistry principles, and the capability of *in situ* analysis of samples in their native environment. The present study employed two innovative AMS techniques, REIMS-QTOF and DART-QDa, as fast and reliable methods to be used for preserving the biodiversity and local economies though the rapid screening of the total metabolome of different herbs and spices. The main goal was the obtaining of univocal fingerprinting for the different samples for the identification of discriminant features among the samples. In this regard, the coupling of these methods to chemometrics was essential, as starting point for finding similarities or dissimilarities across different groups of samples, based on the building of classification models capable to discriminate according to the according to the botanical species or varieties. The models were validated (correctness score higher than 90%) and used for the real-time identification of unknown samples, therefore distinguish genuine from adulterated products.

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ALI-PO -031

Accelerated solvent extraction/UHPLC-Q-Orbitrap-MS-based lipidomic workflow for comprehensive study of lipids in X-ray irradiated Camembert from raw cow's milk

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Food irradiation is a clean and safe non-thermal technology used worldwide for different purposes such as improving safety and extending the shelf-life of several foodstuffs, eliminating pathogenic and spoilage microorganisms, parasites, insects and/or viruses[1,2]. This process was regulated by the Community Directives 1999/2/EC and 1999/3/EC, according to which only Camembert can be irradiated, at a dose maximum of 2.5 kGy[3]. In this study, an optimized accelerated solvent extraction (ASE) procedure[4], employing the temperature of 60 °C, three extraction cycles and isopropanol/methyl-*tert*-butyl ether/cyclohexane (20:30:50 v/v/v) as solvent mixture, was applied to X-ray treated and non-treated samples of Camembert cheese produced from raw cow's milk. The recovered lipid fraction was analized by ultrahigh-performance liquid chromatography quadrupole Orbitrap high-resolution mass spectrometry (UHPLC-Q-Orbitrap-MS), to obtain the lipid fingerprints of the samples. Three different irradiation dose levels, namely 1.0, 3.0 and 4.0 kGy were chosen to investigate the variation of lipids in relation to the X-ray irradiation treatment. In particular, 1.0 kGy was within the range of authorized doses, while 3.0 and 4.0 kGy were considered to explore what type of lipid changes may occur when the cheese has been treated at unconventional levels. More than 400 lipids were identified and characterized, hence the collected data were studied using chemometric approaches, in particular principal component analysis and partial least square-discriminant analysis, to discriminate irradiated respect to non-irradiated samples. The results of our proposed ASE/UHPLC-Q-Orbitrap-MS-based lipidomic workflow confirm its effectiveness for deepening knowledge on the effects of X-ray irradiation on foods and for the evaluation of its safety aspects.

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Keywords: food quality, food safety, metabolomic.

References:

[1] J. Farkas, International journal of food microbiology 1998, 44(3), 189 – 204
[2] R. Ravindran, A.K. Jaiswal, Food chemistry 2019, 285, 363 – 368
[3] European Food Safety Authority; Statement summarising the Conclusions and Recommendations from the Opinions on the safety of Irradiation of Food adopted by the BIOHAZ and CEF Panels. EFSA Journal 2011, 9(4), 2107
[4] A. Mentana, R. Zianni, M. Campaniello, M. Tomaiuolo, A. Chiappinelli, M. Iammarino, V. Nardelli, Food Chemistry 2022, 394, 133542

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ALI-PO -032

Protein content, fatty acid profile and antioxidant capacity of plant-based kefir milks

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Kefir is widely known as an excellent source of probiotics with potential health benefits. Existing reports have suggested important bioactivities associated with kefir consumption, such as antimicrobial, anti-inflammatory and antioxidant activities. kefir is produced through a fermentation process using kefir grains as starter culture. They consist of a consortium of yeasts, lactic acid bacteria (LAB), and acetic acid bacteria (AAB) embedded in a branched galactoglucan matrix, named kefiran.[1]

Most of the reported kefir research has been focused on milk substrates from cow, sheep, goats or other type of milk.[2] An alternative way to intake beneficial health effects from kefir is through of its adaptation to non-dairy substrates for the production of new probiotic products to provide vegan, lactose intolerant, and dairy-product allergic consumers.[3] Thus, plant-based milks were used as medium of kefir fermentation.

Almond, coconut, hazelnut, oat, rice, soy, walnut milks were inoculated with 5% (w/v) milk kefir grains for 24 h at room temperature. Changes in protein content and fatty acid profile of the fermented samples were evaluated and compared with the starting milk values.

The fermentation led to an increase of protein content in all samples, except soy one where it was halved and walnut sample for which it remained unchanged. Beneficial fatty acids such as oleic and linoleic acid rose in all samples with the exception of soy and walnut ones. Phenolic content (TPC), determined by the Folin-Ciocalteu method, increased during fermentation in all samples: kefir from walnut milk showed the highest TPC (350.9 ± 3.0 µg GAE/mL) followed by soy sample (337.2 ± 8.4 µg GAE/mL). According to TPC results, antioxidant activity, evaluated by ferric reducing antioxidant power (FRAP) assay, showed improved activity in all probiotic fermented milks being highest in almond and walnut samples (536.0 ± 1.0 µM $FeSO_4$/mL) followed by the kefir from soy milk (207.8 ± 5.5 µM $FeSO_4$/mL).

The adaptation of milk kefir grains into different substrates such as plant-based milks has shown potential for the production of beverages with functional properties.

References:

[1] C. La Torre, A. Fazio, P. Caputo, A. Tursi, P. Formoso, E. Cione, Foods 2022, 11, 1098 – 1116.
[2] M. Baniasadi, M. Azizkhani, P.E.J. Saris, F. Tooryan, Journal of Food Science and Technology 2022, 59, 1307 – 1316.
[3] F.A. Fiorda, G.V. de Melo Pereira, V. Thomaz-Soccol, A.P. Medeiros, S.K. Rakshit, C.R. Soccol, LWT - Food Science and Technology 2016, 68, 690 – 697.

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ALI-PO -033

Enzymatic deglycosylation and lipophilization of soy glycosides into value-added compounds for food and cosmetic applications

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Soybean is one of the most important crops worldwide, being placed 8th on the chart of the most cultivated species.[1] Its high level of production correlates with a huge amount of waste produced. These residues could be of great interest due to the presence of high value-added molecules. Among these compounds, glycosides (e.g., daidzin, genistin and glycitin) have been widely studied for their potent antioxidant properties.[2]

In the present work two parallel approaches have been followed: enzymatic hydrolysis to the corresponding aglycones and CaLB mediated glycoside lipophilization to obtain derivatives with increased bioavailability and/or stability for potential applications in food, nutraceutical and cosmetic sectors. Firstly, *Escherichia coli* strain BL21 (DE3) STAR was utilized to heterologously produce an extremophilic β-glucosidase from *Halothermotrix orenii* (HOR). This was then exploited for the production of aglycones starting from soybean glycosides. Subsequently, lipophilization reactions of daidzin with butanoic, hexanoic and octanoic acids have been carried out with *Candida anctarctica* lipase B under continuous flow conditions. This work contributes to evidence the possibility of using agri-food residues to produce high value-added compounds through eco-friendly biocatalytic methodologies.

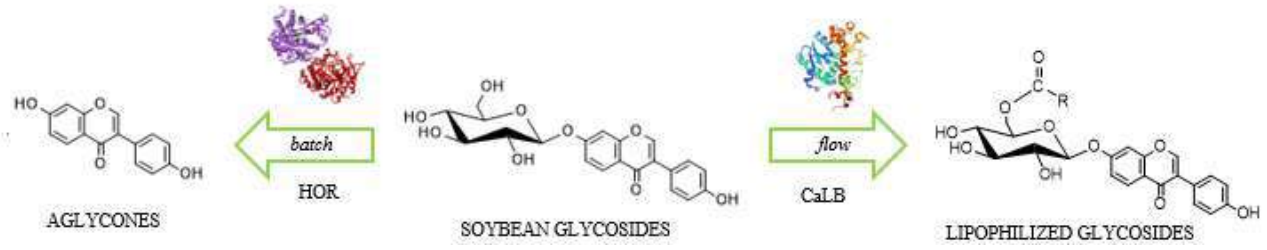

Figure 1: Schematic representation of the work-flow

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References:

[1] https://www.fao.org/faostat/en/#data/QCL/visualize
[2] Z.H. Cao, J.M. Green-Johnson, N.D. Buckley, Q.Y. Lin. Biotechnology Advances 2019, 37, 223– 238.

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ALI-PO-034

Green Datterini tomatoes as a potential nutraceutical in the prevention of aging-related muscle diseases: proof of concept studies in mice

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Sarcopenia is an aging-related muscle disease characterized by the loss of 50% of muscle mass, leading to several adverse effects as frailty and disability. In order to develop a nutraceutical formulation for sarcopenia prevention, our attention was focused on tomatidine, a natural compound able to act simultaneously on the mTORC1 and ATF4 factors, two targets involved in aging-related muscle disease.[1] Tomatidine represents the aglyconic moiety of α-tomatine, a glycoalkaloid identified in green tomatoes (*Solanum Lycopersicum* L.). α-tomatine is converted into tomatidine by an *in vivo* metabolic mechanism.[2] A matrix screening of seven tomato cultivars allowed to identify the green Datterini tomatoes (DT) as the cultivar with the most promising polyphenolic (chlorogenic acid: 1.41 ± 0.01 mg/g dry weight; rutin: 995.57 ± 3.46 µg/g dry weight) and glycoalkaloid content (α-tomatine: 34.70 ± 1.36 mg/g dry weight). Therefore, this cultivar was selected for further investigation through *in vitro* assays and *in vivo* proof of concept study in mice.[3] Tomatidine efficacy on C2C12 muscle cells confirmed tomatidine efficacy in the stimulation of protein synthesis and mitochondrial function. Therefore, an *in vivo* proof of concept study was performed to confirm the efficacy of green DT in sarcopenia prevention in elderly mice. A treadmill test showed the nutraceutical capacity to improve muscle performance in DT treated mice by increasing the time spent and the running distance on the treadmill and by reducing the number of interruptions during the speed. The histological analysis of gastrocnemius tissues showed a remodelling of the muscle profile of DT treated mice, with an increased number of young muscle fibers with high resistance to physical exercise. Moreover, metabolomic analysis confirmed the increment of metabolomic activity and protein synthesis. Therefore, these results suggested the potential use of green DT as a potential food matrix for the development of new nutraceuticals for the prevention of aging-related sarcopenia disease.

References:

[1] Ebert, S.M. et al. Molecular bases of disease, 2020, 295(9), 2787-2803.
[2] Piccolo, V. et al. Foods, 2024, 13(2), 331.
[3] Piccolo, V. et al. Food Chemistry, 2024, 438, 137863.

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Optimized Extraction of Phenolics and Procyanidins from Seven Medicinal Herbs for Nutraceutical Development

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The main objective of the study was the optimization of the procyanidin solid/solvent extraction process, using grape pomace, to ultimately determine the procyanidin profile and bioactivity of seven medicinal herbs to potentially use in nutraceutical products. Procyanidins, oligomeric forms of flavan-3-ols belonging to the flavonoids group, are (poly)phenolic compounds synthesized by plants as secondary metabolites[1]. Parameters influencing the extraction results have been evaluated singularly and the highest procyanidin yields were achieved by the following optimized conditions: extraction solvent 59.5% methanol, 1% formic acid, 10 min sonication, and 10 min shaking. The extraction method was validated by the evaluation of % recovery and % matrix effect. The HPLC-FLD method used for quantification of monomeric to trimeric procyanidins was validated by the ICH guidelines in which the low interday and intraday % bias and % CV values at all standards concentration levels were observed (% CV values not exceeding 20%)[2]. Quantification of 17 polyphenols has been performed by MS working in Multiple Reaction Monitoring (MRM) using a 4000 Qtrap spectrometer. Furthermore, HPLC-HESI-MS/MS analysis performed on the herbal extracts led to the qualitative identification of 27 further polyphenols. To have an insight into the potential bioactivity of the extracts, the *in vitro* antioxidant activity was evaluated by DPPH assay, resulting in 935.23 ± 169.85 µmol Trolox equivalent/g of dry weight in *Peumus boldus Molina* leaves extracts. Moreover, Pearson correlation analysis (PCA) results exhibited higher Pearson coefficient (R^2) and significance (p-value) values between total flavonoid content and DPPH in comparison with the total phenolic content and DPPH, indicating flavonoids as the most relevant active substances of the extracts. Finally, *Paullinia cupana Kunth*. seed extract contained the highest level of procyanidins among all the extracts evaluated and had an antioxidant activity of 693.63 ± 48.04 µmol Trolox equivalent/g of dry weight. In conclusion, the extraction and quantification analysis models proposed are considered valid to produce procyanidin-rich extracts, by which *Paullinia cupana Kunth*. seed (containing over 5000 µg/g of dry matrix of each dimeric and 2829.14 µg/g of dry matrix trimeric procyanidin) was the matrix that would serve better as the source containing a vast range of flavonoid-type antioxidant agents to be used in prospective nutraceutical products. It would also reduce inflammation rates by interfering with oxidative stress signaling and suppressing the pro-inflammatory signaling transductions, effective in the prevention of chronic inflammation and metabolic disorders.

References:

[1] T. de Aquino Gondim, J. A. C. Guedes, E. de Godoy Alves Filho, G. S. da Silva, N. V. dos Santos Nina, F. J. do Nascimento Filho, A.L. Atroch, G.F. Da Silva, G.S. Lopes, and G.J. Zocolo, 2024, *16*(8), 1158-1174.

[2] V. Piccolo, M. Maisto, E. Schiano, F. Iannuzzo, N. Keivani, M.M. Rigano, A. Santini, E. Novellino, G.C. Tenore, V. Summa, 2024, 438, 137863.

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ALI-PO -036

Ulvan from *Ulva lactuca* L.: optimization of enzymatic hydrolysis by ulvan-lyase and characterization of the produced oligosaccharides

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Ulva lactuca L. is a green alga of the Ulvaceae family distributed worldwide, which has gained increased attention due to its high reproductive rate, which leads to the phenomenon known as "green tides", accelerated by water eutrophication. While algae from the Ulvaceae family are used for food and feed purposes, their biomass currently has limited applications. However, the cell wall of these algae is rich in polysaccharides, of which ulvan is the most peculiar and interesting. Ulvan is composed of disaccharides repeating units, constituting in rhamnose-3-sulfate (Rha3S) linked to *D*-glucuronic acid (GlcA), *L*-iduronic acid (IduA) or *D*-xylose (Xyl) by predominantly beta glycosidic bonds. Ulvan oligosaccharides has been associated with anti-cholesterolemic and antioxidant activities, making the production of these compounds a promising opportunity for biomass utilization[1]. Since these bonds are highly resistant to conventional acidic hydrolysis methods, enzymatic hydrolysis is preferred to ensure efficiency and the production of food-grade products. To this end, ulvan lyases (EC 4.2.2), found in marine bacteria, can be used for the catalysis of the endolithic cleavage between Rha3S and uronic acids, by a β-elimination reaction[2].

Aim of the present study was the optimization of the enzymatic hydrolysis of ulvan to obtain a pool of ulvan oligosaccharides to be testet for biological activities. Ulvan were extracted from *U. lactuca* collected in an aquaculture tank of Orbetello lagoon. A recombinant ulvan lyase of PL24 family commercially available was used for the hydrolysis. The enzyme was characterized kinetically and different concentrations of buffer medium (composed of NaCl and Trizma® base both from 0 to 100 nM) were tested to minimize the residual presence of salts in the final products. The activity of the enzyme was measured for 24 h as spectrophotometric absorbance at 235 nm (indication of double bonds formation after β-elimination), ^{1}H-NMR spectra were acquired to monitor the production of oligosaccharides, and Dynamic Light Scattering measurements were applied to evaluate the hydrodynamic volume of the hydrolyzed ulvan in solution.

In summary, ulvan lyase resulted a robust enzyme able to rapidly and extensively hydrolyze ulvan at different composition of the medium. To provide insights into the impact of ulvan on gut health and to promote future uses of *Ulva* biomass, the hydrolyzed ulvan will be tested *in vitro* for its prebiotic activity.

References:

[1] S. Shah et al., International Journal of Biological Macromolecules, 2023, 234, 123669
[2] T. Tang et al., Algal Research, 2021, 60, 102477

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ALI-PO-037

Oxygen Heterocyclic Compounds: Chromatographic Insights and Comparisons

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Due to their pleasing scent, *Citrus* essential oils are widely used in flavouring foods and hydroalcoholic fragrance formulations. These oils contain a non-volatile fraction comprising approximately 10-20% of coumarins, furocoumarins, and polymethoxyflavones. Furocoumarins are known to cause photosensitization and possess potential carcinogenic and mutagenic properties. Therefore, regulatory bodies such as the International Fragrance Association closely monitor the levels of furocoumarins in cosmetic products. Supercritical fluid chromatography (SFC) has emerged as an innovative analytical technique for analyzing these molecules. SFC employs supercritical CO_2 as a mobile phase, offering characteristics between a liquid and a gas, resulting in faster analysis times and reduced solvent consumption compared to conventional liquid chromatography.

This research focuses on developing rapid analytical methods with minimal environmental impact using chromatographic techniques. Two validated methods were developed: the first utilizing SFC coupled with either a photodiode array detector (PDA) or a triple quadrupole mass spectrometry detector (QqQ-MS), enabling fast separation with minimal solvent usage in under 8 minutes; the second employing RP-HPLC-QqQ-MS for quick screening, completing analysis in about 4 minutes with less than 3 mL of ethanol per analysis. These methods aim to provide an environmentally friendly approach for quantifying coumarins, furocoumarins, and polymethoxyflavones in cold-pressed *Citrus* essential oils, flavoured foods and cosmetics. Calibration curves were constructed using distilled lemon essential oils to quantify these compounds in real samples, with satisfactory validation parameters allowing for quantification even at trace levels in finished products. Overall, these methods offer a green analytical approach for analyzing these compounds in *Citrus* essential oils, with the SFC-PDA method being particularly environmentally friendly compared to previously developed liquid chromatography methods. Thus, SFC is well-suited for quality control of these compounds in citrus essential oils and finished products.

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ALI-PO -038

Biocatalytic approaches to enhance exploitation of rice waste

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Rice production generates huge amounts of byproducts. It is estimated that around 80% of these residues are burnt *in situ* or incorporated in soil. These strategies not only fail to exploit the full potential of organic material, but also actively contribute to atmospheric pollution and GHG emissions.[1] Rice straw and husks, the primary components of non-food biomass deriving from rice production, contain a combination of cellulose, hemicellulose, and lignin, along with appreciable amounts of silica and other minor components.[2] Our research activities aim at boosting the valorization of rice waste streams, by developing a biocatalyst covalent immobilization strategy onto silica micro- or nanoparticles, obtained from rice husk with different chemical procedures, and pretreated with 3-aminopropyltriethoxysilane (APTES) and glutaraldehyde. The preliminary results of the immobilization of the lipase B from *Candida antarctica* (CaLB) are promising, as with two different enzymatic loadings (1 mg or 10 mg of enzyme/g of carrier) we obtained up to 100% immobilization yield with a recovered activity ranging from 50 to 100%, depending on the type of silica used as carrier.

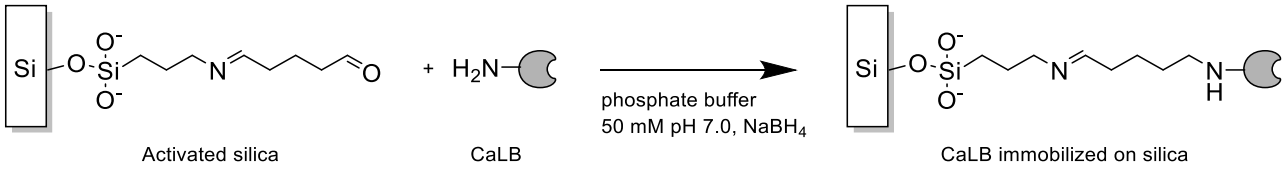

Figure 1: CaLB immobilization on silica pretreated with 3-aminopropyltriethoxysilane (APTES) and glutaraldehyde

The immobilized lipase will be used for the acylation of lignin-based low molecular weight species (LIMO), obtained by a laccase-catalyzed oxidative depolymerization of lignin from rice straw residues, to obtain molecules with enhanced antioxidant activity. These compounds will be ultimately used for the preparation of a bioactive packaging system, whose polymeric skeleton will be constituted by medium chain lignin oligomers containing OH functionalities (MCLO) and commercially available biobased building blocks.

References:

[1] E. Hanafi, H.H. Khadrawy, W. Ahmed, M.M. Zaabal, World Applied Sciences Journal, 2012, 16, 354-361.

[2] B.A. Goodman, Journal of Bioresources and Bioproducts, 2020, 5(3), 143–162.

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ALI-PO -039

Pomegranate peel fermented by *Saccharomyces cerevisiae*: a study on changes in tannin content and polysaccharide structure

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The pomegranate fruit is highly appreciated for its nutritional properties and numerous uses in the food field. After processing pomegranate fruits to produce juice, significant quantities of waste are generated and the peel is the main by-product (approximately 50% of the total weight of the fruit). Peel contains several micronutrients, hydrolysable tannins and appreciable amount of polysaccharides, mainly pectin [1]. As regards the fermentation of the pomegranate fruit, the most widely described processes are those involving the juice through the use of lactic acid bacteria, namely *Saccharomyces c*. to obtain a sort of wine [2]. Among the procedures proposed in the literature, fermentation processes using only the peel of the pomegranate fruit have only been poorly explored and aimed at ethanol production [3]. Since there is a demand for simple and sustainable methods that can favor the obtaining of valuable products from pomegranate peel, the aim of the study was to evaluate the changes induced by fermentation with a common yeast such as *Saccharomices cerevisiae* on the tannins and polysaccharide of the peel (mesocarp and endocarp).

Two varieties (Wonderful and G1) were fermented applying 3 processes: i) fermentation in closed tubes (1N method); ii) fermentation in closed tubes after a blanching of few minutes of the peel at 100°C (2PbN method); iii) fermentation in open-air, with tubes closed only with a cotton cap (3Na method). The experiments were done in triplicate with and without the presence of yeast, to have for each method of fermentation a blank sample (B) characterized by the absence of the yeast (L). All the fermentations were carried out at 25°C adding water to reach a ratio of 1/10 w/v and the same amount of yeast (15 mg/g of dried peel); the samples were collected from 0 to 96 hrs of fermentation. The polysaccharides were recovered after decoction of the whole fermented samples and successive precipitation with ethanol.

HPLC-DAD profiles of tannins in blank samples and yeast samples were very similar or overlapping, within each fermentation method. From a quantitative point of view, the % yields in dry aqueous extracts from fermented samples, calculated on the dried skins, were decidedly higher for the white samples compared to the fermented ones. Interestingly, the concentration of total tannins in the dry extracts obtained from fermentation with *Saccharomices c*. after 48 and 96 hrs was found to be approximately 50% higher than in the corresponding blank samples.

As confirmed by DLS measurements and NMR-DOSY experiments, fermentation reduced the molecular weight of native peel pectin. Since polysaccharides from unfermented peels have previously shown prebiotic activity in vitro [4], an increase in their fermentability is expected as a consequence of the reduced molecular weight obtained after the fermentation processes.

References:

[1] D. Balli et al, *Antioxidants*, 13; 9 (3):238; **2020**; doi: 10.3390/antiox 9030238
[2] M. Gumienna et al, *Eur Food Res Technol*. 242:631–640; **2016**; doi: DOI 10.1007/s00217-015-2582-z
[3] M. Berenguer et al., *Food Chemistry*, 190:848-855, **2016**. doi: 10.1016/j.foodchem.2015.06.027
[4] M. Khatib et al., *Food Chemistry*, (235) 58 – 66; **2017**; doi: 10.1016/j.foodchem.2017.05.041

ALI-PO-040

Determination of pesticide residues in honeydew honeys by QuEChERS extraction followed by Orbitrap LC-MS

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In this study, the occurrence of 73 pesticides residues in Italian honeydew honeys collected between 2022 and 2023 was investigated. Sample preparation was performed by a QuEChERS approach as previously described[1] . Sample analysis was performed by Orbitrap LC-MS. In only 6 of the 56 samples analysed (10.7%), no pesticide residues were found. As regards neonicotinoids, acetamiprid was detected in more than half of the samples with concentration ranging between 0.08 and 11.14 ng/g while imidacloprid was detected in one third of the samples with a content varying between 0.23 and 1.53 ng/g. Other relevant detected analytes include coumaphos (17 samples), 3-hydroxy carbofuran (14 samples), deisopropylatrazine (6 samples), propazine (6 samples) and chlorfenvinphos (5 samples).

References:

[1] P. Catalayud-Vernich, F. Catalayud, E. Simò, Y. Picò, MethodsX 2016, 3, 452-458.

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Medaglie

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CSB-MD-01

The contribution of in-cell NMR to cellular structural biology

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In-cell NMR, i.e. high-resolution NMR spectra of biomolecules in intact, living cells, allow the characterization of conformational and functional properties of biomolecules at atomic resolution in conditions as close as possible to the physiological ones. It also allows to monitor protein-protein interactions and to follow functional processes, as well as protein maturation and post-translational modifications. A further high-impact application is its use for drug screening in real time at cellular level, in human living cells.

A few examples of the striking power of this approach will be presented.

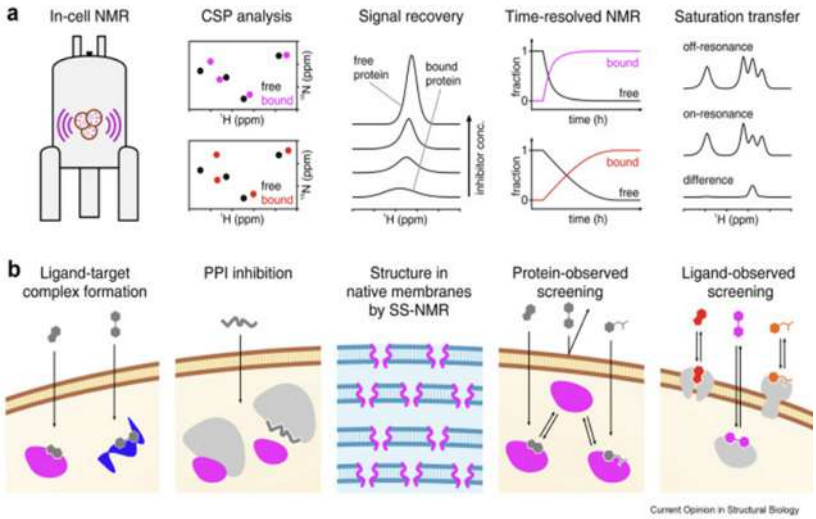

Figure 1: Examples of applications of in-cell NMR.

References:

E. Luchinat, M. Cremonini, L Banci, Chemical Reviews, 2022, 122 (10), 9267 – 9306

E. Luchinat, L. Banci, New structural and functional insights from in-cell NMR. Emerging Topics in Life Sciences, 2018, 2, 29-3

E. Luchinat, L. Barbieri, M. Cremonini, A. Nocentini, C. T. Supuran, L. Banci, Angew. Chem. Int. Ed. 2020, 59, 6535-6539.

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KEYNOTE LECTURES

Carlo Camilloni, Università degli Studi di Milano "Statale"

Giovanna Musco, I.R.C.C.S. Ospedale San Raffaele, Milano

Pasquale Sacco, Università degli Studi di Trieste (KN associata al Premio ItalFarmaco)

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CSB-KN-01

Multi-eGO: molecular modelling of biomolecular self-assembly processes

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Structure-based models have been instrumental in simulating protein folding and suggesting hypotheses about the mechanisms involved. Today, at least for fast folding proteins, folding in explicit solvent can be simulated using classical molecular dynamics. However, other self-assembly processes, such as protein aggregation, are still far from being accessible. With Multi-eGO [1,2], we have introduced a hybrid multistate structure-based model that could bridge the gap to the simulation of out-of-equilibrium, concentration-dependent self-assembly processes. By learning from the dynamics of a few minima of a system simulated by conventional molecular dynamics simulations, Multi-eGO can enable the comprehensive simulation of processes such as protein aggregation, the folding of complex multi-domain proteins, and the binding/unbinding of ligands. In this talk I will present the current state of the model and some recent applications.

References:

[1] F.B. Toplek, E. Scalone, B. Stegani, C. Paissoni, R. Capelli, C. Camilloni, J. Chem. Theory Comput. 2024, 20, 459–468.

[2] E. Scalone, L. Broggini, C. Visentin, D. Erba, F.B. Toplek, K. Peqini, S. Pellegrino, S. Ricagno, C. Paissoni, C. Camilloni, Proc. Natl. Acad. Sci. USA 2022 119, e2203181119.

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CSB-KN-02

The acidic intrinsically disordered region of the inflammatory mediator HMGB1 mediates fuzzy interactions with CXCL12

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Chemokines heterodimer activate or dampen their cognate receptors during inflammation. CXCL12 chemokine forms with the fully reduced (fr) alarmin HMGB1 a relevant heterocomplex (frHMGB1•CXCL12) that synergically promotes the inflammatory response elicited by the G-protein coupled receptor CXCR4. The molecular details of complex formation were still elusive. Here, by an integrated structural approach we show that frHMGB1•CXCL12 is a fuzzy heterocomplex, the first reported for chemokines. Unlike previous assumptions, frHMGB1 and CXCL12 form a dynamic equimolar assembly, with structured and unstructured frHMGB1 regions recognizing the CXCL12 dimerization surface. We uncover an unexpected role of the acidic intrinsically disordered region (IDR) of HMGB1 in heterocomplex formation and its binding to CXCR4 on the cell surface. Our work shows that the interaction of frHMGB1 with CXCL12 diverges from the classical rigid heterophilic chemokines dimerization. Simultaneous interference with multiple interactions within frHMGB1•CXCL12 might offer novel pharmacological strategies against inflammatory conditions[1].

References:

[1] MV Mantonico et al, G. Musco, Nature Communications 2024, 15, article number 1201.

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Advanced extracellular matrix mimics with controlled mechanics for the study of cell mechanosensing

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Natural tissues and extracellular matrices (ECMs) are not purely elastic biomaterials but exhibit dissipative (viscoelastic) properties. Although it has recently emerged as a novel regulator of cellular responses, the contribution of material dissipation to controlling cell fate decisions is still in its infancy. In this talk, I will present an unprecedented strategy to tune the dissipation rate of viscoelastic substrates suitable for 2D cell culture while precisely regulating linear elasticity. In particular, I will present recent findings on viscoelastic hydrogels with varying degrees of linear elasticity that can modulate cellular functions.[1-4] By introducing specific sugar sequences or weak physical entanglements that act as stress dampers, a novel approach to precisely extend the linear stress-strain range is described. Our results show a crucial link between this material property and cell response in 2D cultures. They influence the type and speed of cell migration, the geometry and size of vinculin-dependent focal adhesion, F-actin organization, force transmission and YAP nuclear translocation. I will show that cells require a common actomyosin contractility and microtubule tension to probe the substrate and decide whether to adhere or not. This reveals a clear correlation between force transmission, biomaterial dissipation rate and number of anchoring points. Overall, these results introduce linear elasticity as a new design parameter for the construction of tunable dissipative biomaterials to study the mechanosensing of cells in 2D and possibly also in 3D cultures.

References:

[1] P. Sacco *et al.* Advanced Functional Materials, 2020; 30(31), 2001997
[2] P. Sacco *et al.* Advanced Functional Materials, 2022; 32(29), 2200309
[3] F. Piazza *et al.* Advanced Healthcare Materials, 2023; 12(26), 2300973
[4] F. Piazza *et al.* Advanced Functional Materials, 2023; 33(52), 2307224

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CSB-OR-001

Is proteins structural stability challenged by lipid peroxidation?

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Lipid oxidation can arise in vivo during oxidative stress and redox imbalance situations. This process involves the generation of reactive oxygen species (ROS) within the cells, which can readily attack unsaturated fatty acids in membranes through non-enzymatic mechanisms, triggering a chain reaction that generates various oxygenated small molecules. These molecules often contain reactive electrophilic carbonyl groups, including α,β-unsaturated aldehydes, which can interact with nucleophilic moieties on protein surfaces, inducing misfolding and aggregation.[1]

Lipid peroxidation significantly affects membrane organization and can modify proteins and DNA, leading to functional alterations. Consequently, it was suggested to be implicated in aging and the pathogenesis of various diseases, including atherosclerosis, neurodegenerative disorders, autoimmune diseases, and type 2 diabetes.[2]

To investigate the effects of lipid peroxidation on the conformational stability of model proteins, bovine serum albumin (BSA), hen egg white lysozyme (HEWL), ubiquitin and rabbit IgG were solubilised in phosphate buffer and studied alone or in the presence of DMPG-DOPC (at 1:1 molar ratio) small unilamellar vesicles (SUVs) at either 20° or 40°C.

Oxidative conditions were performed by collecting 30 consecutive repeated synchrotron radiation circular dichroism (SRCD) spectra at beamline B23 of the Diamond Light Source synchrotron. We have previously demonstrated that the high photon flux and brilliance of the synchrotron radiation induces water photolysis and production of ROS that can denature protein/peptide folding and is used to quantify the UV photostability of proteins/peptides with and without ligands and a as a function of environment.[3]

For HEWL in phosphate buffer (PB) and SUV at 20 °C and 40 °C, respectively, the normalised spectral changes at 192 nm reported against the number of scans revealed that the ROS damage and the effects of lipoxidation of protein was less pronounced in SUVs than in PB at higher temperature suggesting a protective property of SUVs against ROS damage on protein.

References:

[1] Á. Viedma-Poyatos et al., Antioxidants 2021, 10, 295.
[2] F. Ito et al., Antioxidants 2019, 8, 72.
[3] P. Ruzza et al, International Journal of Molecular Sciences 2021, 22(12), 6512

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CSB-OR-002

DEVELOPING NEW TOLL-LIKE RECEPTOR 4 (TLR4) MODULATORS AS INNOVATIVE AND INEXPENSIVE VACCINE ADJUVANTS

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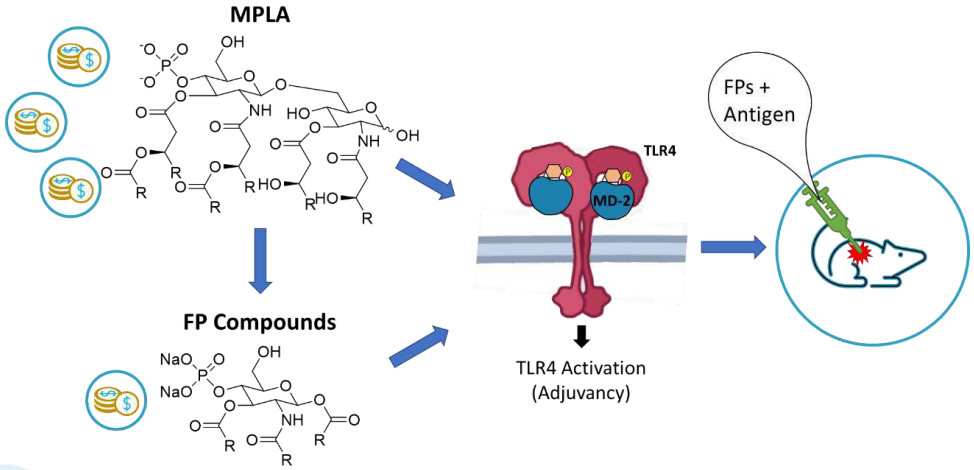
Vaccines have been a breakthrough in medicine: they saved millions, reduced the incidence and morbidity of diseases such as polio, measles and tetanus and caused smallpox eradication. [1]
Modern subunit-based and nucleic acid-based vaccines are safer and easier to produce than inactivated pathogen-based ones, but require vaccine adjuvants to achieve a proper immunization.[2]

A vaccine adjuvant is any entity that enhances a vaccine efficacy. For more than 70 years Alum® has been the only adjuvant licensed for human use: only recently few new adjuvants have been approved.[3] The most prominent example is Monophosphoryl lipid A (MPLA), an agonist of Toll-like receptor 4 (TLR4). MPLA is commercialized by Croda International PLC and is employed in several vaccine formulation vaccines (Fendrix®; Cervarix®; Shingrix®; Mosquirix®; and Pollinex-Quattro).[3] However, MPLA is a complex molecule with a long synthesis (>25 reactions), resulting in high final cost (~230 USD/mg).[4]

We present here a series of simplified, rationally designed MPLA analogues called FP compounds. FPs show a similar or better TLR4 agonists activity than MPLA, thus being promising vaccine adjuvant. As FPs are much easier to synthesize, they are currently being preclinically developed in collaboration with Croda International PLC as innovative and inexpensive vaccine adjuvants.[5–7]



References:
[1]Kayser, V.; Ramzan, I. Hum. Vaccines Immunother. 2021, 17 (12), 5255–5268.
[2]Vetter, V.; Denizer, G.; Friedland, L. R.; Krishnan, J.; Shapiro, M. Ann. Med. 2018, 50 (2), 110–120.
[3] O'Hagan, D. T.; Lodaya, R. N.; Lofano, G. Semin. Immunol. 2020, 50, 101426.
[4] Shaw, W. A.; Burgess, S. W.; et al. Disaccharide Synthetic Lipid Compounds and Uses Thereof, 2016.
[5] Facchini, F. A.; Minotti, A.; et al. J. Med. Chem. 2021, 64, 12261–12272.
[6] Romerio, A.; Gotri, N.; Franco, A. R.; et al.. J. Med. Chem. 2023, 66 (4), 3010–3029.
[7] Romerio, A.; et al. ACS Omega 2023, 8 (39), 36412–36417.

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CSB-OR-003

Monovalent metal ions promote pre-mRNA splicing

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Nucleic acid processing enzymes, composed of both protein and RNA molecules, rely on a two-metal (M^{2+})-ion motif to enact phosphodiester bond breakage and formation. However, structure comparisons revealed that many of them contain highly spatially conserved second-shell monovalent cations, whose precise function remains elusive. A recent cryo-EM structure showed that the spliceosome, a massive ribonucleoprotein complex responsible for excising intron regions from pre-mRNA, also contains an additional K^+ ion in the catalytic site. To decipher its role, we employed hybrid quantum-classical molecular dynamics (QM/MM MD) simulations. We discovered that the K^+ ion promotes the branching reaction by rigidifying the active site and stabilizing the substrate in pre- and post-catalytic state via formation of key hydrogen bonds. This results in the reduction of both the reaction free energy and activation barrier. Our findings highlight the so far overlooked role of monovalent metal ions in RNA processing and provide a mechanistic hypothesis that may be broadly shared by other RNA/DNA-processing engines.

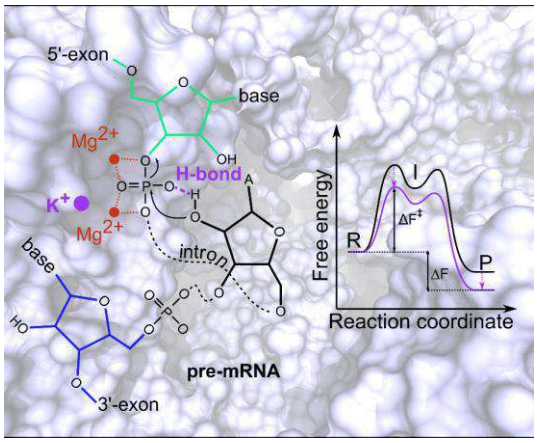

Figure 1: Potassium ion enhances the efficiency of the branching reaction by rigidifying the spliceosome active site, thus facilitating optimal positioning of the attacking hydroxyl group of the branch point adenosine.

References:

[1] J. Aupič, J. Borišek, S. M. Fica, W. P. Galej, A. Magistrato, Nature Communications 2023 14.1 (2023), 1-10

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Integrated metabolomics and proteomics of symptomatic and early pre-symptomatic states of colitis

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Colitis has a multifactorial pathogenesis with a strong cross-talk among microbiota, hypoxia and tissue metabolism. We aimed to characterize the molecular signature of the disease in symptomatic and pre-symptomatic stages of the inflammatory process at the tissue and fecal level. The study is based on two different murine models for colitis; High-Resolution Magic Angle Spinning (HR-MAS) NMR on cryopreserved "intact" colon tissues and LC-MS/MS on colon tissue extracts were used to derive untargeted metabolomics[1] and proteomics information, respectively. Solution NMR was used to derive metabolomic profiles of fecal extracts. By combining metabolomic and proteomic analyses of the tissues, we found increased anaerobic glycolysis, accompanied by altered citric acid cycle and oxidative phosphorylation in inflamed colons; these changes associate with inflammation-induced hypoxia taking place in colon tissues[2]. Different colitis states are also characterized by significantly different metabolomic profiles of fecal extracts, attributable to both the dysbiosis characteristic of colitis, as well as the dysregulated tissue metabolism. Strong and distinctive tissue and fecal metabolomic signatures can be detected before onset of symptoms[2]. Therefore, untargeted metabolomics of tissues and fecal extracts provides a comprehensive picture of the changes accompanying the disease onset already at pre-clinical stages, highlighting the diagnostic potential of global metabolomics for inflammatory diseases.

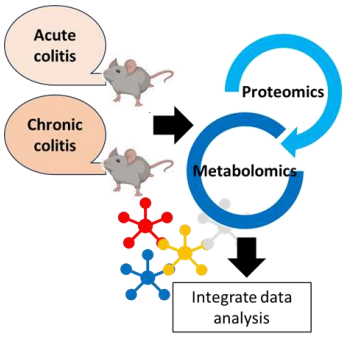

Figure 1: Experimental scheme.

References:

[1] V. Ghini, G. Meoni, A. Vignoli, L. Tenori, P. Turano, C. Luchinat, Progress in Nuclear Magnetic Resonance Spectroscopy 2023, 138-139, 105-135.
[2] E. Shimshoni, I. Solomonov, I. Sagi, V. Ghini, Journal of Proteome Research 2024, Epub ahead of print.

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Potential relationship between secondary structure and biological functionality of Micro-RNAs

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It has been recently discovered that mature miRNAs, a class of highly conserved, short (18-24 nucleotides) and non-coding RNAs [1], could form highly ordered structures similar to aptamers and their structural versatility may determine a variety of functions other than the well-known mechanism of mRNA recognition and degradation [2].Therefore, in addition to sequence even the structure adopted by miRNAs might play an important role to reach the target. However, the biological role of these conformations is still unknown. As a result, identifying the various structures of miRNAs using functional probes capable of interfering with processes governing the biological functions might lead to a better understanding of the mechanisms behind some diseases and the development of new therapies. Indeed in our previous paper we have reported that two endogenous miRNA sequences (miR-15a and miR-15b), having different biological activity (pathogenesis of chronic lymphocytic leukemia and progression of metastasis respectively),[3] can arrange in distinct secondary structures suggesting potential relationship between secondary structure and biological functionality. Then we decide to characterize another fascinating sequence, miR-337-3p, involved in tumor progression and cognitive processes. The miR-337-3p differs only for two basis located in the external portion of the seed region in human and in bat. We think that these differences induce different arrangements of the sequences, which might justify the distinct biological targets.

Finally, in order to investigate if porphyrins can be used as chiroptical probes and/or modulate the stability of miRNA secondary structures, we studied the interactions between another endogenous miRNA, miR-26b-5p, and two porphyrins, having different functional groups and their metallo derivatives.[4] To characterize porphyrin/miRNA interactions, we have used several spectroscopic techniques, namely, absorption, fluorescence, resonance light scattering (RLS), circular dichroism (CD) and CD-melting.

References:

[1] H. Dong, J. Lei, L. Ding, Y. Wen, H. Ju, and X. Zhang. Chem Rev 2013, 113(8), 6207.
[2] a) Janas, M.M.; Wang, B.; Harris, A.S.; Aguiar, M.; Shaffer, J.M.; Subrahmanyam, Y.V.B.K.; Behlke, M.A.; Wucherpfennig, K.W.; Gygi, S.P.; Gagnon, E.; et al. Rna 2012, 18, 2041–2055; b) Belter, A.; Gudanis, D.; Rolle, K.; Piwecka, M.; Gdaniec, Z.; Naskre¸t-Barciszewska, M.Z.; Barciszewski, J. PLoS ONE 2014, 9, e113848/1–e113848/23; c) Gangemi, C.M.A.; Alaimo, S.; Pulvirenti, A.; García-Viñuales, S.; Milardi, D.; Falanga, A.P.; Fragalà, M.E.; Oliviero, G.; Piccialli, G.; Borbone, N.; et al. Scientific Reports 2020, 10, 1–11.
[3] C.M. Croce, Curr. Top Microbiol. Immunol. 2017, 407, 191–203.
[4] G. Travagliante, M. Gaeta, C.M.A. Gangemi, S. Alaimo, A. Ferro, R. Purrello, A. D'Urso Nanoscale 2024, 16, 5137-5148.

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Combined chemical tools to tackle a challenging mitochondrial target with therapeutic relevance: synergic use of NMR, SAXS and MS unveils the structural properties of the protein OSCP

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Proteins structural characterisation at the atomic level is a key purpose for all chemists working at the interface of chemistry of biological systems and medicinal chemistry. X-ray diffraction, cryo-EM and NMR spectroscopy represent the three most powerful techniques to analyse protein structure, but each of them has specific requirements: the first one needs protein crystallisation, the second one provides high resolution structure only for very large proteins (e.g. MW > 50-60kDa) and the last one works well for small proteins in solution (e.g. MW < 40-30kDa). But what if a protein that cannot crystallise and whose molecular weight is large for NMR spectroscopy and tiny for Cryo-EM must be characterised? This is the case of the ATP synthase subunit OSCP (Oligomycin Sensitivity Conferral Protein), a protein we found to be a dimer of 40kDa in solution, highly dynamics and not suitable for crystallization. OSCP represents an emerging therapeutic target for its connection with the Permeability Transition Pore (PTP), a mitochondrial channel whose dysregulated activity is related to ageing and several human diseases such as Alzheimer's and cancer[1]. Importantly, OSCP subunit is indicated as the molecular site for the regulation of the pore[2]. Targeting OSCP to achieve drug-based control of the PTP opening represents an interesting therapeutic perspective. In this context, a strong limit is the characterization of the isolated OSCP in solution: in fact, this protein, as well as its C-terminal domain (OSCP-CT)[3], is described to be aggregated when disconnected from the rest of the ATP synthase.

Here, we present the first structural characterisation of human OSCP, by the synergic use of NMR, Small Angle X-ray Scattering (SAXS), and native mass spectrometry (MS). Unlike that reported in literature, we obtained the recombinant C-terminal domain and the full protein through pET SUMO expression strategy. We found that both protein constructs do not aggregate but are involved in an unexpected oligomerization equilibrium in which the monomeric state is poorly populated. We therefore designed and synthetized a peptide for stabilizing the monomeric OSCP-CT as well as the full protein. Our results make OSCP suitable for future drug discovery processes, in the field of PTP related diseases. We also show a strategy to characterise the structural features of a protein when it is a challenging candidate for being studied from X-ray diffraction, cryo-EM, or NMR alone.

References:

[1] P. Bernardi, F. Di Lisa, F. Fogolari, and G. Lippe, 2015, 116, 1850 – 1862
[2] V. Giorgio, F. Fogolari, G. Lippe, and P. Bernardi, 2019, 176, 4247 – 4257
[3] R. J. Carbajo, F. A. Kellas, M. J. Runswick, M. G. Montgomery, J. E. Walker and D. Neuhaus, 2005, 351, 824 – 838

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CSB-OR-007

Targeting METTL3-14 degradation via "hijacking" of the ubiquitin-proteasome system by medicinal chemistry design and synthesis of a promising library of PROTACs[1]

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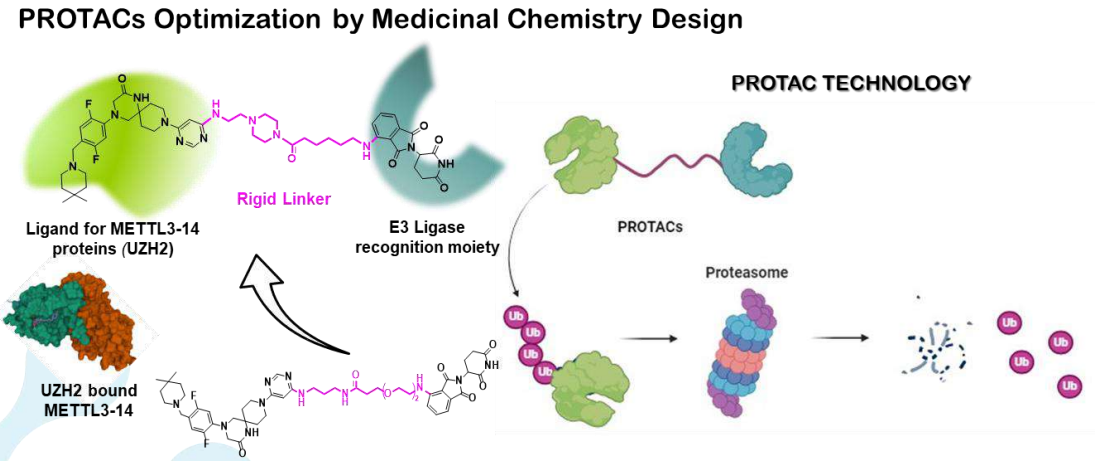
Recent studies of the ''epitranscriptome'' reveal important roles of different RNA modifications in cancer.[2] Methylation of adenine N6 (m6A) is the most frequent RNA modification, and it has been first associated with tumorigenesis in Acute Myeloid Leukemia (AML) and with other types of blood cancers and solid tumors. On mRNA, it is catalyzed by the core writer complex formed by two methyltransferase-like proteins, METTL3 and METTL14. Here, we disclose the first PROteolysis TArgeting Chimeras (PROTACs) for an epitranscriptomics protein harnessing the ubiquitin–proteasome system to degrade a target protein. Based on the crystal structure of the METTL3−14 complex with a potent and selective small-molecule inhibitor (UZH2), here, we report the design, synthesis, and biological evaluation of new PROTACs.[3] To modulate the physicochemical properties of resulting PROTACs, a variety of linkers and functional groups has been investigated featuring PEG- or alkyl-based linkers of different lengths and rigidity. The formation of the ternary complex was validated by a FRET-based biochemical assay and an in vitro ubiquitination assay. The PROTACs that promote a more significant degradation of METTL3-METTL14 measured by Western blot in MOLM-13 cells are characterized by a rigid "handle" and a longer linker.



References:

[1] These studies were supported by the AIPRAS Onlus (IT, http://www.aipras.org/). [2] Kumar, S.; Mohapatra, T. Cell Dev. Biol. 2021, 9, 628415. [3] Errani, F.; Invernizzi, A; Herok, M.; Bochenkova, E.; Stamm, F.; Corbeski, I.; Romanucci,V. Di Fabio, G.; Zálešák, F.; Caflisch, F. JACS Au 2024, 4, 713−729.

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CSB-OR-008

Exploiting the Bile Acid Binding Protein as Transporter of a Cholic Acid/Mirin Bioconjugate for Liver Cancer Therapy

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In the last decade, the bioconjugation of small molecules to biocompatible carriers has emerged as an efficient approach for targeted drug delivery, controlled release, and distribution in cancer therapy. Amongst the biomolecules exploitable as carriers, bile acids (BAs) have been intensively explored, due to their peculiar physicochemical properties and biocompatibility.[1] The cellular trafficking of BAs is regulated by intracellular Lipid-Binding Proteins (iLBPs). Notably, chicken liver Bile Acid-Binding Proteins (cL-BABPs), a sub-family of iLBPs, provide a valuable model to investigate the transport of bioactive molecules within the liver, due to the higher similarity with the human counterpart.[2] A recent strategy to treat cancer has focused on the development of molecules capable of interfering with the DNA repair mechanism, mainly the MRN complex. Inhibitors of the activity of this complex, such as Mirin, have shown potential in sensitizing cancer cells to chemotherapy and radiotherapy, although their clinical utility is limited by selectivity and pharmacokinetic issues.[3] This underlines the need for efficient bioconjugation strategies to renew its therapeutic potential. In this investigation, a multidisciplinary approach has allowed us to develop and characterize, both structurally and biologically, a novel cholic acid (CA)-Mirin conjugate (CA-M11), as a potential adjuvant in liver cancer treatment. We conducted *in-silico* analysis on various BAs and identified CA as the optimal candidate for developing the bioconjugate. The results have been confirmed through X-ray crystallography. Following the analysis of CA, we performed similar *in-silico* assessments on CA-M11, specifically designed and synthesized. By examining the crystal structure of the complex, we confirmed the successful accommodation of CA-M11 in the ligand-binding pocket of cL-BABP, providing robust evidence of its transportability by the protein. Subsequently, CA-M11 was extensively studied to characterize the first ADME properties and its possible antitumor activity on Hep G2 cells, used as an *in vitro* model of liver cancer. These promising preliminary findings demonstrate the potential of our strategy to develop novel conjugates as adjuvant treatments for liver cancer. In addition, being the cytotoxic agent and an MRN inhibitor, this also represents a valid opportunity to find renewed applications for such agents in cancer therapy.

References:

[1] F. Li, R. I. Mahato, Mol Pharm 2017, 14, 1321–1324.
[2] G. Tassone, M. Orlandini, M. Olivucci, C. Pozzi, Biomolecules, 2021, 11, 645–661.
[3] A. Dupré, Nat Chem Biol, 2008, 4, 119–125.

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Role of A111/114R in the biosynthesis of giant virus PBCV-1 N-glycan assembly

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Giant dsDNA viruses are gaining interest in the field of Glycobiology because, and differently from other viruses, they can glycosylate their own proteins by a host independent process. Giant dsDNA viruses include different species, and this contribute will focus on the prototype chlorovirus, PBCV-1,[1] whose capsid protein, Vp54, is glycosylated by an unusual and complex oligosaccharide (Figure 1).[2] This glycan is N-linked and the substituted asparagine residues always occur in non-canonical protein sequences, NIPG, NTAT, NTET and NTGT. The main glycoform is a nonasaccharide with a fucose unit fully substituted at all available positions instead of being terminal as typically occurs in most N-linked glycans. The Vp54 N-glycan contains both D- and L-Rha residues, a feature that is rare and only found in bacteria. Interestingly, the comparative study of the N-glycan of PBCV-1 with those of other chloroviruses has evidenced that all share a common oligosaccharide core made of four sugar units, which comprehends the glucose unit linked to the capsid protein, its two substituents (xylose and fucose), and the galactose unit linked on the fucose (Figure 1).[3] To date, several spontaneous mutants of PBCV-1 are available and the study of their glycans has enabled the structure-to-function assignment of the mutated genes.[4] This contribute will focus on the activity of the protein encoded by PBCV-1 gene *a111/114r* involved in the biosynthesis of the conserved core region, as determined by a combination of bioinformatics and preliminary biochemical studies.

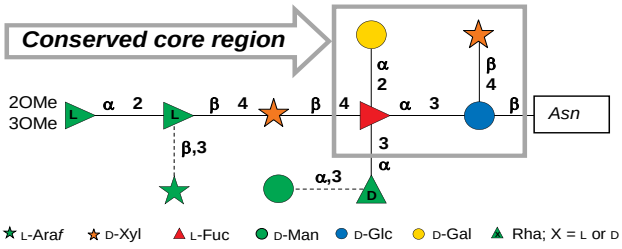

Figure 1: Structure of the Vp54 N-glycan.

References:

[1] De Castro, C.; Molinaro, A.; Piacente, F.; Gurnon, J.R.; Sturiale, L.; Palmigiano, A.; Lanzetta, R.; Parrilli, M.; Garozzo, D.; Tonetti, M.; Van Etten, J.L. PNAS. 2013, 110, 13956.

[2] De Castro C.; Speciale I.; Duncan G.; Dunigan D.D.; Agarkova I.; Lanzetta R.; Sturiale L.; Palmigiano A.; Garozzo D.; Molinaro A.; Tonetti M.; Van Etten J.L. Angew. Chem. Int. Ed. 2016, 55, 654.

[3] Speciale, I.; Duncan, G. A.; Unione, L.; Agarkova, I. V.; Garozzo, D.; Jimenez-Barbero, J.; Lin, S.; Lowary, T. L.; Molinaro, A.; Noel, E.; Laugieri, M. E.; Tonetti, M. G.; Van Etten, J. L.; De Castro, C. J. Biol. Chem. 2019, 294, 5688-5699.

[4] Noel, E.; Notaro, A.; Speciale, I.; Duncan, G. A.; De Castro, C.; Van Etten, JL. Viruses, 2021, 13, 87.

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Otub1 deubiquitinase as a possible target to regulate tau fibrils formation: insights into functional interactions

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The accumulation of aggregates and fibrils of tau protein is a pathological hallmark of many neurological diseases such as Alzheimer's disease. Tau filaments are subjected to a large variety of post-translational modification which reflect disease progression[1].

Ubiquitination is involved in many cellular functions and requires the action of a series of enzymes for the covalent attachment of one or multiple ubiquitin molecules to substrates to regulate the cell signaling under physiological conditions. Many evidences suggest that ubiquitination may also be a key player in the transition of tau towards toxic species[2]. Therefore, the tau-ubiquitin pathway has been proposed as a target for the development of novel treatments to alleviate tau pathology.

In this context, the elucidation of the structural determinants for specific protein-protein interactions at the basis of ubiquitin signaling is crucial. We employed site-resolved solution NMR spectroscopy to characterize the interaction of tau with the deubiquitinating enzyme Otub1, which has been proposed to be involved in the formation of pathological Tau forms[3]. Using enzymatic reaction, we produced samples of ubiquitinated tau with segmentally isotope-labeled units and exploited chemical shift perturbation to map protein-protein interfaces, gaining significant insights into the molecular recognition of tau with Otub1, a regulator of tau ubiquitination.

References:

[1] Wesseling H, et al. Cell. 183, 1699-1713 (2020)
[2] Munari F, et al. Angew Chem Int Ed Engl. 59, 6607-6611 (2020)
[3] Wang P, et al. Acta Neuropathol. 133, 731-749 (2017)

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Phosphorylation-independent binding of Arrestin 3 to beta2-adrenergic receptor driven by a small molecule

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Termination of G protein-coupled receptor (GPCR) signaling is driven by arrestin (Arr), which acquires a binding competent, active state by interacting with the phosphorylated activated receptor through its phosphate and activation sensors[1]. Despite having a well-conserved structural fold and high sequence similarity, the four Arr subtypes display remarkable differences in their preferences towards the phosphorylation state of the receptor. Cytoplasmic unbound Arr3 is flexible and can sample pre-activated states, which are described by structural parameters at the N-C domain interface, and the inter-domain rotation angle[2]. In this work, we aim at stabilizing those pre-activated conformations by means of small molecules targeting activation hotspots at the N-/C-domain interface. Towards this end, we i) performed molecular dynamics simulations to sample pre-activated conformational states of Arr3, ii) performed virtual screening on multiple structures by targeting the selected pockets emerging from dynamics, and iii) computationally examined the impact of ligands on Arr3-ligand complexes. The successful ligands, computationally predicted to bind Arr3 and stabilize the domain rotation angle required for activation, were tested for their effect in driving recruitment of Arr3 to phosphorylation-deficient beta2-adrenergic receptor (beta$_2$AR) in N2a and H9C2 cells. One small molecule showed activity in increasing the interaction between phosphorylation-deficient beta$_2$AR and Arr3 *in vitro* studies performed by FRET and functional cAMP assay. A nanoBIT assay confirms the activity on unphosphorylated, WT beta$_2$AR, and shows that the molecule is not active on WT muscarinic M2R. This study opens new avenues for the development of small molecule tools that target GPCR signaling termination independent of receptor phosphorylation and support the discovery of therapeutics to selectively modulate phosphorylation-deficient receptors.

References:

[1] L.M. Luttrell, R.J. Lefkowitz, J.Cell.Sci. 2002, 115, 455 – 465.
[2] O. Sensoy, I. Moreira, G. Morra, ACS Chem Neurosci 2016, 7, 1212–1224.

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Exploring mesothelin-Fn3 interaction by computational modeling and epitope mapping

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Mesothelin (MSLN) is 40 kDa surface glycoprotein overexpressed in many solid tumors. In addition, MSLN is known to interact with CA125/MUC16, promoting cancer progression and metastasis. For these reasons, MSLN has been studied as a target for therapeutic and diagnostic purposes. In the last decades, multiple antibody-based strategies were developed to target MSLN, but their therapeutic efficacy remains limited, potentially due to antibodies' large size (~140 kDa). To overcome this limitation, we engineered a small peptide derived from the tenth type III domain of human fibronectin (Fn3, 12.8 kDa, Figure 1A) to bind MSLN with high affinity in ovarian cancer and mesothelioma cell lines ($K_D = 12 \pm 4$ nM). The engineered Fn3 variants were observed to internalize into MSLN-expressing cancer cells and induce apoptosis[1,2]. Here, we explored the Fn3-MSLN interaction site through computational modeling and experimental validation.

Fn3-MSLN binding was predicted by a consensus strategy using three protein-protein docking algorithms (HDOCK, pydock, and ClusPro). A homology model of Fn3 and the published MSLN structure (pdb ID 8CX3) were used[3]. In addition, MD simulations were carried out using GROMACS 2021.2 software package and the Amber ff99SB-ILDN force field. To validate the models, full-length MSLN, combinations or single MSLN domains (named A, B, C, and D as in Zhan *et al.*, 2023)[3] were expressed on the yeast surface. Cells were treated with fluorescently labelled Fn3 and binding was analysed through flow cytometry (Figure 1B).

The three docking algorithms predicted a similar binding of Fn3 to MSLN: the binding site includes domain A, B, and partially C. The models showed that the Fn3 loops are interacting with MSLN and that Fn3 residues mostly contributing to the binding are in Fn3 BC and DE loops (Figure 1C). Overall, domain-level epitope mapping confirmed the docking prediction. In addition, experimental validation revealed that MSLN domain B predominantly binds to MSLN. Interestingly, the Fn3 binds a minimal domain on MSLN that interacts with CA125/MUC16, highlighting that Fn3 potentially competes with MUC16, possibly affecting MSLN-positive cancer development. Further experiments are necessary to validate the Fn3/MSLN interacting residues and to explore Fn3/MUC16 competition.

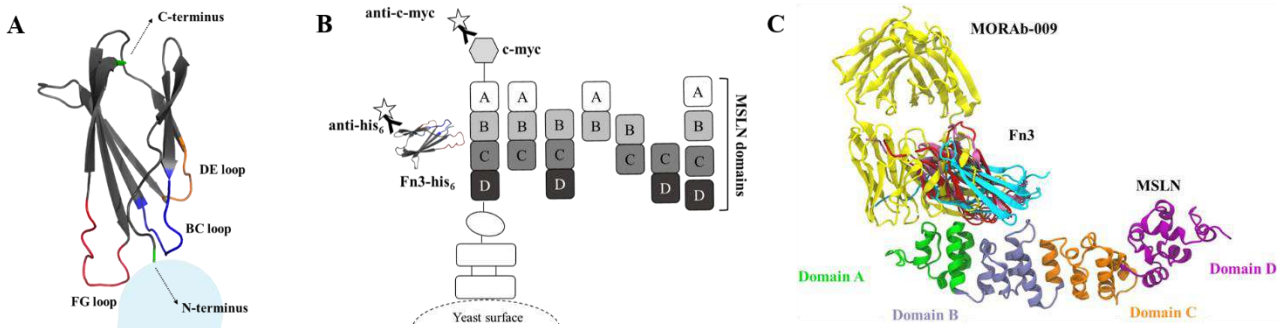

Figure 1: (A) Fn3 structure consists of a hydrophobic core (grey), C-terminus bound to a His_6-tag (green), variable regions or loops (blue, orange, red); (B) MSLN expressed on yeast surface. MSLN domains expression was evaluated through c-myc epitope labelling. Fn3-MSLN binding was analysed using an anti-His_6-tag antibody; (C) Superposition of the top ranking models (pink, red, and cyan ribbons). These models were superposed with the X-ray structure of the complex between MSLN and Fab of MORAb-009 (yellow ribbons, pdb ID 7UED)[3].

References:

[1] A.R. Sirois, D.A. Deny, S.R. Baierl, K.S. George, S.J. Moore. PLoS One 2018 May 8;13(5):e0197029

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Proteins as biomolecular carriers of photosensitizing agents for application in nanomedicine

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Photodynamic therapy (PDT) and photothermal therapy (PTT) are innovative approaches to treating various medical conditions, such as cancer or infections. Both therapies utilize harmless VIS-NIR light to activate a photosensitizing agent (PS) and achieve therapeutic effects, but they differ in their mechanisms of action. PDT is based on the local generation of reactive oxygen species (ROS) while PTT induces localized hyperthermia.

Photosensitizers may either be a single molecule species or a nanomaterial. Due to their hydrophobicity, most photosensitizers lack solubility and biocompatibility in the physiological environment, hampering the full exploitation of their potential in nanomedicine.

To address this issue, protein-based theranostics nanoplatforms were recently proposed for transporting hydrophobic photosensitizers. Due to their biocompatibility, physiological stability, structural diversity, and abundance from natural sources, proteins meet the strict requirements for biomedical usage.1

Human serum albumin (HSA) is the natural carrier of many hydrophobic endogenous and exogenous compounds. We demonstrated the possibility of using albumins and other proteins as versatile carriers for photosensitizers, both via covalent conjugation and supramolecular interactions, for PDT (i.e., Chlorin e6, Temoporfin, fullerenes)2-5 and PTT (gold nanoparticles, carbon nanotubes) applications. We also developed alternative protein-based formulations, synthesizing protein nanoparticles. Spectroscopic and thermometric analysis showed that the photophysical properties of PSs were preserved upon protein binding. In addition, the functionality of the proteins can be improved with the bioconjugation of imaging tags and targeting agents.

The PSs-protein hybrids were tested in vitro and in vivo, evaluating their performances in cancer, antimicrobial, and regenerative medicine applications.

References:

[1] M. Di Giosia, F. Zerbetto, M. Calvaresi, Accounts Mater. Res. 2021, 2, 594–605.
[2] A. Marconi, E.J. Mattioli, F. Ingargiola, G. Giugliano, T.D. Marforio, L. Prodi, M. Di Giosia, M. Calvaresi, Molecules 2023, 28, 2348
[3] M. Di Giosia, P. H. H. Bomans, A. Bottoni, A. Cantelli, G. Falini, P. Franchi, G. Guarracino, H. Friedrich, M. Lucarini, F. Paolucci, S. Rapino, N. A. J. M. Sommerdijk, A. Soldà, F. Valle, F. Zerbetto, M. Calvaresi, Nanoscale 2018, 10 (21), 9908–9916.
[4] M. Di Giosia, A. Soldà, M. Seeger, A. Cantelli, F. Arnesano, M. I. Nardella, V. Mangini, F. Valle, M. Montalti, F. Zerbetto, S. Rapino, M. Calvaresi, V. A. Ntziachristos, Adv. Funct. Mater. 2021, 31, 1–8.
[5] A. Cantelli, M. Malferrari, A. Soldà, G. Simonetti, S. Forni, E. Toscanella, E.J. Mattioli, F. Zerbetto, A. Zanelli, M. Di Giosia, M. Zangoli, G. Barbarella, S. Rapino, F. Di Maria, M. Calvaresi, JACS Au 2021, 1, 925–935

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A paradigmatic example of multidomain protein studied by NMR spectroscopy: The nucleoprotein of SARS-CoV-2

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Multi-domain proteins are composed of folded domains connected by disordered regions, each with a distinct function. The presence of these components is crucial for the protein's overall function.

This is the case of the Nucleocapsid protein of SARS-CoV-2 (N). N is a modular protein composed of 419 amino acids divided into an N-terminal RNA-binding domain (NTD), a C-terminal dimerization domain (CTD), and three intrinsically disordered regions (IDRs) (Figure 1a)[1].

Nuclear magnetic resonance (NMR) spectroscopy represents a powerful and versatile tool for studying the structural and dynamic features of multi-domain proteins, providing a wealth of information at the atomic level. Despite its versatility, NMR spectroscopy must face several challenges when applied to modular proteins. These challenges stem from the size, conformational heterogeneity, and structural complexity of these proteins. Here, I will present how N, a paradigmatic example of a multidomain protein, was characterized through NMR exploiting diverse NMR strategies[2,3]. By studying various N constructs (NTD, NTR, N), each possessing specific structural and dynamic features, we were able to shed light on the importance of the various modules of N in defining its characteristics. Moreover, the importance of IDRs in the interaction of N with different partners was elucidated by exploiting NMR in conjunction with other biophysical techniques[4,5].

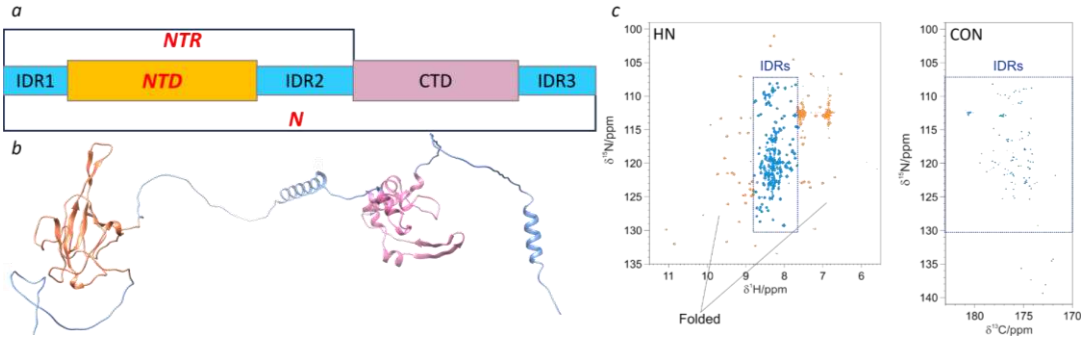

Figure 1: Panel *a* reports schematically the domains of N protein and the names of the three studied constructs in red (N, NTR, NTD). A structure of N, obtained with Alpha Fold software, is reported in *b*. Some of the spectra obtained with our proposed strategy to study multi-domain proteins are reported in *c*.

References:

[1] A. Eltayeb, et Al., International Journal of Biological Macromolecules 2024, 260, 129523W.
[2] M.Schiavina, et Al., Nature Protocols 2024, 19, 406-440
[3] M Schiavina, et Al., Journal of Magnetic Resonance Open 2024, 18, 100143
[4] M. Schiavina, L. Pontoriero, G. Tagliaferro, R. Pierattelli, I.C. Felli, Biomolecules 2022, 12, 1302
[5] L. Pontoriero, M. Schiavina, S.M. Korn, A. Schlundt, R. Pierattelli, I.C. Felli, Biomolecules 2022, 12, 929.

CSB-OR-015

Enhancing Vaccine Efficacy through TLR4-based Adjuvant systems

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Our study delves into the innovative realm of vaccine enhancement by leveraging the synergistic capabilities of co-formulated Toll-like receptor 4 (TLR4) modulators. We systematically explore two pivotal approaches: firstly, the strategic combination of distinct TLR4 agonists targeting different downstream pathways; and secondly, the integration of TLR4 modulators with saponin based QS-21 variants.

In our initial investigation, we focused on the co-formulation of TLR4 modulators FP18 and FP20, which uniquely activate the MyD88 and TRAM-TRIF pathways, respectively[1,2]. A meticulous exploration of varying ratios led us to identify an optimal blend (60% FP18, 40% FP20) that remarkably amplified cytokine response in THP1 derived macrophages, surpassing the baseline set by conventional MPLA and LPS controls. This breakthrough, evidenced by SEAP assay results followed by *in vivo* experiments, underscores the potential of TLR4 modulators' combination in augmenting immune responses.

Further, we ventured into formulating FP20 in tandem with saponin variants, drawing inspiration from the FDA-approved AS-01 (MPLA and QS-21) adjuvant system[3]. Utilizing synthetic counterparts - FP20[2] for MPLA and QS-21 Echinocystic acid for QS-21[4], we crafted novel co-formulations. These were characterized via differential scanning calorimetry, dynamic light scattering, zeta potential, and TEM analyses. The *in vivo* studies revealed that these co-formulations substantially bolstered the immune response beyond the scope of individual compounds.

The synergistic effects of the adjuvant systems can offer a promising foundation for the development of advanced vaccine adjuvants, marking a significant stride in immunological research.

References:

[1] Facchini, Fabio A., Minotti Alberto, et al. *Journal of Medicinal Chemistry*, 2021, 64, 12261−12272.
[2] Romerio, Alessio, et al. *Journal of Medicinal Chemistry*, 2023, 66, 4, 3010–3029.
[3] Coccia, Margherita, Collignon, Catherine, et al. *NPJ Vaccines*, 2017, 2, 25.
[4] Fuentes, Roberto, et al. *Frontiers in Immunology*, 2022, 27, 4731 –4737.

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Revealing the regulatory mechanisms of Rac1 small GTPases through all-atom simulations

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The Rac1 (Ras-related C3 botulinum toxin substrate 1), member of the Rho-GTPase family, regulates cell adhesion, morphology, and movement, and it is over-expressed in various types of cancers. [1] An elegant and intricate system of protein-protein interaction network regulates the function of Rho-GTPases. GTPase-activating proteins (GAPs) and guanine exchange factors (GEFs) repeatedly promote the exchange between GTP and GDP thereby allowing to switch between an active to and inactive form of the Rho GTPase protein.

The crystal structures of DOCK proteins and their small-GTPase complexes provided insights into the GEF activity mechanism. However, the regulation mechanism of DOCKs by partner proteins and the signal transduction events responsible for Rho-GTPases regulation in larger macromolecular assemblies remains elusive. Due to their key regulatory role, Rho GTPases are the object of cancer associated mutations, and, following the recent approval of Sotorasib, they are emerging as amenable target for the discovery of small molecule covalent inhibitors.

In this contribution, we apply all-atom simulations to uncover the regulatory mechanisms of Rac1. Several model systems are compared, starting with the homodimeric cryo-structure (Figure 1) of ELMO1-DOCK5-Rac1 [2], the monomer and only the DOCK5-Rac1 complex bound to a GDP and in the apo form, are investigated. Additionally, a comparison between the different wild-type systems, the most frequent Rac1P29 mutations and the Rac1b splice variant was done.[3]

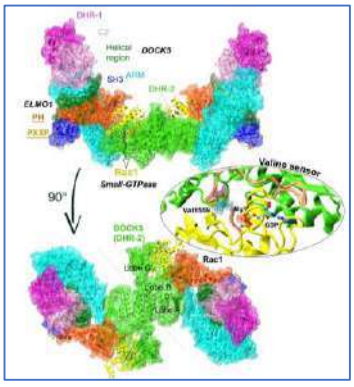

Figure 1: Structure of human ELMO1-DOCK5-Rac1 homodimer (PDB id 7DPA)

References:

[1] A. Payapilly, A. Malliri, Current opinion in cell biology, 2018, 54, 50-56.
[2] J. Xu, F. Simonelli, X. Li, A. Spinello, S. Laporte, V. Torre, A. Magistrato, JCIM, 2021, 61(6), 2967-2980.
[3] A. Parise, A. Magistrato, Protein Science, 2024, 33, e4939.

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A drug-repurposing strategy to target DNA G-quadruplexes in breast cancer

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Breast cancer is the most common type of cancer diagnosed among women.[1] Notably, advanced breast cancer is characterized by an unstable genome and aberrant gene expression patterns, in which noncanonical DNA conformations play an important role by regulating gene expression and influencing disease progression.

Among the noncanonical nucleic acid structures, G-quadruplex (G4), a transient structure formed by guanine-rich DNA and RNA sequences, is gaining increasing interest due to its involvement in key biological processes, like DNA replication, gene regulation, and telomere protection.[2] In the context of breast cancer, of significant interest are the regulatory G4s that are within or near the promoter regions of some key oncogenes, including *c-MYC*, *HER2*, *NRAS*, and *YY1*.[3] These genes confer increased proliferative capacity and invasive properties in breast cancer, making them critical areas of research.[4]

In this study, a drug repurposing approach was used to rapidly identify drug-like compounds targeting G4s in some key oncogenes involved in breast cancer. Starting from a library of 3000 FDA-approved compounds, we performed a ligand-based pharmacophore virtual screening and identified 50 potential G4 ligands. From these, taking advantage of the pharmacophore hypotheses generated, 22 drugs were selected. To assess their affinity for *c-MYC*, *HER2*, *NRAS*, and *YY1* G4s, various biophysical techniques such as circular dichroism, nuclear magnetic resonance, and isothermal titration calorimetry were used. 10 of the 22 selected drugs were found to be promising G4 ligands. Therefore, they were evaluated for their ability to inhibit the proliferation of three different breast cancer cell lines. Only 3 drugs, raloxifene, belotecan and irinotecan, showed interesting antiproliferative activity. In particular, irinotecan demonstrated ability to bind and stabilize G4 structures in cells, leading to a decrease of the G1 phase of the cell cycle, preventing the M phase of mitosis and duplication, ultimately resulting in inhibition of tumour growth. Our results suggest that already existing drugs could be used as G4-targeting anticancer agents in breast cancer treatment, being able to interact with such noncanonical structures present in the promoters of overexpressed oncogenes, interfering with their functionality.

References:

[1] H. Sung, J. Ferlay, R. L. Siegel, M. Laversanne, I. Soerjomataram, A. Jemal, F. Bray, CA Cancer J Clin. 2021, 71, 209–249.
[2] D. Varshney, J. Spiegel, K. Zyner, D. Tannahill, S. Balasubramanian, Nat Rev Mol Cell Biol. 2020, 21, 459–474.
[3] F. Romano, A. Di Porzio, N. Iaccarino, G. Riccardi, R. Di Lorenzo, S. Laneri, B. Pagano, J. Amato, A. Randazzo, Expert Opin Ther Pat. 2023, 33, 745–773.
[4] M. Liu, M. C. Casimiro, C. Wang, L. A. Shirley, X. Jiao, S. Katiyar, X. Ju, Z. Li, Z. Yu, J. Zhou, M. Johnson, P. Fortina, T. Hyslop, J. J. Windle, R. G. Pestell, Proc Natl Acad Sci U S A. 2009, 106, 19035–19039.

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New Curcumin Mimics based on Ethyl Phosphonates: Neuroprotective or Anticancer Activity depending on Aromatic Moiety[1]

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Curcumin, a well-known polyphenol extracted from *Curcuma longa*, is one of the most studied natural products. Its pharmacological action has been mainly attributed to its antioxidant, anticancer, and neuroprotective activities.[2] Despite such potential, curcumin suffers from low bioavailability and poor chemical stability, features that limit its pharmacological applications.[3]

To overcome these relevant limitations, here we reported the design, synthesis, and biological evaluation of new tyrosol-based Ethyl Phosphonates curcumin mimics (EP, Figure 1). The new mimics present the phenolic moieties based on tyrosol, homovanillyl and 3-hydroxytyrosol alcohols, in addition to the 5-methoxy tryptophol. The substitution of β-diketone moiety with an ethyl phosphonate, keeping a seven atoms linker, confers at all the mimics better stability in biological media.

By our investigations, the two mimics EP2 and EP4 result very interesting in different manner. EP2 represents a potential candidate for neurodegenerative disorders, displaying a strong antioxidant activity, a potent inhibitory effect on ferroptosis, and an anti-aggregating effect on Aβ amyloids. Conversely, EP4 presents a strong anticancer activity against different human cancer cell lines (HeLa, A375, WM266, MDA-MB-231) with an apoptotic mechanism of cell death and with a high selectivity for tumor cells. This potency was also confirmed by ubiquitination assays were emerged an inhibitory action comparable to that of curcumin.

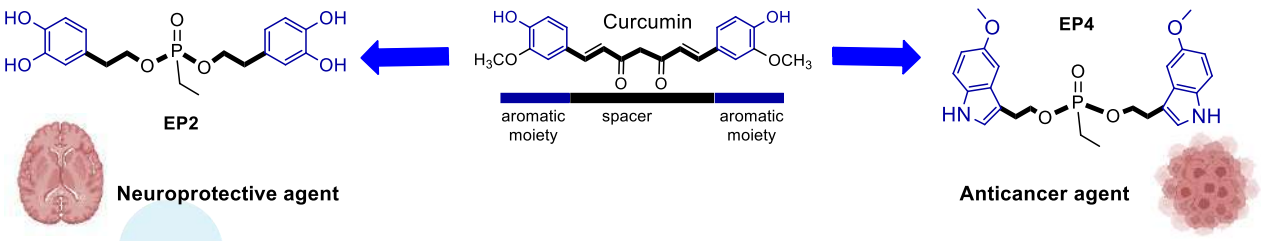

Figure 1: Ethyl Phosphonates: new curcumin mimics.

References:

[1] These studies were supported by the AIPRAS Onlus (http://www.aipras.org/).
[2] K.M. Nelson, J.L. Dahlin, J. Bisson, J. Graham, G.F. Pauli, M.A. Walters, Journal of Medicinal Chemistry 2017, 60, 1620 – 1637.
[3] P. Anand, A.B. Kunnumakkara, R.A. Newman, B.B. Aggarwal, Molecular Pharmaceutics 2007, 4, 807 – 818.

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CSB-OR-019

Not only vinegar: Acetic Acid Bacteria as versatile biocatalysts for selective oxidation

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Acetic acid bacteria (**AAB**) are aerobic, Gram-negative microorganisms able to oxidise a wide variety of sugars, alcohols, and polyols with high stereo- and regio-specificity, thanks to the presence of dehydrogenases located in their membrane and periplasmic space[1]. Moreover, several strains of AABs are also able to produce bacterial cellulose (**BC**), a natural polymer with high crystallinity and purity, which of particular relevance not only for its mechanical properties but also as an innovative support for enzymatic immobilization[2].
Our research group kept an all-round view on the synthetic potentialities of AAB as biocatalysts for oxidations. *Acetobacter malorum*, isolated from the mother of vinegar, demonstrated good to excellent conversions (60-100%) in the oxidation of different aryl-aliphatic alcohols to their corresponding acids (**Figure 1**). This result was obtained either using resting cells or immobilised cells into barium alginate beads, thus allowing to maximize the productivity by using continuous-flow reactors. Among the tested compounds, regiospecific desymmetrization of 1,4-benzenedimethanol to 4-(hydroxymethyl) benzoic acid (m.c. 90%) is particularly noteworthy, since the only available procedures show low conversion (40%) and require heavy metals and harsh conditions[3].

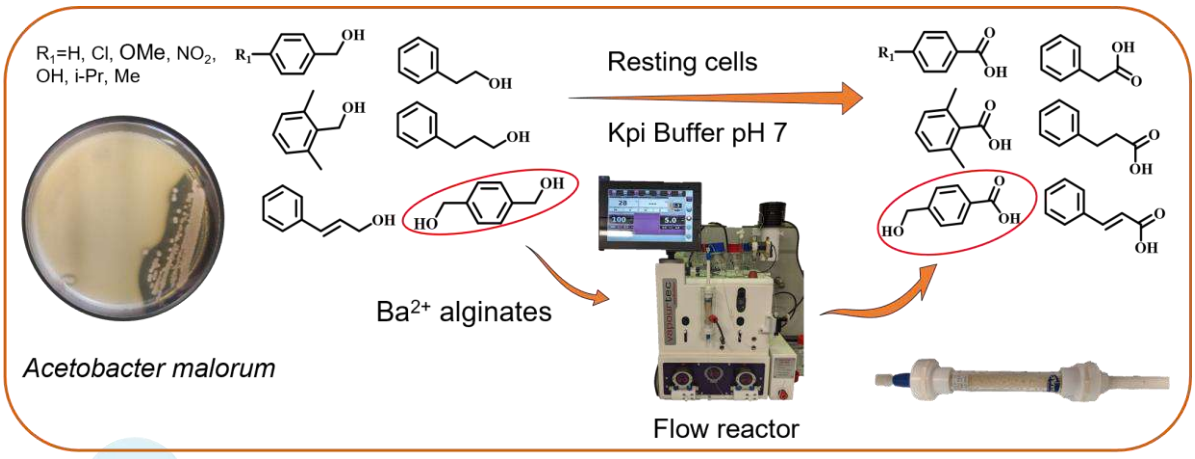

Figure 1: Oxidative versatility of *A. malorum* as biocatalysts.

References:

[1] N. Saichana, K. Matsushita, O. Adachi, I. Frébort, J. Frebortova, Biotechnology Advances, 2015, 33, 1260–1271.
[2] R. Drozd, R. Rakoczy, A. Wasak, A. Junka, K. Fijałkowski, International Journal of Biological Macromolecules, 2018, 108, 462-470.
[3] M. Trincado, H. Grützmacher, F, Vizza, C, Bianchini, Chemistry – A European Journal, 2010, 16, 2751-2757.

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Surface Plasmon Resonance and Photo-Induced Crosslinking as novel tools to monitor protein misfolding and oligomerization.

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Alterations on protein conformation and aggregation state are at the basis of the pathogenesis of different pathologies, such as neurodegenerative diseases, characterized by the formation of misfolded and/or aggregated proteins. Understanding the biomolecular mechanisms involved in this process is of paramount importance for tackling many diseases, such as Diabetes and Alzheimer's Disease.

In this presentation, I will show a novel Surface Plasmon Resonance (SPR)-based method[1] to monitor the diffusion coefficient (D) of proteins with a different oligomerization/conformation state. This is possible because D is sensitive to any differences in the hydrodynamic radius of molecules, either due to an unfolding or an aggregation process. In particular, through this method, we have been able to study the oligomerization of Insulin at different experimental conditions, such as pH or the presence of metal ions (zinc and copper)[2]. In addition we report the D value of Bovine Serum Albumin in native and denatured conditions, demonstrating the possibility to obtain conformational information from D measurements.

Furthermore, we have coupled the SPR-based investigation with a Photo-Induced Crosslinking of Unmodified Proteins (PICUP) technique, which allowed us to monitor and identify specific oligomeric species present in solution. In particular, the method was used to obtain more information about Insulin oligomerization at different experimental conditions.

The new way of applying SPR represents an innovation in the bio-sensing field which permits to expand the applicability of the technique. Moreover, the synergy between SPR and PICUP will permit us to obtain a deeper insight into the biomolecular mechanism involved in protein aggregation pathways.

References:

[1] G.A. Zingale, I. Pandino, A. Distefano, N. Tuccitto, G. Grasso, Biosensors and Bioelectronics: X, 2023, 13,1000306.
[2] D. Calcagno, M.L. Perina, G.A. Zingale, I. Pandino, N. Tuccitto, V. Oliveri, M.C. Parravano, G. Grasso. Protein Science, 2024, 33(4).

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Computational Multiscale Approach applied to NDM-1 to better understand the inhibition mechanism promoted by Ebselen

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The hydrolysis of the β-lactam core, typical of some antibiotics such as penicilins, cephalosporins and carbopenemes, is caused by the presence in bacteria of enzymes belonging to β-lactamases family[1]. Specifically, the New-Dehli metallo-β-lactamase (NDM-1) is able to hydrolyze the four-membered structure of the β-lactam ring[2] assisted by two zinc ions that share the coordination of a bridge water molecule. A recently published experimental study proposed the ebselen molecule as promising NDM-1 inhibitor.[3] Spectroscopic analyses evidenced that ebselen is covalently bound to NDM-1 by a S-Se bond with the Cys-166 residue coordinated with a zinc ion 2 at the active site. The aim of this work by using a multiscale methodology that combined dynamic simulations and computational modeling, is to examine the molecular mechanisms governing substrate(inhibitor) affinity, enzyme activity such as the final product release. At this purpose, starting from crystallographic structure (PDB=3SPU)[4] 1 μs of molecular dynamics (MD) simulation was performed on the apo-form of NDM-1 protein and 100 ns on its non-covalent complex (enzyme-ebselen). Aiming to gain insights on zinc ions of the active site when the Se-S is formed, a further MD of 1 μs was done on NDM-1 with ebselen in covalent interaction. Results evidence the role played by the amino acid residues inside the active site during the recognition, the chemical reaction and final product release.

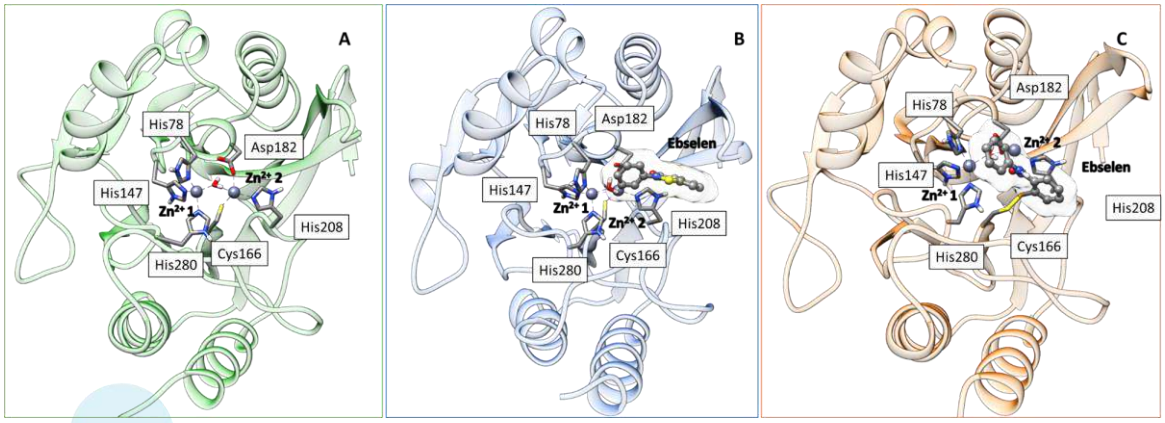

Figure 1: The NDM-1 enzyme without substrate (A), with ebselen bound non-covalently (B) and with ebselen bound covalently (C) with evidence of the coordination of the two Zn^{2+} ions.

References:

[1] Z. Sun, et al., Nature communications 2018, 9.1, 4524.
[2] S. Farooq, A. U. Khan, Current Protein and Peptide Science 2023, 24.8, 655-665.
[3] E. Wai-chiáChan, et al., Chemical communications 2015, 51.46, 9543-9546.
[4] https://doi.org/10.2210/pdb3SPU/pdb

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Role of the metal ion and of the coordinating residues in the metallo-protein Ros as model of the prokaryotic zinc finger domain

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Prokaryotic zinc finger Ros is a protein involved in the horizontal transfer of genes from *A. tumefaciens* to a host plant infected by it. It acts as transcriptional repressor and was identified in 1998 by Chou et al[1]. Ros belongs to a family of proteins, namely Ros/MucR, whose members have been recognized in different bacteria, mostly α-proteobacteria, symbionts, and pathogens of mammals and plants[2]. The Ros/ MucR gene is very conserved in proteobacteria and is central for host-bacterium interactions[3].

The protein contains a single Cys_2-His_2 zinc finger domain and assumes a βββαα fold stabilized by the presence of a metal cofactor and by a 15 amino acids hydrophobic core. It was intensely studied as suitable model domain to unveil the effect of the metal ion replacement in metallo-proteins and appeared to tolerate the Zn to Cd substitution but not the replacement of the wild type metal by Ni(II), Pb(II) and Hg(II)[4].

Interestingly, the sequence alignment of the prokaryotic Ros homologs, it shows that the second cysteine residue is frequently replaced by an aspartate residue, raising questions about the role of this amino acid in metal coordination. Previous research, carried out on RosC27D, a Ros mutant in which the second cysteine is replaced by an aspartate, has shown that the presence of this residue has only a slight effect on the functional structure of the protein, but it does influence its thermodynamic properties[5].

Here, we report the binding affinities of RosC27D to cadmium and cobalt and compare the geometrical characteristics, obtained by using computational methods, of both the wild type and mutated coordination sphere in the presence of different metal ions.

References:

[1] AY Chou, J Archdeacon, CI Kado Proc Natl Acad Sci U S A. 1998 Apr 28;95(9):5293-8.
[2] C.C. Caswell, AE Elhassanny, EE Planchin, CM Roux, JN Weeks-Gorospe, TA Ficht, PM Dunman, RM Roop Infect Immun. 2013 Apr;81(4):1040-51.
[3] G. Malgieri, M. Palmieri, L. Russo, R. Fattorusso, P.V. Pedone, C. Isernia FEBS J. 2015 Dec;282(23):4480-96.
[4] V. Sivo, G. D'Abrosca, I. Baglivo, R. Iacovino, P.V. Pedone, R. Fattorusso, L. Russo, G. Malgieri, C. Isernia Inorg Chem. 2019 Jan 22;58(2):1067-1080.
[5] G. D'Abrosca, L. Russo, M. Palmieri, I. Baglivo, F. Netti, I. de Paola, L. Zaccaro, B. Farina, R. Iacovino, P. V. Pedone, C. Isernia, R. Fattorusso, G. Malgieri, Journal of Inorganic Biochemistry 2016,161: 91-98

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Amino Acid Chirality to Design Functional Superstructures

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Nature's choice for homochiral biopolymers (*i.e.*, L-peptides, D-polysaccharides) has inspired our scientific journey, as we question it through the design and characterization of heterochiral minimalistic peptides, composed of L- and D-amino acids at specific positions along the sequence. We found how and why heterochiral short peptides behave differently from the homochiral analogs at supramolecular level, by monitoring their self-assembly *in continuo* from the nanoscale to the macroscale.[1] In particular, amphipathic conformations play a key role to stabilize superstructures,[2] to enable various functions, such as catalytic activity,[3] antimicrobial activity,[4] or coordination with metals for their subsequent reduction to nanoparticles.[1] Alternatively, the conjugation of amino acids that are prone to self-assembly with those that favor disassembly, can be used to yield stereoisomers that inhibit amyloid fibrillation, and with different selectivities depending on their stereoconfiguration, for instance binding Alzheimer's Abeta[5] or insulin,[6] thus giving scope for their future use as stabilizers for protein biotherapeutics.

Figure 1: Two supramolecular structures emerging from the self-assembly of dipeptides in water.[5]

References:

[1] S. Adorinni, *et al. ACS Nano* **2024**, *18*, 3011-3022.
[2] M. Monti, *et al. Chem. Commun.* **2023**, *59*, 10948-10951.
[3] S. Adorinni, *et al. Chem. Commun.* **2023**, *59*, 7619-7622.
[4] O. Bellotto, *et al. Pharmaceutics* **2022**, *14*, 446.
[5] A. M. Garcia, *et al. ACS Nano* **2021**, *15*, 3015.
[6] B. Rosetti, *et al. Biomacromolecules* **2024**, *in press.*

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Exploring nano-plastics supramolecular interactions in biological systems by combined *in vitro* and in *vivo* techniques

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The increasing global issue of micro- and nano-plastics (MPs/NPs) arises from their wide distribution and complicated effects on living organisms.[1] Plastic particles easily fragment in smaller pieces so they can enter our body through inhalation, food, skin[2] or blood[3]. Given the limited understanding of the causes and effects, it's crucial to understand how they interact with biological systems and (bio)macromolecules within them.
Proteins associate with nano-plastics, forming a complex which shields the nanoparticle's surface and largely determines its biological identity, thereby influencing the *in vivo* response.
Here, a structural and dynamic characterization of the human Ubiquitin (Ubq), in presence of 23 nm polystyrene nano-plastics (PS-NPs), was performed by using Circular Dichroism (CD) and Transmission Electron Microscopy (TEM) integrated with high-resolution homo- and hetero-nuclear NMR (Nuclear Magnetic Resonance) methodologies. The ability of NPs to induce protein conformational rearrangement may represent one of the mechanisms through which nanoparticles exert nanotoxicity on humans. Furthermore, we examined the impact of these polymers on ubiquitin functions by studying ubiquitination both *in vitro* and *in cell*. Our findings confirm that NPs lead to a sensible reduction of ubiquitination mis-function that underlies many neurodegenerative and oncogenic diseases.[4]
In addition, according to numerous studies, the nano-plastics can also affect human health via the gastrointestinal tract, interfering the tolerance and immune response of the intestine through bioaccumulation. In this context, the influence of NPs on the intestinal microbial community was tested by analysing the survival of bacteria, their ability to form biofilms and metabolism.

References:

[1] C. Covello, F. Di Vincenzo, G. Cammarota, M. Pizzoferrato, Curr Issues Mol Biol 2024, 46 (3), 2658 – 2677.
[2] D. Sawicka, L. Chojnacka-Puchta, L. Zapór, K. Miranowicz-Dzierżawska, J. Skowroń, Med Pr. 2024, 75 (1), 81 – 96.
[3] O. Hollóczki, S. Gehrke, Sci Rep. 2019, 9, 16013.
[4] M. della Valle, G. D'Abrosca, M. T. Gentile, L. Russo, C. Isernia, S. Di Gaetano, R. Avolio, R. Castaldo, M. Cocca, G. Gentile, G. Malgieri, M. E. Errico, R. Fattorusso, Chem. Sci. 2022, 13, 13563 – 13573.

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Mastering proteostasis as a promising therapeutic avenue in Alzheimer's Disease

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Alzheimer's Disease (AD) arises from the aberrant accumulation of toxic amyloid Aβ peptides in neuronal tissues, prompting the exploration of the "Amyloid Hypothesis" targeting Aβ misfolding to thwart disease progression. Yet, the setbacks of anti-aggregating drug trials underscore the necessity for a better understanding of proteome maintenance mechanisms (proteostasis)[1]. In our interdisciplinary research, we delve into the intricate biochemical pathways governing Aβ homeostasis, employing a multi-target approach to screen diverse small molecules for their potential to restore physiological Aβ balance. Furthermore, we also explore the molecular mechanisms through which amyloid aggregates exert their toxicity, such as their ability to penetrate lipid membranes,[2] and examine how small molecules can inhibit this process.

In this contribution, our focus is on presenting a comprehensive overview of our studies, with a primary emphasis on exploring the effectiveness of small natural molecules, in halting toxic amyloid aggregation[3]. We also investigate their potential to revive natural degradation mechanisms, such as the ubiquitin proteasome system (UPS) and proteases. Furthermore, we delve into synthetic compounds, assessing their ability to modulate proteasome activity based on their structural characteristics[4]. Finally, we consider repurposing "old" drugs, formerly potent antipyretics, as potential regulators of proteasome function[5]. Our research spans from fundamental inquiries into protein/lipid membrane stability to medicinal chemistry pursuits bridging the gap between basic science and therapeutic applications, and potentially opening new avenues in AD treatment.

References:

[1] D. Milardi, E. Gazit, S. E. Radford, Y. Xu, R. U. Gallardo, A. Caflisch, G. T. Westermark, P. Westermark, C. L. Rosa and A. Ramamoorthy, Chem. Rev. 2021, **121**, 1845–1893.
[2] M. F. Sciacca, F. Lolicato, C. Tempra, F. Scollo, B. R. Sahoo, M. D. Watson, S. García-Viñuales, D. Milardi, A. Raudino, J. C. Lee, A. Ramamoorthy and C. La Rosa, ACS Chem. Neurosci. 2020, **11**, 4336–4350.
[3] M. F. Sciacca, V. Romanucci, A. Zarrelli, I. Monaco, F. Lolicato, N. Spinella, C. Galati, G. Grasso, L. D'Urso and M. Romeo, ACS Chem. Neurosci. 2017, **8**, 1767–1778.
[4] A. M. Santoro, A. Cunsolo, A. D'Urso, D. Sbardella, G. R. Tundo, C. Ciaccio, M. Coletta, D. Diana, R. Fattorusso, M. Persico, A. D. Dato, C. Fattorusso, D. Milardi and R. Purrello, Chemical Science, 2016, **7**, 1286–1297.
[5] A. M. Santoro, V. Lanza, F. Bellia, D. Sbardella, G. R. Tundo, A. Cannizzo, G. Grasso, M. Arizzi, V. G. Nicoletti, S. Alcaro, G. Costa, A. Pietropaolo, G. Malgieri, G. D'Abrosca, R. Fattorusso, S. García-Viñuales, I. M. M. Ahmed, M. Coletta and D. Milardi, ChemMedChem, 2020, **15**, 302–316.

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Screening of Inhibitors of ALR Protein–Protein Interaction Pathway using NMR spectroscopy

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MIA40 and ALR of the MIA pathway mediate the import of protein precursors that form disulfides into the mitochondrial intermembrane space. This import pathway is suggested to be a linear pathway in which MIA40 first binds to the precursor via a disulfide linkage and oxidizes it[1,2]. Subsequently, ALR re-oxidizes MIA40 and then ALR transfers electrons to terminal electron acceptors. With a collection of small molecule modulators (MB-5 to MB-9 and MB-13) that inhibit ALR activity, we characterized the import mechanism in mitochondria. NMR studies show that most of the compounds bind to a similar region in ALR.

Here NMR spectroscopy provided a method to investigate protein–ligand interactions in solution, mimicking, even though not fully reproducing, the physiological flexibility of a protein target present in the cell compartment. Appropriate protein preparation protocols coupled with sensitive NMR experiments and systematic data analysing schemes were applied for a drug discovery investigation that clearly showed that the integration of several techniques is needed. Characterization was carried out mainly in vitro and in silico with some information on the inhibitory activity in cellulo by Koehler and coworkers[3,4].

Mechanistic studies with small molecules demonstrate that treatment with compound MB-6 locks the precursor in a state bound to MIA40, blocking re-oxidation of MIA40 by ALR. Thus, small molecules that target a similar region in ALR alter the dynamics of the MIA import pathway differently, resulting in a set of probes that are useful for studying the catalysis of the redox-regulated import pathway in model systems.

References:

[1] L. Banci, I. Bertini, C. Cefaro, S. Ciofi-Baffoni, A. Gallo, M Martinelli, D.P. Sideris, N. Katrakili, K Tokatlidis. Nat. Struct. Mol. Biol. 2009, 16, 198–206.

[2] L. Banci, I. Bertini, V. Calderone, C. Cefaro, S. Ciofi-Baffoni, A. Gallo, K Tokatlidis. J. Am. Chem. Soc. 2012, 134, 1442–1445.

[3] D.V. Dabir, S.A. Hasson, K. Setoguchi, M.E. Johnson, P. Wongkongkathep, C.J. Douglas, J. Zimmerman, R. Damoiseaux, M.A. Teitell, C.M. Koehler. Dev. Cell 2013, 25, 81–92

[4] D.V. Dabir, E.V. Leverich, S.-K. Kim, F.D. Tsai, M. Hirasawa, D.B. Knaff, C.M. Koehler. EMBO J. 2007, 26, 4801–4811

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Differential Interactions between ATP and NGF / proNGF: Chance or Necessity?

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The prototype of the neurotrophin family, Nerve Growth Factor (NGF), is essential for the development and maintenance of neurons and is crucial in immune and endocrine systems and in the pain pathway. NGF precursor, proNGF, whose pro-peptide is an intrinsically unstructured domain (IUD), is endowed with different biological properties. The binding to TrkA, $p75^{NTR}$ and sortilin receptors activates the NGF/proNGF signaling pathways. Much is known about NGF in neuronal physiology. However few reports described essential endogenous ligands as modulators of NGF biology.

Recently, the binding of ATP to NGF was identified. To determine the molecular elements of this binding, we used integrative structural biology to unveil for the first time the binding cartography of ATP to NGF [1]. Isothermal Titration Calorimetry (ITC), ^{1}H Saturation Transfer Difference NMR (^{1}H STD-NMR), 2D ^{1}H-^{15}N HSQC, coupled to the determination of the 3D solution NMR structure of NGF and MD simulations, helped identifying the likely binding mode of ATP on NGF. ATP/NGF binding to the receptors was investigated through Surface Plasmon Resonance (SPR).

We also undertook a complementary biophysical study on the binding of ATP to proNGF. Our results reveal a different binding profile for mature and precursor proteins. A combination of Small Angle X-ray Scattering (SAXS), Hydrogen-Deuterium Exchange Mass Spectrometry (HDX-MS) and limited proteolysis showed that ATP binding induces a change in the conformation and/or dynamics of proNGF, predominantly in the IUD pro-peptide [2].

Combined, these results suggest a functional role for ATP in modulating the biological role of proNGF/NGF in health and disease states.

References:

[1] F. Paoletti, F. Merzel, A. Cassetta, I. Ogris, S. Covaceuszach, J. Grdadolnik, D. Lamba, S. Golič Grdadolnik, Comput. Struct. Biotechnol. J., **2021**, 19, 2938-2949.
[2] F. Paoletti, S. Covaceuszach, A. Cassetta, A.N. Calabrese, U. Novak, P. Konarev, J. Grdadolnik, D. Lamba, S. Golič Grdadolnik, Protein Sci., **2023**, 32(2): e4563.

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Design, synthesis and characterization of novel nucleopeptides targeting ATP and GTP

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Nucleopeptides represent a novel class of biomolecules where the peptide backbone incorporates nucleobases in the side chains (Fig. 1)[1]. The inherent versatility of nucleopeptides arises from the potential to manipulate both the peptide and nucleobase constituents, modulating favorable characteristics such as biostability, biocompatibility, multifunctionality, and the ability to spontaneously self-assemble in aqueous solutions[2]. Herein, we present an ongoing investigation into the US-assisted[3] synthesis of tailored nucleopeptides aimed at identifying novel binders for ATP and GTP (Fig. 2). While these nucleopeptides feature diverse amino acid sequences, they share distinctive functional moieties: a nucleobase-bearing amino acid (NBA) in the C-terminus (Lys) to bind Adenine or Guanine of the ATP or GTP, respectively; aromatic L-Phe and hydrophobic L-Leu, to enhance aggregation processes after target sequestration; three L-Arg residues to interact with the phosphate groups of ATP/GTP in cell and facilitate cell penetration through electrostatic interactions with negatively charged molecules on the cell surface; L-Ser as a hydrophilic spacer to balance the hydrophobic component and improve the solubility of the nucleopeptides in aqueous environments. Preliminary CD studies reveal nucleopeptide-ATP/GTP interactions by adopting distinct binding modes. NMR studies are in progress to gain further insights into their local conformational peculiarities and structural changes driving the target recognition process. Remarkably, some of these nucleopeptides, except for those bearing an acetyl group that replaced nucleobase on the side chain of Lys, also exhibited gel-forming abilities, highlighting the involvement of the nucleobase in sol-gel transition and opening new perspectives for drug delivery applications.

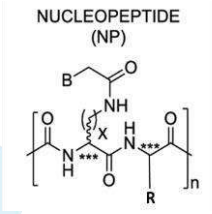

Figure 1: Nucleopeptide (NP) structure.

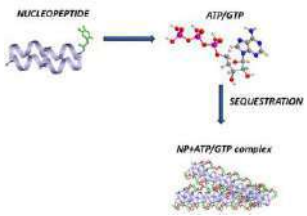

Figure 2: Nucleopeptide assemblies sequester ATP and GTP.

References:

[1] Doel, M. T. et al. *Tetrahedron*, (**1974**), 30.16, 2755-2759.
[2] Wang, Huaimin et al. *Angewandte Chemie*, (**2018**), vol. 57,18: 4931-4935.
[3] a) Merlino, Francesco et al., *Organic letters* vol. 21,16 (**2019**): 6378-6382. b) Del Bene, Alessandra et al. *Ultrasonics sonochemistry*, (**2023**) vol. 95: 106360.

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Design, Synthesis and characterization of synthetic and natural derived TLR4 antagonists.

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TLR4 is an inflammatory receptor belonging to the class of Pattern Recognition Receptor (PRRs), whose function is to sense Pathogens or Damages Associated Molecular Patterns (PAMPs, DAMPs) and start the innate immune response.[1] The natural ligand of TLR4 is Lipopolysaccharide (LPS), an essential component of Gram-negative bacteria outer membrane.[1,2] The minimal portion of LPS required for immunogenicity is a glycolipid called Lipid A.[2] Through molecular simplification starting from Lipid A, our group developed two new compounds which showed promising TLR4 antagonism: FP7 (Fig. 1, **a**) and FP12 (Fig.1, **b**) (HEK-Blue hTLR4 IC_{50} = 2.0 and 0.63 µM; RAW-Blue TLR4 IC_{50} = 7.7 and 1.7 µM).[3,4]

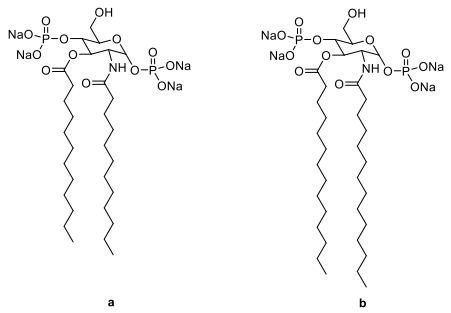

Figure 1: TLR4 antagonists developed by our group.

The aim of this work is to produce novel TLR4 antagonists. This goal will be achieved modifying the substituent on the anomeric position of FP7 and FP12 to increase stability for further functionalization of the C6 position. Furthermore, starting form promising natural compounds active as TLR4 antagonists, computer assisted docking will be applied to select new scaffolds to be synthetized and chemically modified.

References:

[1] Ruslan Medzhitov. Toll-like receptors and innate immunity. *NATURE REVIEWS* (2001).
[2] Park, B. S. *et al.* The structural basis of lipopolysaccharide recognition by the TLR4-MD-2 complex. *Nature* **458**, 1191–1195 (2009).
[3] Peri, F. & Piazza, M. Therapeutic targeting of innate immunity with Toll-like receptor 4 (TLR4) antagonists. *Biotechnology Advances* vol. 30 251–260 Preprint at https://doi.org/10.1016/j.biotechadv.2011.05.014 (2012).
[4] Facchini, F. A. *et al.* Structure-activity relationship in monosaccharide-based toll-like receptor 4 (TLR4) antagonists. *J Med Chem* **61**, 2895–2909 (2018).

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Study on the impact of Toll-like Receptor 4 (TLR4) modulation in rare inflammatory-fibrotic diseases

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The project focuses on the modulation of fibrotic phenotype up-set in rare diseases through a Toll-like Receptor 4 (TLR4) antagonist.
In particular, in this work, we started to test the possible impact on fibrosis progression of FP7 and FP12 that showed inhibition activity against TRL4 activation by LPS in a dose-dependent way in both human and murine cells [1].
Fibrosis is an outcome of the repair response to tissue damage caused by inflammation. When the fibrotic process is excessive or dysregulated it leads to a pathological condition that can affect different organs and functions. Here, it is now clear that inflammation, which however is not the only trigger, plays a key role in the critical cellular process of fibroblast activation that leads to fibrosis up-set [2].
The recent discovery of complex crosstalk between fibrosis progression and inflammatory pathways underlines the central role of TRL4 and its potential as a new drug target[3]. Here it is proposed an in vitro screening on cellular models of fibrosis with TLR4 antagonists to identify new potential drugs targeting Idiopathic Pulmonary Fibrosis (IPF), a rare fibrotic pathology where a pivotal role of TLR4-mediated inflammation has been observed [4 5].

References:

[1] Facchini, F. A. *et al.* Structure–Activity Relationship in Monosaccharide-Based Toll-Like Receptor 4 (TLR4) Antagonists. *J. Med. Chem.* **61**, 2895–2909 (2018).

[2] Upcoming treatments for morphea - Wenzel - 2021 - Immunity, Inflammation and Disease - Wiley Online Library. https://onlinelibrary.wiley.com/doi/full/10.1002/iid3.475.

[3] Bhattacharyya, S. *et al.* Pharmacological Inhibition of Toll-Like Receptor-4 Signaling by TAK242 Prevents and Induces Regression of Experimental Organ Fibrosis. *Frontiers in Immunology* **9**, (2018).

[4] Emerging Roles of Innate Immune Signaling and Toll-Like Receptors in Fibrosis and Systemic Sclerosis | SpringerLink. https://link.springer.com/article/10.1007/s11926-014-0474-z.

[5] Bolourani, S., Brenner, M. & Wang, P. The interplay of DAMPs, TLR4, and proinflammatory cytokines in pulmonary fibrosis. *J Mol Med* **99**, 1373–1384 (2021).

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Towards Peptidase Mimicry by Supramolecular Tripeptide Assemblies

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The ability of some peptide sequences to self-assemble into functional nanostructures is an appealing alternative to the industrial use of natural enzymes, such as hydrolases.[1] Common designs incorporate sequences with a β-sheet conformation, and, in this regard, L-His-D-Phe-D-Phe is the first example of an unprotected tripeptide that gels at physiological conditions and catalyses ester hydrolysis.[2] C-terminal amidation yields L-His-D-Phe-D-Phe-$CONH_2$, which displays an improved catalytic ability.[3]

Our aim is to further enhance the catalyst performance through co-assembly with other sequences bearing residues commonly found in enzyme catalytic sites, such as L-Asp-D-Phe-D-Phe-$CONH_2$. The resulting nanostructured materials are being characterized by several techniques and will be tested for catalytic hydrolysis of chromogenic substrates, also under suitable conditions to apply the Michaelis-Menten model.

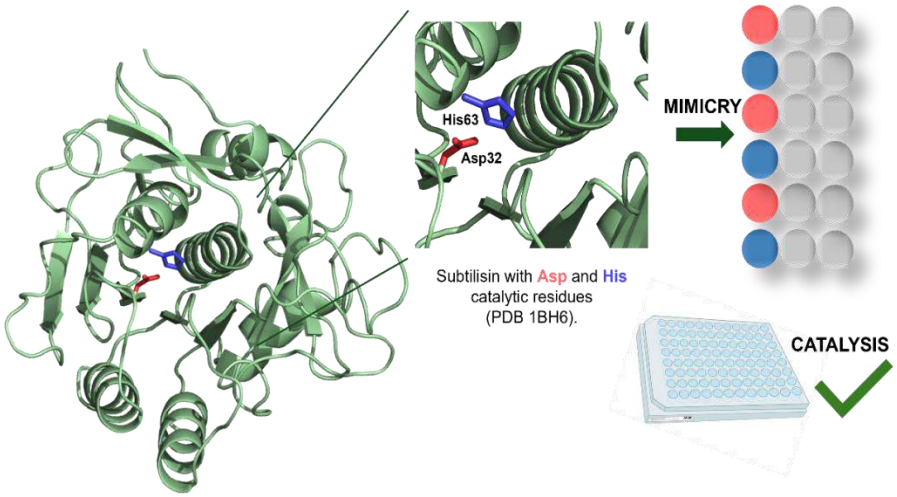

Figure 1: Hydrolase active site features Asp and His residues, which are used for the design of catalytic tripeptide co-assemblies.

References:

[1] P. Alletto, A. M. Garcia, S. Marchesan, *Gels* 2023, *9*, 678.
[2] A. M. Garcia, M. Kurbasic, S. Kralj, S. Marchesan, *Chem. Commun.* 2017, *53*, 8110-8113.
[3] M. Kurbasic, A. M. Garcia, S. Viada, S. Marchesna, *Molecules* 2021, *26*, 173.

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Metabolomic profiling to explore the role of PIN1 in mouse skeletal muscle

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PIN1 is a ubiquitous enzyme involved in the control of myofibers metabolic behaviour the roles of which in skeletal muscle is still to be defined.[1] We investigated the metabolic consequences of *Pin1* depletion in mammalian skeletal muscles using a murine model. In particular, a metabolomic study on slow-twitch soleus (SO) and fast-twitch tibialis anterior (TA) muscles, from *Pin1* knock out (KO, N=10) and wild type (WT, N=10) mice, was carried out using high-resolution magic angle spinning nuclear magnetic resonance (HR-MAS NMR) spectroscopy, directly applied on tissue samples, without any pre-treatment.[2]

Multivariate statistical analysis highlighted metabolic differences between SO and TA muscles. The SO samples are richer in lipids, fumarate, succinate, glutamate and glutamine, instead TA samples show higher content of creatine, glucose, lactate and pyruvate. These results agree with the notion that slow-twitching SO have an oxidative metabolism, whereas fast-twitching TA are characterized by glycolytic metabolism.

We detected metabolic changes in *Pin1* depleted muscles that suggest a tendency of TA to become more oxidative, whereas those observed on SO are more nuanced.

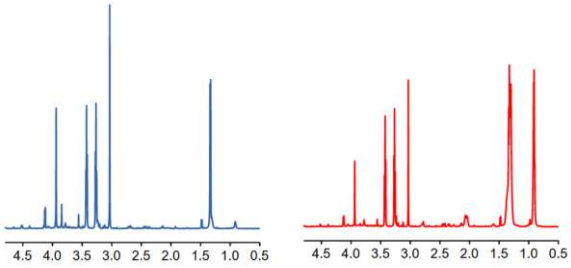

Figure 1: ^{1}H HR-MAS NMR spectra of TA (blue) and SO (red) muscles.

References:

[1] Y.C. Liou, X.Z. Zhou, K.P. Lu, Trends Biochem. Sci. 2017, 36, 501-514.
[2] L. Schenetti, A. Mucci, F. Parenti, R. Cagnoli, V. Righi, M.R. Tosi, V. Tugnoli, Concepts Magn. Reson. Part A 2006, 28A, 430-443.

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CSB-PO-009

New Promising Curcumin Mimics as Neurodegenerative Hallmarks Rescuers [1]

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Proteins' misfolding and the formation of their aggregates is a common event to several human pathologies (Protein Misfolding Diseases – PMDs) and neurodegenerative disorders, as Alzheimer's Disease (AD). Recently, it has been observed that a decreased activity of Ubiquitin Proteasome System (UPS),[2] fundamental pathway of misfolded or damaged proteins, leads to an accumulation of the proteins that plays a key role in Protein Conformational Diseases (PCDs). Starting from the selected lead-metabolite Curcumin (**Cur**),[3] reported to have an unprecedented therapeutic potential in the pathophysiology of AD, but poor pharmacokinetics (PK), different approaches of drug discovery[4] have been pursuing for the development of novel molecules capable both to interfere with protein misfolding processes and to enhance the activity of UPS. To create derivatives with better drug-like properties and inspired by the presence of common structural elements among small-ligand proteasome activators, we have designed, synthesized, and characterized a mini-library of novel Curcumin mimics by varying the two aromatic moieties and modulating the length and rigidity of the newly settled diamide spacers. (**Figure 1**). These compounds will be functionally probed for their antiaggregating ability and to stimulate h20S proteasome, both crucial capabilities in restoring cellular proteostasis. Resulting structure-activity relationships will be used to implement the pharmacophore model to drive future structure optimization.

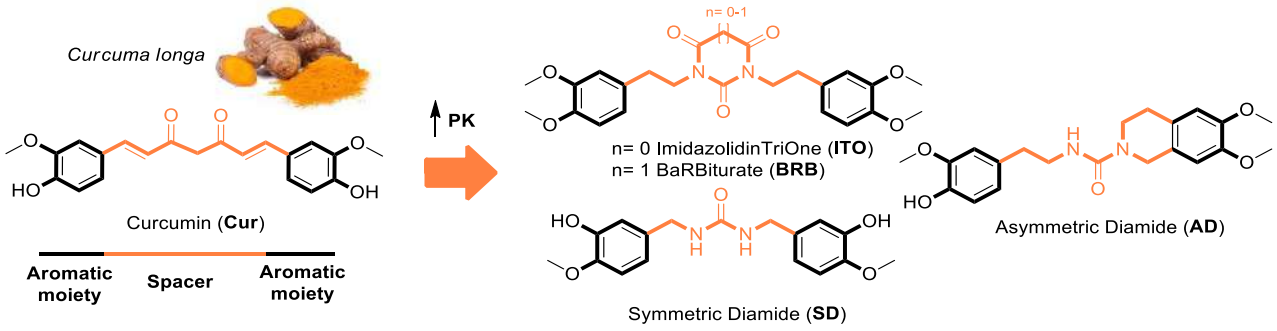

Figure 1: Curcumin and its synthetized mimics.

References:

[1] These studies were supported by the AIPRAS Onlus (http://www.aipras.org/).
[2] I. Dikic, Annual Review of Biochemistry 2017, 86, 193 – 224.
[3] K.M. Nelson, J.L. Dahlin, J. Bisson, J. Graham, G.F. Pauli, M.A. Walters, Journal of Medicinal Chemistry 2017, 60, 1620 – 1637.

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CSB-PO-010

Development of NIRF probes for FAP imaging

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Fibroblast Activation Protein is a pan-cancer target[1], thus the development of diagnostic approaches by targeting FAP would be impactful. Besides diagnostic imaging techniques, optical imaging guides the clinician's decision making in real-time, thus the development of novel tumour-targeted dyes has been increasing interest. This work aims at synthesizing, and *in vitro/in vivo* testing two novel FAP-targeting probes for Near Infrared-fluorescence imaging applications based on IRDye800CW and FNIRTag fluorophores. The FAP targeting fluorescent conjugates were synthesized through amidic bond (Fig 1A). The absorption, emission and excitation spectra were recorded at different concentrations both in PBS pH=7.4 and in PBS:MeOH (1:1). Stability in human serum and photobleaching were investigated by UPLC-MS and fluorescence emission decrement measurements respectively. Albumin binding was evaluated incubating the two molecules (0.5 μM) in human serum albumin (0-30 μM) for 1h at room temperature. The uptake on FAP-expressing cells (293T-FAP$^+$) was evaluated by flow cytometry measurements. Preliminary *ex vivo* experiments were conducted to assess the FAP expression, by inoculating subcutaneously TUBO cells in female *Balb-C* mice through flow cytometry analysis and immunohistochemical evaluation. *In vivo* fluorescence imaging studies were performed on TUBO tumor-bearing athymic mice by *i.v.* administration of 5 nmol of dyes. Biodistribution studies at 24h post injection were performed to quantify the fluorescence in the main organs. Photophysical properties investigation revealed a linear relationship in the range 0-2 μM and a 3-fold higher fluorescence for FAPI-FNIRTag (fluorescence measurements and phantom imaging). FAPI-IRDye800CW and FAPI-FNIRTag showed no degradation in serum and exhibited remarkable stability to photobleaching after 2h-irradiation, higher for FAPI-FNIRTag (92% vs 68%). Albumin binding data showed a comparable affinity, as shown from the K_D values obtained from the fitting of the binding isotherm (10^{-7}). Flow cytometry analysis revealed that the conjugation of FAP-inhibitor mojety to the fluorescent dyes did not affect the FAP specificity (Fig.1B). IHC staining and FACS analysis proved that TUBO tumor-bearing mice is a suitable model for the preclinical validation of imaging probes based on FAP-inhibitors. *In vivo* imaging studies (Fig. 1C) revealed a good tumor-to-background ratio for both of the dyes but competition experiments are needed to confirm the specificity of the signal. Biodistribution studies showed a liver uptake of the dyes and a kidney clearance. IRDye800CW and FNIRTag dyes are used for the first time to develop FAP-targeting NIRF probes with FAPI-46 FAP inhibitor.

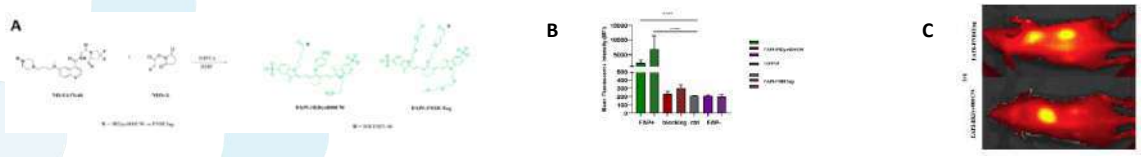

Figure 1 (A) Synthetic procedure. (B) Uptake on FAP-expressing cells. (C) *In vivo* imaging 24h p.i.

[1] C. Kratochwil et al., J. Nucl. Med. 2019, 60, 801–805.

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Targeting the Rel$_{Seq}$ Synthetase Domain with Amino Benzoic Acid Centred Inhibitors

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It is well established that antibiotic resistant bacteria have the genetics to specifically target and disarm an antibiotic's mode of action. The more obscure phenotypic resistance, i.e. *temporarily* antibiotic tolerant, has yet remained relatively unexplored. These elusive sub-populations called persisters, are in a transient pseudo-reduced metabolic state, sometimes occurring without environmental pressure. They can be multidrug tolerant and often contribute to chronic and recurring infections. Furthermore, persisters have been credited as an evolutionary stepping stone to antibiotic resistance.[1]

The downregulation of metabolism displayed by persisters is interconnected with activation of the stringent response and thus is believed to also be initiated by the accumulation of the intracellular signalling alarmone, guanosine penta- or tetra-phosphate, (p)ppGpp.[2] The intracellular concentration of (p)ppGpp is controlled by the superfamily of RSH (RelA/ SpoT Homologue) proteins (Fig.1), making them potential targets for drug development to reduce chronic infections and help restrict antibiotic resistance.

The main objective of this study is to design small molecules to selectively inhibit the synthetase domain of Rel proteins, from which we have chosen Rel$_{Seq}$ (*S. equisimilis)* as our model protein. Among the chemotypes identified through in silico screening,[3,4] we present the growth of the amino benzoic acid fragment into the first family of synthetase selective Rel inhibitors.[5]

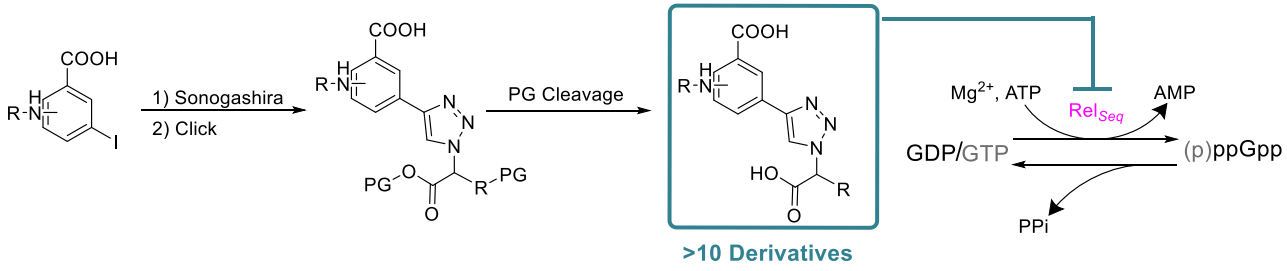

Figure 1: The general synthetic scheme of inhibitors designed around amino benzoic acid to inhibit the forward enzymatic reaction catalysed by the synthetase domain of RSH protein Rel$_{Seq}$. PG: protecting group.

References:

[1] I. Levin-Reisman, I. Ronin, O. Gefen, I. Braniss, N. Shoresh, N. Q. Balaban, *Science* **2017**, *355*, 826 – 830.
[2] S. E. Irving, N. R. Choudhury, R. M. Corrigan, *Nat. Rev. Microbiol.* **2021**, *19*, 256 – 271.
[3] M. Civera, S. Sattin, *Front. Mol. Biosci.* **2021**, *8*, 628596
[4] C. Coppa, L. Sorrentino, M. Civera, M. Minneci, F. Vasile, S. Sattin, *Molecules* **2022**, *27*, 3097
[5] S. Sattin *et. al.*, Manuscript in preparation, **2024**.

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Metabolic profiling of solid matrices under HR-MAS NMR and ASAP HR-MS conditions

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The NMR- and LC-MS-based metabolic profiling of complex matrices, such as whole cells, biopsies, or food flours, are usually carried out in the liquid state, after metabolite extraction.

Such approaches involve time-consuming sample manipulation that also prevents both relative and absolute quantification of matrix components since extraction efficiencies for the different metabolites strictly depend on the experimental conditions.

NMR analysis under High-Resolution Magic Angle Spinning (HR-MAS) conditions and High-Resolution Mass Spectrometry (HR-MS) with the Atmospheric Solids Analysis Probe (ASAP) allow the analysis of semi-solid and solid samples, respectively, the latter through desorption of compounds by heated nitrogen gas flow and ionization by corona discharge[1].

Here we report the application of both techniques to the analysis of the metabolites contained in five different food flour samples (rice, quinoa, chickpeas, faba beans, and lentils). We compared the data collected by extraction and analysis in the liquid state with the data provided under HR-MAS NMR and ASAP HR-MS conditions from both a qualitative and quantitative point of view.

Once validated, this approach will be very useful for rapid anti-fraud checks of foodstuffs but will also increase the versatility and speed of NMR and MS techniques in resolving complex mixtures of organic compounds in a wide range of applications, minimizing solvent usage and environmental impact.

[1] C. McEwen, R. McKay, B. Larsen, Anal Chem 2005, 77, 7826-7831

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CHEAP BUT RICH: Yeasts containing carotenoids and lipids as sustainable feed additives

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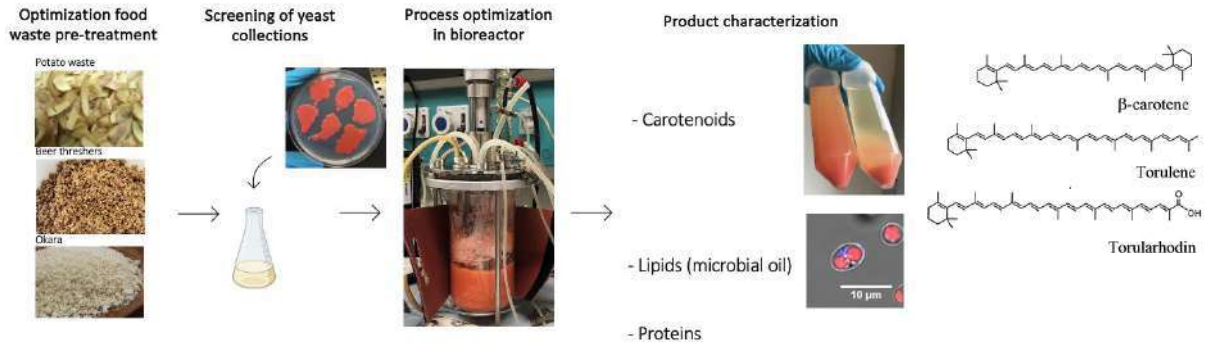
The global market of carotenoids, commonly included in animal feed as colorants and sources of antioxidants and vitamin A, is growing significantly together with the attention in their sustainable and green synthesis. The biotechnological production of carotenoids by yeasts emerges as a valuable strategy, also fitting the circular economy pillars when low-cost feedstocks are used as main components of culture media [1]. In the context of OnFOODS-PNRR, bioprocesses employing red yeasts were set up starting from agro-industrial residues such as potato waste, threshers, and soy okara. The enzymatic pre-treatment of waste residues was optimized to obtain a balanced and effective fermentation medium in terms of carbo and nitrogen sources. The HPLC screening of red yeast collections (including *Rhodosporidium* or *Rhodotorula* genera) revealed strains naturally rich in β-carotene but also in torulene and torularhodin, uncommon but potent carotenoids not yet commercially available [2]. The carotenoid production process on waste-derived medium was optimized in 2L bioreactor and stress conditions were applied to boost the production of carotenoid-rich biomass, reaching more then 100 mg/L of total carotenoids in 90h process, corresponding to 20 mg/g_{dw}. In addition, some of these strains are also oleaginous, meaning that they are able to accumulate intracellular triglycerides into vesicles called lipid bodies [3]. Notably, carotenoids produced by oleaginous yeasts are stored within these lipid bodies, enhancing their stability against oxygen and light exposure and preserving their nutritional and biological properties. Therefore, this product can be introduced in animal nutrition as lyophilised whole cells, thus serving as a multifunctional feed additive source of several valuable nutrients as carotenoids, lipids, and proteins.



[1] S. Bertacchi, C. Cantù, D. Porro, P. Branduardi, Fermentation 2021, 7, 208.
[2] A.M. Kot, S. Błażejak, I. Gientka, M. Kieliszek, M. Bryś, Microb Cell Fact 2018, 17, 49.
[3] S. Donzella, I. Serra, A. Fumagalli, L. Pellegrino, et al, Biotechnol Biofuels Bioprod 2022, 15, 51.

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Computational Study of a Metamorphic Protein

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Metamorphic proteins, also known as fold-switchers, are capable of interconverting their structure between two or more stable native states to perform different functions in response to changes in the environment. The origin and purpose of fold-switchers in protein evolution have been the subject of an exciting literature debate[1,2,3]. The selective access of different folds and functions suggests potential applications in drug discovery and molecular target treatment. A small molecule that interferes with the fold switch could directly control the biological process, offering a new avenue for function modulators. Known fold-switchers are present in both eukaryotic and prokaryotic cells and are involved in essential biological processes such as chemotaxis, cell cycle regulation, ion transport, and regulation of transcription and translation[4,5,6]. A metamorphic protein has also been discovered in the SARS-Cov-2 genome. The study examines the viral protein ORF9b13 and its interaction with the human mitochondrial protein Tom70. When co-expressed, ORF9b13 adopts an all-alpha conformation, whereas in isolation, it dimerizes as a beta-sheet protein[7]. The study of ORF9b revealed that two residues (S50 and S53) are the driving force for the conformational switch from alpha helix monomer to beta-sheet dimer[7].

Here we show a computational study of the metamorphic Collagen Binding Domain (CBD) from bacterial Collagenase. This enzyme degrades collagen tissue in cases of gangrene. The metamorphic properties of CBD are induced by changes in calcium concentration, as demonstrated by X-Ray, NMR, and SAXS. We simulated both metamorphic states of the CBD and identified atomistic details of the pseudo-transitions in metamorphic regions of the domain.

References:

[1] Davidson, A. R. *Proceedings of the National Academy of Sciences of the United States of America* 105, 2759–2760 (2008)
[2] Tian, P. *et al. PLOS Computational Biology* 16, e1008285 (2020)
[3] Sikosek, T. *et al. PLOS Computational Biology* 8, e1002659 (2012)
[4] Lei, Y. *et al. Microbes and Infection* 14, 262–267 (2012)
[5] Luo, X. *et al. Nature Structural & Molecular Biology 2004 11:4* 11, 338–345 (2004)
[6] Burmann, B. M. *et al. Cell* 150, 291–303 (2012)
[7] Porter, L. L. *Protein Science* 30, 1723–1729 (2021)

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Unraveling the molecular basis for G-quadruplex-binders targeting ALS/FTD-associated G4C2 repeats of the *C9orf72* gene

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The present work is part of the "HEAL ITALIA" project in the general context of the Italian National Recovery and Resilience Plan. The main goal of this extended partnership is the development of novel, inexpensive, and noninvasive diagnostic routes for more efficient prediction, detection, and monitoring of complex diseases. In this context, many research projects are currently being performed, and one of those will be the subject of the present communication.

Intronic G4C2 expanded hexanucleotide repeats in the *C9orf72* gene were identified as the most common genetic cause of amyotrophic lateral sclerosis (ALS) and frontotemporal dementia (FTD), two devastating neurodegenerative disorders. It was shown that these repeating sequences can fold into distinct G-quadruplex (G4) structures, which were recently solved using NMR techniques.[1] Small molecules, able to selectively target RNA G4C2 G4-forming repeats, showing promising therapeutical activities, were reported.[2] Unfortunately, to date, insights into the mechanism of action at the atomistic level for these compounds are still missing. For these reasons, considering the absence of any structural data, we have applied distinct computational tools to unravel the structural basis for the selectivity of these small molecules. Finally, we have tested the activity of the recently reported Au(I)/N-heterocyclic carbene G4-binder, $AuTMX_2$,[3] and we have rationally designed novel Cu(II) metal complexes able to strongly and selectively bind G4C2 repeats forming RNA G4 motifs. Thus, our findings could help to shed light on this novel potential therapeutic strategy to tackle neurodegenerative disorders.

References:

[1] Brcic, J.; Plavec, J. *Nucleic Acid Res.* **2018**, *46*, 11605-11617.
[2] Simone, R. et al., *EMBO Mol. Med.* **2017**, *10*, 22-31.
[3] Wragg, D.; De Almeida, A.; Bonsignore, R.; Kuhn, F.E.; Leoni, S.; Casini, A. *Angew. Chem. Int.* **2018**, *57*, 14524-14528.

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ANTICANCER EFFECTS OF TILORONE DIHYDROCHLORIDE IN DMBA INDUCED BREAST CANCER

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Breast cancer is one of the most commonly diagnosed cancers in females globally [1]. Type 1 interferons (IFNα and β) are known to have a considerable inhibitory impact on cancer cells' survival and growth. IFN1 induction stimulates cell intrinsic apoptotic pathways while simultaneously priming the immune cells to exert their cytotoxic effects on cells producing the IFN1 by activating the immune cells including the natural killer (NK) cells [2,3]. Further, IFN1 induction also suppresses oxidative stress and inhibits the release of tumor-promoting pro-inflammatory cytokines [4]. Also, the presence of a repressed IFN/STAT1 signature is correlated with the progression of breast cancer characterised by an increased epithelial to mesenchymal (E-M)/cancer stem cells (CSC) plasticity [5]. Tilorone dihydrochloride (Tilorone) is an orally active interferon-inducing agent that is used as an over-the-counter broad-spectrum antiviral agent [6]. Apart from its antiviral effects, tilorone has been shown to have anticancer effects that are mediated by multiple mechanisms including DNA intercalation and promotion of anticancer immunity mediated by interferon induction and activation of NK cells and cytotoxic lymphocytes [7]. On account of its interferon-inducing effects, we hypothesized that tilorone can have tumor suppressing effects on breast cancer by virtue of its opposing effects on tumor promoting pro inflammatory cytokines and oxidative stress. Therefore in the current studies, the relationship between oxidative stress, pro-inflammatory cytokines and tumor growth in response to treatment with tilorone in cell and animal model of breast cancer will be presented.

References

[1]. Giaquinto, A.N., et al., Breast Cancer Statistics, 2022. 2022. 72(6): p. 524-541
[2]. Holicek, P., et al., Type I interferon and cancer. 2024. 321(1): p. 115-127.
[3].von Locquenghien, M., C. Rozalén, and T. Celià-Terrassa, Interferons in cancer immunoediting: sculpting metastasis and immunotherapy response. J Clin Invest, 2021. 131(1).
[4].Bakrania, A.K., B.C. Variya, and S.S. Patel, Role of β-Interferon Inducer (DEAE-Dextran) in Tumorigenesis by VEGF and NOTCH1 Inhibition along with Apoptosis Induction. Front Pharmacol, 2017. 8: p. 930.
[5].Doherty, M.R., et al., Interferon-beta represses cancer stem cell properties in triple-negative breast cancer. 2017. 114(52): p. 13792-13797.
[6].Ekins, S., T.R. Lane, and P.B. Madrid, Tilorone: a Broad-Spectrum Antiviral Invented in the USA and Commercialized in Russia and beyond. Pharm Res, 2020. 37(4): p. 71.
[7].Sharapova, T.N., et al., Tilorone activates NK cells and cytotoxic lymphocytes that kill HLA-negative tumor cells. IUBMB Life, 2019. 71(3): p. 376-384.

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The Effect of Tolcapone on Metal-Free and Metal-Bound Protein Aggregation

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Emerging evidence suggests transition metal ions accelerate pathological protein aggregation. Imbalances in metal levels, notably copper, impact brain, tissue function and can worsen amyloidosis, leading to toxic protein build-up, oxidative stress, and inflammation. [1,2]

Tolcapone (3,4-dihydroxy-4′-methyl-5-nitrobenzophenone, Tol), an inhibitor of COMT, stands out as one of the most commonly prescribed FDA-approved medications for Parkinson's disease (PD) demonstrating remarkable potency as an adjunct to levodopa and carbidopa for the treatment of PD patients with motor fluctuations.[3] Additionally, Tol inhibits amyloidogenic protein aggregation, including Aβ and Syn, protecting against the cytotoxicity caused by their oligomers and aggregates.[4]

Despite the widespread use of Tol in PD treatment, its interaction with Cu^{2+} and Zn^{2+} has not been explored. To address this gap, we investigated the Cu^{2+} and Zn^{2+} complexes of Tol using various analytical techniques. Furthermore, we evaluated the ability of Tol to scavenge free radicals in the presence of metal ions and to affect the metal-induced aggregation of amyloidogenic proteins.

Our findings underscore the ability of Tolcapone to interact with metal ions and affect metal ion-triggered processes. This phenomenon offers potential to restore metal balance in amyloid diseases.

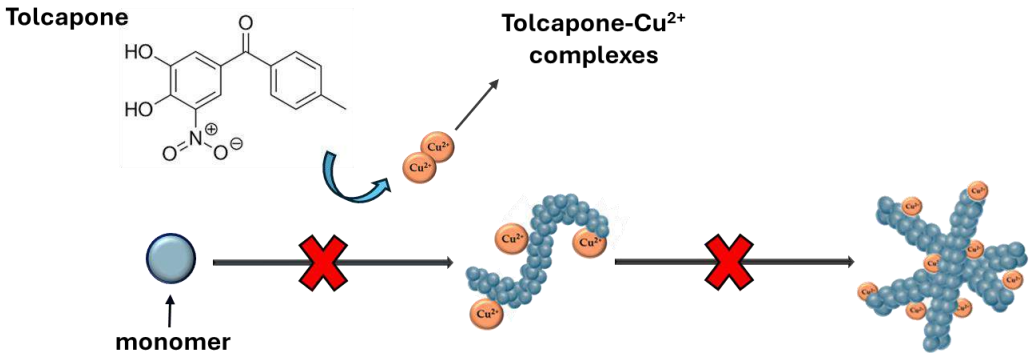

Figure 1: Schematic representation of the protein aggregation pathway promoted by Cu^{2+}.

References:
[1] V. Oliveri, Coordination Chemistry Reviews 2020, 422, 213474
[2] V. Oliveri, Molecules 2023, 28, 6446.
[3] C.W. Olanow, P.B. Watkins, Clinical neuropharmacology 2007, 30(5), 287-294
[4] S. Di Giovanni, S. Eleuteri, Journal of Biological Chemistry 2010, 285, 14941-14954.

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Design of new inclusion complexes between cyclodextrins and fungal compounds increasing antiviral activity against Bovine Coronavirus

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Funicones and structurally related compounds represent a homogeneous group of fungal polyketides that were initially characterized as determinants of the antagonistic abilities by the producers against other microorganisms but were later found to possess remarkable biological properties that have promoted their consideration as drug prospects[1]. Furthermore, their low toxicity, high bioavailability, low molecular weight, and chemical structures make them compatible for designing various pharmaceutical formulations. Within our recent activity aimed at studying the antiviral properties of 3-O-methylfunicone (OMF), a member of this group of secondary metabolites obtained from Talaromyces pinophilus, were studied. The results showed that OMF is able to reduce the infectivity of bovine herpesvirus and canine coronavirus. (CCoV), in addition two additional funicon-like compounds, penimplicixin and vermistatin, were also tested in CCoV[2]. Cyclodextrins (CDs) are used in pharmaceutical formulations for their ability to improve the pharmacokinetic characteristics of the species included[3]. In particular, OMF has a low solubility, therefore the formation of inclusion complexes between CDs and OMF can improve this aspect, also increasing its bioavailability, allowing for better administration in animal organisms. In view of their potential application as novel drugs against coronaviruses (CoV), inclusion complexes involving the use of β-cyclodextrin (β-CD) as a complexing agent have been designed. The affinity that funicons have towards β-CD was evaluated by Molecular Docking. UV-Vis analysis of the complex was used to determine the stoichiometry of the complex and binding affinity. Finally, following CoVs (Bovine, Canine, and Feline CoVs) infection *in vitro*, cytotoxicity analysis and antiviral activity of inclusion complexes will be performed.

References:

[1] Salvatore M. M., DellaGreca, M., Andolfi, A., & Nicoletti, R., *Toxins* 2022**,** 14, (7), 466.
2. Cerracchio, C., Salvatore, M. M., Del Sorbo, L., Serra, F., Amoroso, M. G., DellaGreca, M., ... & Fiorito F, 2023**,** 12(8), 1319.
3. Di Donato C, Lavorgna M, Fattorusso R, Isernia C, Isidori M, Malgieri G, Piscitelli C, Russo C, Russo L, Iacovino R. *Molecules* **2016,** *21*, 1644. doi: 10.3390/molecules21121644. PMID: 27916966; PMCID: PMC6273350

CSB-PO-019

NMR Characterization of metabolic response in glioblastoma cells interacting with gold nanorods.

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Magnetic Resonance Spectroscopy (MRS) is a very powerful and non-invasive technique for the study of biological systems *in vitro.* MRS may provide information on cultured tumour cell metabolism, aiming to an increased knowledge of cell response to anti-cancer therapies.[1] In particular, once identified the most relevant metabolic signals (spectroscopic markers), their variations can give insight on the response of tumour cells to different treatments, including drug delivery systems based on gold nanorods (AuNRs).[2] AuNRs are arousing great interest in the biomedical field, thanks to their peculiar physicochemical properties, and the possibility of differentiated surface functionalization, allowing the transport of drugs.[3,4] This study focused on the synthesis and characterization of AuNRs stabilized with cetyltrimethylammonium bromide (AuNRs-CTAB) and their effects on the metabolism of a glioblastoma cell line (namely, T98G). ^{1}H MRS characterization of the metabolic profile of T98G cells was performed to identify the main observable metabolic pathways. Then, ^{1}H MR cell spectra were acquired at different times after T98G incubation with AuNRs-CTAB at different concentrations. Both one-dimensional (1D) and two-dimensional COrrelation SpectroscopY (2D COSY) spectra were acquired.

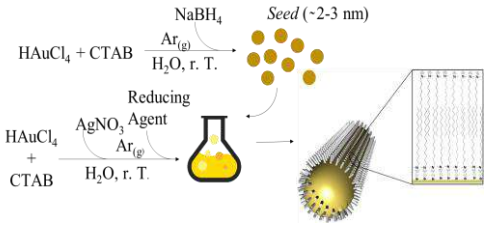

Figure 1. Schematic steps of AuNRs-CTAB synthesis.

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References:

[1] A. Palma et al., Int J Mol Sci. 2021, 22(23), 12709.
[2] I. Venditti; Bioengineering 2019, 6(2), 53
[3] L. Binelli et al. Nanomaterials 2023, 13, 1898
[4] F. Silva, et al., Materials, 2021, 14, 4.

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Molecular Dynamics Simulations Elucidate the Molecular Basis of Pre-mRNA Translocation by the Prp2 Spliceosomal Helicase

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The following abstract is based on a recently published paper:
S.N. Agrò, et al. "Molecular Dynamics Simulations Elucidate the Molecular Basis of Pre-mRNA Translocation by the Prp2 Spliceosomal Helicase." J. Chem. Inf. Model. (2023) 63(13), 4180-4189.

The spliceosome is a dynamic molecular machinery essential for precursor-messenger RNA (pre-mRNA) splicing, orchestrated by specific RNA-dependent ATPases/helicases. In the study cited above, we delve into the functional dynamics of Prp2, a member of the DExH-box ATPase/helicase family, which harnesses the energy of ATP hydrolysis to translocate a single pre-mRNA strand in the 5′ to 3′ direction, thus promoting spliceosome remodeling to its catalytic-competent state[1].

Through extensive molecular dynamics simulations, we uncovered the functional coupling between ATPase and helicase activities of Prp2. Our findings reveal a typewriter-like rotation of the Prp2 C-terminal domain, driven by pre-mRNA selection, ATP binding, hydrolysis, and dissociation. This rotational movement is facilitated by the swing of interactions between Prp2 residues and nucleobases at the 5′- and 3′-ends of pre-mRNA, ultimately driving the translocation of pre-mRNA. Moreover, our results suggest a conserved translocation mechanism across the DExH-box helicase family, with implications for understanding splicing regulation in diverse cellular contexts.

Dysregulation of DExH-box ATPase helicases can often be associated with tumorigenesis and genetic diseases, as they are involved in vital biological functions[2]. The molecular mechanism of Prp2 described in this study provides a basis for the therapeutic development of RNA helicase inhibitors for the treatment of several human diseases.

References:

[1] *F. Hamann, L. C. Zimmerningkat, R. A. Becker, R. A.; T. B. Garbers, P. Neumann, J. S. Hub, R. Ficner, Acta Crystallogr., Sect. D:Struct. Biol. 2021, 77, 496−509.*
[2] *O. Andrisani, Q. Liu, P. Kehn, W. W. Leitner, K. Moon, N. Vazquez-Maldonado, I. Fingerman, M. Gale, Nat. Immunol. 2022, 23, 354−357.*

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New class of contrast agents for Ultra-low field Overhauser MRI, responsive to esterases enzymatic activity.

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The assessment of enzyme activity is a critical factor in the early diagnosis of many diseases. In this study, we propose the use of the Ultra-Low field Overhauser MRI (OMRI) as an alternative diagnostic approach for the detection of enzymatic activity.[1] OMRI is a double resonance imaging technique that combines the advantages of MRI with the use of stable radicals as polarizing agents to enhance the NMR proton signal.[2] For this purpose, a "off/on" radical probe in micellar form was investigated to target esterase enzymes over-expressed in pathological tissues. We synthesized an Oxo-TEMPO radical derivative containing an ester group and an aliphatic chain, namely Tempo-2-C_{12} ($T2C_{12}$).[3] A new formulation with Tween 80 (T80) (20 mol %) was also investigated and in aqueous solution the two compounds self-aggregate to form EPR-silent micelles ($T2C_{12}$-T80) with an enhanced stability and reduced size. But in presence of esterases, the radical becomes free in solution showing an intense EPR signal, that is correlated to the enzyme activity. Thank to this change in the EPR signal, allows the probe to act as a reporter of enzymatic activity with OMRI. The enzymatic activity was well detected with ultra-low field OMRI system at 206 μT using this OFF/ON system displaying any signal when the probe is in micellar form. On the other hand, after the hydrolysis an increase of the Overhauser enhancement is observed, giving bright images. Furthermore, preliminary tests were performed by incubating the $T2C_{12}$-T80 probe with human pancreatic cancer (HS776t), human hepatocarcinoma (HepG2) and fibroblast (3T3) cytosolic cells extracts to evaluate the expression of esterases. The results confirmed a higher expression of esterases in tumour cells compared to healthy fibroblast 3T3. In summary, $T2C_{12}$-T80 probes provide an excellent technique for detecting enzymatic activity in diseases characterized by esterase overexpression. For the first time, an in vitro esterase kinetic were monitored with an OMRI system that operates almost at earth field, revealing an enormous off-on change of the signal caused solely by probe hydrolysis. The results proved the technique's great potential and its possible translation to in vivo OMRI.

References:

[1] D. Boudries, P. Massot, E. Parzy, S. Seren, P. Mellet, J.-M. Franconi, S. Miraux, E. Bezançon, S. R. A. Marque, G. Audran, M. Muetzel, S. Wintzheimer, F. Fidler and E. Thiaudiere, *J. Magn. Reson.*, 2023, **348**, 107383.
[2] D. J. Lurie, D. M. Bussell, L. H. Bell and J. R. Mallard, *J. Magn. Reson. 1969*, 1988, **76**, 366–370.
[3] S. Elkhanoufi, R. Stefania, D. Alberti, S. Baroni, S. Aime and S. G. Crich, *Chem. – Eur. J.*, 2022, e202104563.

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Detergent Screening for Membrane Protein Purification

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Gram-negative bacteria build a cell wall that functions as a protective envelope around their cell membrane. Lipopolysaccharide (LPS) units are among the primary components of this wall. A collection of membrane proteins, very unique to each bacterial strain, controls the synthesis of the LPS[1]. This project aims at characterizing two of these proteins, WZX and WZY, to understand their structure and function. In the long term, the goal of this research is to hamper the construction of the protective wall of Gram-negative bacteria, thus weakening their defenses.

We developed a good purification protocol that allows the isolation of significant amounts of WZX in detergent solution, a crucial step in the characterization of the protein through structural techniques. However, initial results from light scattering and circular dichroism indicate a short-term protein stability in detergent micelles.

In membrane protein (MP) structural studies, the identification of a detergent able to preserve the native conformation of the target is often a challenging process[2]. For this reason, we started working on the development of an in-silico approach to detergent screening. A library of detergent models has to be established by building micelles of various surfactants. These systems will be examined along time utilizing molecular dynamics. However, as traditional approaches to molecular dynamics of single proteins are not suitable for large micelles held together by hydrophobic interactions, a new protocol for relaxing the system has already been evaluated and optimized to improve the stability of the models.

The behavior of the in silico system is compared with experimental data to validate the protocol. Testing with different detergents highlights the best detergent, or detergent mixture, to stabilize the native structure of WZX and WZY.

Furthermore, mutations can enhance membrane protein stability outside of the cell membrane. We apply computational techniques to identify single-point mutations able to stabilize the protein folding. The best mutants of WZX and WZY will be expressed as recombinant proteins.

References:

[1] S. M. Huszczynski , Pathogens. 2019,
[2] M. Orwick-Rydmark, T. Arnold, D. Linke, Curr Protoc Protein Sci. 2016,

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Antiviral Compounds Against SARS-CoV-2

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In 2020, we took a leap back in time, from the era of modern medicine to the great flu of 1918. The recent pandemic caught us off guard, with the same defence tools as the last century. As one group, several researchers from all over the world have turned their attention to the discovery of new antivirals. The research line based on the chemistry of nitrosocarbonyls generated from nitriloxides has been active in Pavia since 1997. Through the use of computational methods we wanted to investigate which molecules potentially active as antivirals could be accessed via these two synthetic routes.[1,2] Two different enzymatic targets have been studied: RNA polymerase and protease. Docking experiments of nucleotide derivatives were conducted on the first target, characterized by different modifications of the scaffold and the heterobase, obtained through the 1,3-dipolar cycloaddition of different nitriloxides to N-benzoyl-2,3-oxazanorborn-5-ene, in the crystal structures of SARS-CoV-2 RdRp in the pre- and post-catalytic state. The docking poses were classified and compared, the best ones were subjected to molecular dynamics simulations and the trajectories analyzed focusing on the requirements necessary for catalysis. With these tools, structural modifications have been proposed to improve the affinity of compounds to the catalytic pocket.[3] As regards the second target, M^{Pro}, following the analyzes performed on the most representative structures identified through molecular dynamics of the dimer, two allosteric sites with good druggability characteristics were identified. By characterizing the allosteric pockets thus identified with a clustering approach, a docking screening of a database containing compounds obtainable via the chemical pathways studied in this research unit was performed on the representative structures. Then, MDs simulations of the complexes gave us clues regarding allosteric effects of the designed nitrosocarbonyl derived compounds. This allowed the selection of candidate molecules to synthesize. Antiviral activity tests are ongoing to evaluate the agreement between computational predictions and the biological systems studied. Initial biological testing has shown that, at present, one compound stands out in terms of activity compared to others, with the ability to reach an IC_{50} of 22 µM.

References:

[1] M.G. Memeo, F. Lapolla, B. Bovio, P. Quadrelli, Tetrahedron 2004, 60, 3643-3651.
[2] Memeo, M.G. Memeo, P. Quadrelli, Chemical Reviews 2017, 117, 2109-2200.
[3] M. Leusciatti, B. Macchi, F. Marino-Merlo, A. Mastino, G. Morra, P. Quadrelli, ACS Omega 2023, 8, 36311-36320.

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Photochemotherapy by design

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Photochemotherapy (PCT) is an emerging cancer treatment that combines phototherapy and chemotherapy.[1] This kind of combination therapy can provide a more potent treatment than using either treatment alone, leading to additive and synergistic antitumor effects. Since PCT is based on the administration of two different compounds, a photosensitizer (PS) and a chemotherapeutic drug, many problems can arise due to the different pharmacokinetic and/or pharmacodynamic profiles of the two molecules.[1]

Here we propose two innovative approaches to develop novel solutions for PCT:

i) Use of proteins or protein nanoparticles to simultaneously transport both the photosensitizer and the chemotherapeutic drug. We have previously showed the ability of human serum albumin (HSA) to disperse temoporfin (mTHPC), an approved photosensitizer. This protein-based formulation improves the phototoxicity of mTHPC, when compared to its clinical formulation.[2] Through a virtual screening approach we now identified chemotherapeutic drugs capable of binding to HSA in a different pocket than the PS, creating an efficient protein-based delivery systems loaded with both the chemotherapeutic agent and the PS.

ii) Exploitation of the intrinsic photosensitizing properties of some chemotherapeutic drugs, like doxorubicin,[3] to enhance their anticancer activity upon light irradiation. We built a structural database of approved anticancer drugs, and we calculated all the photophysical properties of these molecules. We identified 17 promising molecules (i.e. mitoxantrone, pixantrone, daunorubicin, dactinomycin, sunitinib) with the photochemical characteristics to be also a PS. In principle, these chemotherapeutic drugs *per se* can be also used as a PS in phototherapy.

For both the approaches we selected the most promising candidates for *in vitro* testing. We observed excellent results, validating the new developed PCT protocols, through the i) simultaneous transport of the PS and the chemotherapeutic drug with a protein-based formulation and ii) light-enhanced cytotoxicity by photoactivation of selected approved drugs.

References:

[1] D. Luo, K. A. Carter, D. Miranda, J. F. Lovell, Adv. Sci. 2017, 4, 1600106.
[2] E.J. Mattioli, L. Ulfo, A. Marconi, V. Pellicioni, P.E. Costantini, T.D. Marforio, M. Di Giosia, A. Danielli, C. Fimognari, E. Turrini, M. Calvaresi Biomolecules 2023, 13, 68.
[3] G. Greco, L. Ulfo, E. Turrini, A. Marconi, P.E. Costantini, T.D. Marforio, E.J. Mattioli, M. Di Giosia, A. Danielli, C. Fimognari, M. Calvaresi, Cells 2023, 12, 392.

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CSB-PO-025

Expression of the Nucleocapsid Protein (N) from SARS-CoV 2 and its Characterization through High-Field NMR Spectroscopy

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The Nucleocapsid protein (N) of SARS-CoV-2 is a complex protein with 419 amino acids, including an N-terminal RNA binding domain (NTD), a C-terminal dimerization domain (CTD), and three intrinsically disordered regions (IDRs)[1]. N is highly expressed, and during viral infection plays a crucial role in organizing the RiboNucleoProtein complex, essential for viral replication. Our central aim is to characterize the Full-Length (FL) N protein and study its interaction with RNA. We want to understand how this interaction evolves with increasing system complexity, from NTD (44-180) to FL (1-419), including a construct comprising the NTD and the two flanking IDRs (NTR 1-248). Studies on NTR have highlighted that the NTD's affinity for nucleic acids is augmented by the presence of the two positively charged disordered regions[2]. The FL protein, which forms a dimer through its CTD domain, is expected to further increase N's affinity for RNA due to synergistic effect. Therefore, we have chosen to enlarge our focus moving our attention from the smaller NTR construct to the more complex and interesting FL protein. Here I will present the latest results on FL protein, starting from its challenging expression and purification. Its structural and dynamic features are obtained through Nuclear Magnetic Resonance (NMR) and compared with those of smaller constructs.

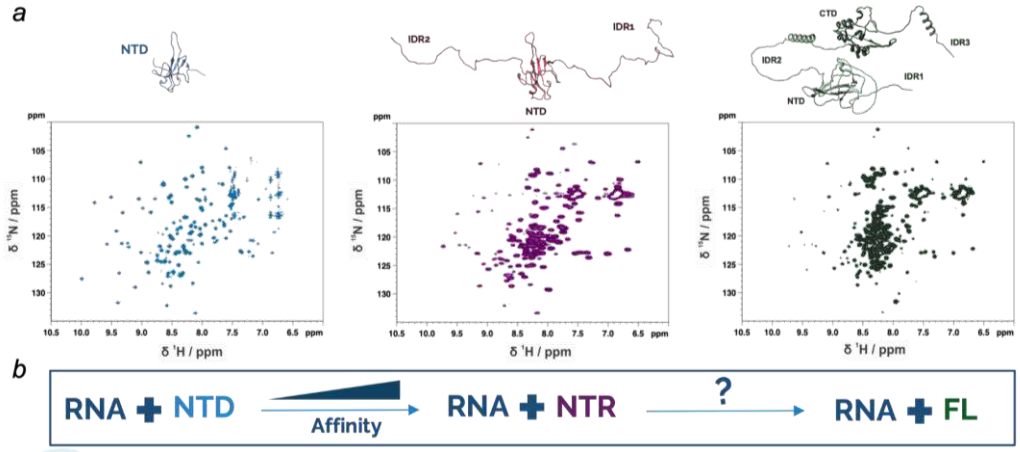

Figure 1: Panel *a* reports a possible conformation for each of the three *in-studio* constructs (NTD blue, NTR purple, FL green) with their corresponding HN-HSQC spectra; Panel *b* shows schematically the increased affinity for RNA moving from NTD to NTR and our upcoming subject of study.

References:

[1] L. Pontoriero, M. Schiavina, S. M. Korn, A. Schlundt, R. Pierattelli, I. C. Felli, Biomolecules **12**, 929 (2022)
[2] M. Schiavina, L. Pontoriero, G. Tagliaferro, R. Pierattelli, I. C. Felli, Biomolecules **12**, 1302 (2022)

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Characterization of different metal adducts in human Carbonic Anhydrase II for artificial photosynthesis

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Natural photosynthesis inspired the development of artificial devices aiming to convert solar energy into chemical energy. In this scenario, artificial photosynthesis (AP) might lead to more sustainable ways for energy production based on light-driven water splitting, with not-polluting gases as side-products (e.g., O_2 and H_2).[1] The present work aims to develop and optimise novel biological catalysts for their application in AP. Human carbonic anhydrase II (hCAII) is a ubiquitous enzyme catalysing the reversible hydration/dehydration of carbon dioxide/bicarbonate.[2] The Zn^{2+} metal ion is an essential cofactor for hCAII, being located in the protein active site where it tetrahedrally coordinated by three histidine residues. As reported in previous works, the replacement of zinc with different metal ions (e.g., Co^{2+}, Ni^{2+}, Cu^{2+}, Mn^{2+}) can modify the catalytic activity of hCAII, opening new interesting perspectives for biotechnological application.[3]

To this end, we focused on the development of metal-substituted hCAII to explore their role in modulating the catalytic activity of the enzyme. In particular, we focused on Ir^{3+}-substituted hCAII, because it was formerly reported to acquire peculiar water-splitting properties.[4] In this work, hCAII was expressed as recombinant enzyme in *E. Coli,* and the active protein was attained from multiple chromatographic stages (direct and reverse affinity, and size exclusion). Following the removal of zinc via chelation, the apo-protein was used to obtain various metal substitutions. The metal-substituted enzymes were then characterized through Isothermal Titration Calorimetry and X-ray crystallographic analysis. Furthermore, we also characterized the water-splitting capabilities of metal-substituted hCAIIs for AP applications. The structures of the metal-adducts revealed the pivotal contribution in metal binding of different His-residues. Their role in metal binding and catalysis has been recently investigated by the generation of mutants, obtained through site-directed mutagenesis. Our studies aim to obtain engineered enzymes, having increased turnover rates of oxygen production and long-term stability, exploitable for large-scale implementation in AP.

References:

[1] E. S. Andreiadis, Photobiol. 2011, 87 (5), 946–964
[2] V. M. Krishnamurthy, Chem. Rev, 2008, 108, 946–1051
[3] I. Bertini, C. Luchinat, A. Scozzafava, Structure and Bonding 1982, 48:45–92
[4] M. C. Kim, S.Y.Lee, Chem. - An Asian J. 2018, 13 (3), 334–341

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Impact of aberrant N-glycosylation on GRP94 functionality: insights from Molecular Dynamics simulations

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The glucose-regulated protein 94 (GRP94), a member of the Hsp90 family, acts as a chaperone in the endoplasmic reticulum, aiding in the folding and activation of client proteins. Structurally, GRP94 is a homodimer with three globular domains per chain: the N-terminal, middle, and C-terminal. Mechanistically, ATP binding at the N-terminal domain induces conformational changes in GRP94, facilitating client protein binding and folding. Upon ATP hydrolysis, rearrangement of client-binding-site residues occurs, inducing conformational changes in the bound client protein.

Recently, a glycosylation-dependent disease specific variant of the chaperone GRP94 has been identified[1]. Aberrant glycosylation at specific asparagine residues triggers a structural shift in GRP94, leading to its relocation to the plasma membrane and stable interactions with the membrane proteins. This altered state transforms GRP94 from a folding to a scaffolding protein, resulting in the reorganization of protein assembly and connectivity, ultimately leading to widespread proteome dysfunction and disruption of normal cellular pathways.

In this study, we use molecular dynamics simulations to elucidate, at an atomistic level, the mechanism by which N-glycans at different protein sites modulate the conformational dynamics of GRP94, affecting both its interaction mode with clients and nucleotide processing, and ultimately GRP94's function. More specifically, our findings reveal a crucial structural role of N-glycans in regulating the internal dynamics of the protein, which is associated with its functional motions. Furthermore, we demonstrate that N-glycosylation promotes specific protein states, ultimately influencing interactions with different partners involved in the assembly of complexes determining cell phenotypes. Finally, we used these insights to rationalize the engagement of GRP94's conformational states by both active and inactive ligands, providing guidance for designing molecules targeting disease-specific, aberrantly glycosylated variants of GRP94.

References:

[1] Yan, P., Patel, H.J., Sharma, S., Corben, A., Wang, T., Panchal, P., Yang, C., Sun, W., Araujo, T.L., Rodina, A., et al. 2020, Cell Rep. 31, 107840.

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Unrevealing NLP cytolysin dynamics: All-Atom Simulation of pore formation in plant Plasma Membrane

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Global food security is constantly threatened by plant pathogens that cause crop diseases. This is mainly due to the ability of pathogens to develop new invasion strategies through their effective co-evolution with hosts. Microbial plant pathogens secrete a wide range of effector proteins to facilitate infection. Necrosis- and ethylene-inducing peptide 1 (Nep1)–like proteins (NLPs) form a large family of microbial proteins produced by bacteria, fungi and oomycetes. NLP-producing pathogens infect a variety of important crops, including potatoes, tomatoes, soybeans, grapevines and tobacco[1].

NLPs are the only known cytolytic pathogen effectors that can permeabilize plasma membranes of eudicot plants by forming transient small pores. Recently, major plant membrane components, glycosylinositol phosphorylceramides (GIPCs), have been identified as targets of NLP binding to plant plasma membranes. NLP has been shown to oligomerize on plant membrane, but the molecular mechanism of oligomerization and pore formation of NLPs remains elusive[2].

This research aims to improve our understanding of the interaction between NLP toxins and plant plasma membranes. In particular, we aim at unravelling the molecular mechanism of membrane pore formation as induced by NLP monomers and oligomers and the behaviour of protein/lipid complexes during membrane attachment. In doing so, we employed AI-based modelling tools and all-atom computer simulations, which provide well-established support for experimental methods by allowing the determination of key interactions at the atomic level and the time-dependent monitoring of the accessible conformational space of protein-lipid complexes. These findings are expected to support the development of innovative and efficient strategies to control plant diseases caused by NLP-producing pathogens.

References:

[1] K. Pirc, L.A Clifton, , N. Yilmaz, A. Saltalamacchia, M. Mally, T. Snoj, N. Žnidaršič, M. Srnko, J. Borišek, P. Parkkila, I. Albert, M. Podobnik, K. Numata, T. Nürnberger, T. Viitala, J. Derganc, A. Magistrato, J. H. Lakey And G Anderluh., Sci Adv 2022, 8, eabj9406.

[2]T. Lenarčič, I. Albert, H. Böhm, V. Hodnik, K. Pirc, A. B. Zavec, M. Podobnik, D. Pahovnik, E. Žagar, R. Pruitt, P. Greimel, A. Yamaji-Hasegawa, T. Kobayashi, A. Zienkiewicz, J. Gömann, J. C. Mortimer, L. Fang, A. Mamode-Cassim, M. Deleu, L. Lins, C. Oecking, I. Feussner, S. Mongrand, G. Anderluh And Thorsten Nürnberger, Science 2017, 358, 1431–1434.

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PROTAC-based approach to develop broad-spectrum antiviral agents triggering the proteolysis of the major viral protease

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In 2020, with the spread of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection, the PROteolysis TArgeting Chimeras (PROTACs) strategy to defeat coronaviruses (CoV) disease was also investigated[1]. Indeed, PROTAC degraders acting against the major viral protease 3-chymotrypsin-like protease ($3CL^{Pro}$) were hypothesized to be next-generation anti-CoV drugs[2]. $3CL^{Pro}$ (also named nsp5 or main protease) is shared by all coronavirus genera as well as by members of the large genus Enterovirus in the Picornavirus family[3]. Combining NMR spectroscopy and X-ray crystallography, we characterize the interaction between the α, β-unsaturated peptidomimetic-based PROTAC (FT235) with $3CL^{Pro}$ from SARS-COV-2 and $3C^{Pro}$ from Coxsackievirus B3 (CVB3), the latter being a cardiotropic virus belonging to enterovirus genus[4]. The results are compared with those obtained with the precursor molecule (FT234). We demonstrate that PROTAC molecule bind to the active site of both enzymes and the residues involved in the interaction are identified by solution NMR experiments. Furthermore, the crystal structures of SARS-CoV-2 $3CL^{Pro}$ in complex with both FT234 and FT235 molecules are obtained. For both ligands the Cβ carbon of the α, β-unsaturated amide moiety forms a covalent bond with the catalytic Cys145. Moreover, we obtain the crystal structure of $3C^{Pro}$ from CVB3 in complex with FT234 molecule, revealing the covalent binding with Cys147. Finally, preliminary cellular studies show that the synthetized PROTAC molecule drastically reduces protein levels of SARS-CoV-2 $3CL^{Pro}$ in cultured cells. In the future the interaction of PROTAC molecule with both proteases and Cereblon, the substrate receptor of the CRL4 E3 ubiquitin ligase responsible for the polyubiquitination of the target proteins, will be investigated to verify the formation of a stable ternary complex.

References:

[1] J. Desantis, L. Goracci, Future Med Chem. 2022, 14, 459-462.
[2] M. Shaheer, R. Singh, ME. Sobhia, J Biomol Struct Dyn. 2022, 40, 10905-10917.
[3] L. Zhang, D. Lin, Y. Kusov, Y. Nian, Q. Ma, J. Wang, A. von Brunn, P. Leyssen, K. Lanko, J. Neyts, A. de Wilde, EJ. Snijder, H. Liu, R. Hilgenfeld, J Med Chem. 2020, 63, 4562-4578.
[4] C. Massilamany, A. Gangaplara, J. Reddy, Int J Cardiol. 2014, 177, 330-339.

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Cell-Free and In Vivo Characterization of the Inhibitory Activity of Lavado Cocoa Flavanols on the Amyloid Protein Ataxin-3: Toward New Approaches against Spinocerebellar Ataxia Type 3

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Spinocerebellar ataxia type 3 (SCA3) is a neurodegenerative disorder characterized by ataxia and other neurological manifestations, with a poor prognosis and a lack of effective therapies. The amyloid aggregation of the ataxin-3 protein is a hallmark of SCA3 and one of the main biochemical events prompting its onset, making it a prominent target for the development of preventive and therapeutic interventions.

Here, we tested the efficacy of an aqueous Lavado cocoa extract and its polyphenolic components against ataxin-3 aggregation and neurotoxicity. The combination of biochemical assays and atomic force microscopy morphological analysis provided clear evidence of cocoa flavanols' ability to hinder ATX3 amyloid aggregation through direct physical interaction, as assessed by NMR spectroscopy. The chemical identity of the flavanols was investigated by NMR spectroscopy and ultraperformance liquid chromatography-high-resolution mass spectrometry. The use of the preclinical model Caenorhabditis elegans allowed us to demonstrate cocoa flavanols' ability to ameliorate ataxic phenotypes in vivo.[1]

To the best of our knowledge, Lavado cocoa is the first natural source whose extract can directly interfere with ATX3 aggregation, leading to the formation of off-pathway species.

References:

[1] B. Sciandrone, A. Palmioli, C. Ciaramelli, R. Pensotti, L. Colombo, M. E. Regonesi, C. Airoldi, *ACS Chem. Neurosci.* 2024, 15, 2, 278–289.

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Exploring the molecular dynamics of SARS-CoV-2 nsp13 helicase: production, protocol optimisation and drug screening for COVID-19 therapeutics

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The multifunctional non-structural protein nsp13 is an helicase encoded on the ORF1b and consists of 601 amino acids. It belongs to the superfamily 1B and exhibits a high degree of conservation across all Coronaviruses. Nsp13 plays a crucial role in viral replication, initiating the first step of RNA cap synthesis. This capping process is essential for shielding the viral RNA from cellular innate immune responses, stabilising it, and facilitating its translation[1,2]. The installation of the type 1 cap (m7GpppNm-RNA) involves several enzymes: nsp13, nsp14, nsp16, and nsp10. Nsp13 functions as an RNA 5'-triphosphatase, catalyzing the hydrolysis of the 5' γ-phosphate of the pppN-RNA as the initial step of capping. In addition to its role in RNA capping, nsp13 exhibits NTP-dependent unwinding of RNA duplexes with a 5' to 3' polarity. This activity is enhanced by its interaction with nsp12, the RNA-dependent RNA polymerase (RdRp). Nsp13 consists of five domains: the N-terminal Zinc binding domain (ZBD) (amino acids 1-100), the stalk domain (101-150), 1B (151-261), 1A (262-442), and the 2A domain (443-601). Research indicates that the latter three domains are responsible for nucleic acid binding and NTPase activity[2].

In an effort to better elucidate the molecular behaviour of the enzyme and explore potential therapeutics for COVID-19, my project involved the production of the SARS-CoV-2 nsp13 protein. To enhance existing protocols, particularly those detailed by Chen et al. 2020, adjustments were implemented, primarily focusing on the choice of expression system and the timing of zinc administration to the Rosetta PlysS strain, before induction in the protein production process. These adjustments were found to be crucial for both the quantity and stability of helicase production, a task that posed inherent challenges.

Following protocol refinement, our focus shifted to conducting a drug screening of various in-house small molecules libraries to assess their interaction with nsp13. This screening aimed to identify potential direct antiviral agents against SARS-CoV-2. Through a comprehensive approach involving both computational and experimental methods, we aimed to pinpoint promising candidates for enzyme inhibition.

References:

[1] E. Konkolova, M. Klima, R. Nencka, E. Boura. J Struct Biol. 2020 doi: 10.1016/j.jsb.2020.107548.

[2] J. Chen, B. Malone, E. Llewellyn, M. Grasso, P.M.M. Shelton, P.D.B. Olinares, K. Maruthi, E.T. Eng, H. Vatandaslar, B.T. Chait, T.M. Kapoor, S.A. Darst, E.A. Campbell. Cell. 2020 doi: 10.1016/j.cell.2020.07.033.

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CSB-PO-032

Understanding the structure and function of the human Vault particle

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Vaults are large ribonucleoprotein (RNP) particles with a size of 70 nm × 40 nm × 40 nm. Initially reported in 1986, vaults have a distinct ovoidal architecture made of two symmetric 39-meric shells composed of the major vault protein (MVP). Despite its large size and the high levels of conservation of the vault components, the precise role of this complex in the cell is not yet fully understood.
Here, we report the first cryoelectron microscopy (cryoEM) reconstruction of the human vault complex at 3.3 Å and provide a comparison to the previously published structures of its murine counterpart. Additionally, we investigated the interaction and binding site to the human onco-suppressor protein PTEN with Grating-Coupled Interferometry (GCI) and Small Angle X-ray scattering (SAXS), which showed a strong affinity (kd of 1 μM) in presence of 10 mM of Ca(II), this supports the role of the vault as molecular scaffold and transport of the onco-suppressor protein.

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ABC-MD-01

Sustainability, Circular Economy and Chemistry

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The paradigm of circular economy has become a vital way to develop the future social and production system, considering that the so named "linear" model has proven its inherent failure, due to the so many impacts on the environment, on human health, on Earth resources[1]. However, the concept of circular economy has taken a certain time to be accepted and introduced in European strategic documents and legislation.

But an important question is: how circular economy and sustainability could move forward together?

It must be born in mind that sustainability is the final goal of human activities, it can be measured through different approaches, among which the Life Cycle Assessment is the most common and widely used, with an important application also in the chemical industry[2]. Conversely, circularity is a tool, which is usually the best way to reach that aim, even though it cannot be defined sustainable "by default".

Chemistry could play a crucial role in the comprehension and in the development of these concepts. D. Meadows was the first author of the world famous book *The limits to growth*, a pivotal document describing the necessity of a change in human behaviour, to avoid the exceedance of the physical boundaries of our planet[3]. Another chemist, M. Braungart, was one of the main inspirers of the principle "cradle to cradle", which represents a concept strictly related to the circular economy[4].

There are some specific flows which require a diversion from some practices that in principle could be considered the more sustainable, such as reuse or recycling, to preserve the priority guideline of environmental sustainability (e.g., in the case of highly energy-consuming old appliances, or when substances of very high concern are present in the end-of-life materials). This is also in line with the European Waste Framework Directive[5], which states that specific waste streams may depart from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste.

References:

[1] Ellen Macarthur Foundation, 2024, https://ellenmacarthurfoundation.org/what-is-the-linear-economy
[2] D. Cespi, F. Passarini, E. Neri, R. Cucciniello, F. Cavani, 2020, Life Cycle Assessment in the Chemical Product Chain: Challenges, Methodological Approaches and Applications, Springer Nature Switzerland AG, 53-73
[3] D.H. Meadows, D.L. Meadows, J. Randers, W.W. Behrens III (1972) Club of Rome
[4] W. McDonough, M. Braungart (2002) North Point Press New York
[5] EC (2008), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20240218

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ABC-MD-02

The challenging role of chromatography in environmental analysis: unveiling the polyhedrality of separation sciences

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This talk aims to highlight how separation science, and mainly liquid chromatography, is a strategic approach to address the challenges of environmental analysis in all its key phases. The quantitative recovery of pollutants from difficult matrices, that hinder their correct quantification, through high selectivity separations, also based on the modelization of the equilibria involved, can be achieved ensuring their accurate identification and quantification in various environmental matrices. These requirements are the basis for a correct interpretation of the data obtained, for a reliable risk assessment[1,2], and for issuing recommendations for policy actions[3]. Environmental analysis faces analytical challenges due to achieving low detection limits and high selectivity and specificity in agreement with regulatory and standardization issues. Chromatographic approaches based on selective interactions between analytes-stationary phase and eluent represent the only possible answer to solve the mentioned problems as well as to implement technologies for the removal of pollutants. Examples of how the elucidation of analyte-adsorbent interactions can be exploited in environmental analysis[4] and remediation will be provided[5].

References:

[1] M.C. Bruzzoniti, T. Schilirò, M. Gea, L. Rivoira, Environmental Research 2024, 242, 117731.
[2] M.C. Bruzzoniti, M. Del Bubba, E. Giordani, D. Fibbi, M.S. Beldean-Galea, D. Piesik, L. Rivoira, Water 2024, 16(6), 830
[3] M.C. Bruzzoniti, L. Rivoira, L. Meucci, M. Fungi, M. Bocina, R. Binetti, M. Castiglioni, Journal of Chromatography A 2019, 1605, 360350.
[4] M.C.Bruzzoniti, R.M. De Carlo, K. Horvath, D. Perrachon, A. Prelle, A. R. Tófalvi, C. Sarzanini, P. Hajós, Journal of Chromatography A 2008, 1187, 188-196.
[5] L. Rivoira, M. Appendini, S. Fiorilli, B. Onida, M. Del Bubba, M.C. Bruzzoniti, Environmental Science and Pollution Research 2016, 23, 21682-21691.

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KEYNOTE LECTURES

Enrico Greco, Università di Trieste

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ABC-KN-01

Ancient Alchemies: Analytical Identification of Psychotropic Substances in Archaeology

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In this presentation, we would explore the intersection of ancient rituals and the use of psychotropic substances, unveiling the sophisticated chemical knowledge of past civilizations through the lens of modern analytical science. Our journey delves into the methodological innovations and interdisciplinary approaches that have enabled the identification of psychoactive compounds in archaeological finds, shedding light on the cultural, medicinal, and ritualistic contexts of their use. The core of our exploration is centered on a comprehensive study that employs state-of-the-art analytical techniques—including proteomics [1], metabolomics by using Liquid Chromatography coupled with Mass Spectrometry in tandem with Orbitrap analysers (LC-MS/MS), genetics, synchrotron radiation-based Fourier Transformed Infrared microSpectroscopy (SR μ-FTIR)—to decode the chemical signatures preserved in ancient artifacts. This approach has unveiled the complex concoctions used in rituals, revealing a rich palette of nutraceutical, psychotropic, and medicinal substances that underline the advanced understanding ancient cultures had of their natural environment. Particular emphasis is placed on the discovery of substances from plants such as Peganum harmala, Nymphaea nouchali var. caerulea, within a 2nd-century BCE Egyptian ritual vase, showcasing the diverse pharmacopeia that was available to ancient Egyptians. The identification of these compounds, alongside traces of human fluids and fermented fruit-based liquids, provides unprecedented insights into the ritualistic practices of Ptolemaic Egypt [2]. Furthermore, we address the challenges and controversies surrounding the identification of the same molecules in traditional Amazonian hallucinogenic brews, such as ayahuasca, in archaeological contexts. The speculative detection of harmine and harmaline in Andean finds raises intriguing questions about the historical use of Banisteriopsis caapi and the origins of its psychoactive use. Through critical examination of archaeological, ethnobotanical, and analytical data, we highlight the complexities of confirming the ancient use of ayahuasca and the importance of a cautious, evidence-based approach to interpreting archaeological findings [3]. This presentation aims not only to showcase the groundbreaking discoveries in the field but also to encourage a discussion on the implications of these findings for our understanding of ancient cultures. By bridging the gap between the past and present through the analytical identification of psychotropic substances, we gain a deeper appreciation for the sophisticated ways in which ancient societies interacted with their natural world. The insights gained from this research enhance our knowledge of historical belief systems, cultural practices, and the potential therapeutic uses of these substances, offering a unique perspective on the ancient alchemies that have shaped human history.

References:

[1] Greco, E., El-Aguizy, O., Fouad Ali, M., Foti, S., Cunsolo, V., Saletti, R., Ciliberto, E., Analytical Chemistry (2018) 90 (16), 9673-9676. DOI: 10.1021/acs.analchem.8b02535

[2] Tanasi, D., de Ruiter, B. V. O., Florian, F., Pavlovic, R., Chiesa, L., Fochi, I., ... & Greco, E. (2023). Ritual revealed: psychotropic substances in a Ptolemaic Egyptian vase. Doi: 10.21203/rs.3.rs-3000218/v1

[3] Greco, E., Rivier, L., Samorini, G., D'Arienzo, A., Archaeology of Psychotropic Substances: the problem of analytical detection of Ayahuasca. Archaeometry, (2024). Doi: 10.111/arcm.12965

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ABC-OR-001

Synthesis of ZIF-8 in glycerol carbonate: process optimization and life cycle assessment

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ZIFs (Zeolitic Imidazolate Frameworks) are recently developed materials belonging to the MOF (Metal Organic Framework) family. They are composed of transition metal cations (Fe, Co, Cu, Zn) coordinated with imidazolate ligands in a tetrahedral structure. These materials are attractive as they combine the advantages of both MOFs and zeolites, such as crystallinity, porosity, as well as high chemical and thermal stability[1]. Recent interest from the scientific community has been attributed to ZIF-8, consisting of zinc clusters linked to 2-methylimidazole units. The most studied method for the synthesis of this material is the solvothermal one: currently the best performing solvent in terms of crystallinity is *N,N*-Dimethylformamide[2], followed by water which gives ZIF-8 with excellent yield and crystallinity. In both cases, a huge excess of organic linker is requested[3]. In this work we described the use of glycerol carbonate as green and alternative solvent in the synthesis of ZIF-8 starting from 2-methylimidazole and zinc acetate. The reaction conditions were optimized in terms of temperature, reagents molar ratio, amount of solvent and reaction time. Glycerol carbonate, a glycerol derivative, shows several advantages such as (a) its preparation from glycerol (5 billion liters in 2021)[4], obtained as the main byproduct of the bio-diesel production; (b) polar as the *N,N*- Dimethylformamide and, above all, (c) it's atoxic and biodegradable. In this work we also tested the feasibility of recycling the reaction mixture after each reaction cycle with encouraging results regarding the crystallinity of the product. It turned out that glycerol carbonate seems to be able to carry out the ZIF-8 preparation for five consecutive cycles in the optimized conditions. In terms of simple E-Factor the use of glycerol carbonate shows the best results in comparison to the other systems (contemplating respectively DMF and water as solvents). As a support of the current work, we elaborated a "cradle to gate" life cycle assessment (LCA) to counterpose the results obtained in glycerol carbonate with those reported in literature for ZIF-8 preparation (water and DMF). The comparative study shows promising results and paves the way for perspectives and improvements in order to overcome the impacts associated with the synthesis of glycerol carbonate.

References:

[1] M. Jian et al., RSC Adv., 2015, 5, 48433 - 48441
[2] A.A. Tezerjani et al., RSC Adv., 2021, 11, 19914-19923
[3] K. Kida. et al., CrystEngComm, 2013, 15, 1794-1801
[4] A. Da Costa et al., Catalysts MDPI, 2022, 12, 570

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ABC-OR-002

Marine biota as an environmental indicator: determination of heavy metals and rare earth elements.

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The increasing anthropogenic pressure on the marine ecosystem is a growing concern, as the health of the oceans is closely linked to the health of the planet and humanity. This crucial connection is highlighted by the incessant increase in pollutants discharged into the seas, a direct consequence of human activities such as industry and natural resource extraction.[1]

In this context, a study of considerable importance was conducted in the Sicilian area of Gela, with the main objective of assessing the effects of direct discharge of wastewaters resulting from hydrocarbons and metals extraction on the health of waters and aquatic ecosystems. The study focused on the quantification of trace elements such as heavy metals and rare earth elements (REEs), which can have devastating effects on the marine ecosystem. The heavy metals studied include mercury (Hg), lead (Pb), and cadmium (Cd), known for their toxicity even at low concentrations. REEs, on the other hand, are a group of metals including the 15 lanthanides together with Yttrium and Scandium, which are also subject to release into the environment during industrial processes[3]. The technique used for analysis was inductively coupled plasma mass spectrometry (ICP-MS), a sensitive and precise methodology that allows for the accurate determination of the concentrations of these elements in the analyzed samples[2]. The processing of the data obtained using this technique allowed the evaluation of bioaccumulation and biomagnification indices, providing crucial information on the accumulation of pollutants along the marine food chain. The results obtained from this study revealed the persistence of pollution in the Gela area and its potential threat to marine biodiversity and human health.

The results highlight prevalent concentrations of essential metals such as aluminium, iron, copper, and zinc. The concentrations of heavy metals and REEs detected in 28 fish species analyzed indicate a significant accumulation of pollutants, with the risk of transfer to predatory organisms along the food chain. Specifically, for metals like mercury, cadmium, and lead, the obtained values exceed the limit values established by European regulations regarding the treatment of fishery products.

References:

[1] Bosch, A. C.; O'Neill, B.; Sigge, G. O.; Kerwath, S. E.; Hoffman, L. C. Heavy Metals in Marine Fish Meat and Consumer Health: A Review: Heavy Metals in Marine Fish Meat. J. Sci. Food Agric. 2016, Vol. 96 (1): 32–48.

[2] Thomas R., Practical guide to; ICP-MS, a tutorial for beginners, Practical spectroscopy series; 2008. Vol. 37: 245-249.

[3] Brouziotis, A. A.; Giarra, A.; Libralato, G.; Pagano, G.; Guida, M.; Trifuoggi, M. Toxicity of Rare Earth Elements: An Overview on Human Health Impact. Front. Environ. Sci. 2022, Vol. 10, 948041.

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ABC-OR-003

Street art materials: characterisation by analytical pyrolysis coupled with gas chromatography and mass spectrometry

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Analytical pyrolysis coupled with gas chromatography and mass spectrometry (Py-GC-MS) is a versatile analytical tool that is currently applied in different fields including heritage science. This technique can be used to characterise the organic fraction of paint materials at the molecular scale. Besides the Py-GC-MS set-up, the same instrument can be exploited to directly analyse the evolved volatile fraction by mass spectrometry during controlled heating of the sample in an inert environment (EGA-MS mode).

Both Py-GC-MS and EGA-MS are successfully exploited in the analytical work package of the PRIN project Sustainable Preservation Strategies for Street Art – SUPERSTAR SUPERSTAR sets as a goal the definition of innovative guidelines for the preservation strategy of street art, aimed at safeguarding its powerful social and cultural message in the urban context. Py-GC-MS have been used to study the composition of street art materials of relevant murals in different cities in Italy (Milano, Torino, Bari, Bologna and Collelongo) and in Europe: the Graffiti Alley (Ghent, Belgium) and Galeria del Arte Urbana (Lisbon, Portugal). For the last two urban art sites, which have undergone up to 25 years of repaintings on the same surfaces, providing a unique perspective on material evolution within a specific time frame, our investigation was enhanced by experiments conducted at the European facility IPANEMA Employing a combination of multiscale and multispectral methods alongside micro-destructive Py-GC-MS analysis, we gained chemical insights into the various layers of paint. This approach allowed us to discern the stratigraphy of paint binders, distinguishing between different classes of organic polymers such as alkyds, acrylics, and nitrocellulose resins present in each layer, and provided valuable information on the evolution of these materials' formulations over time. The information obtained will be crucial for the definition of the best preservation and conservation strategies, and to guide the choice of the materials and methods for the conservation of street art murals.

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ABC-OR-004

Sustainable biodeterioration prevention for Built Heritage stone surfaces: increasing essential oils antimicrobial features through encapsulation with SiO_2-based NPs

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When dealing with Cultural Heritage stone artifacts, biodeterioration is considered one of the main threats to maintaining an adequate conservation state. Biodeterioration can begin with the colonization of microorganisms, which could then favor the establishment of larger organisms.[1] These microorganisms can damage the material, leading to other physical and chemical degradation phenomena. Therefore, to avoid such degradation phenomena, preventive actions must be employed, such as the application of protective coatings.[2]

Currently, most antimicrobial products used to contrast microbiological growth are highly toxic not only for the target organisms but also for the operators and the environment. For this reason, attention must be given to employing sustainable alternatives. In this regard, the use of essential oils (EOs) has emerged. EOs have a high antimicrobial power; however, their action is often time-limited and regulated by the evaporation time of the active molecules.[3]

In this work, two essential oils (*i.e.*, *Origanum Compactum* and *Thymus Vulgaris*) were encapsulated in MCM-41 silica porous nanoparticles (SiO_2 NPs). The proposed method ensures that the antimicrobial features of EOs are maintained for a longer duration, reducing the evaporation rate and also diminishing the quantity required: the amount necessary to achieve the minimum inhibitory concentration (MIC) and the minimum fungicidal concentration (MFC) was halved. Moreover, since the NPs can host a higher quantity of product than is necessary to exert the antimicrobial effect, the duration of activity is further prolonged, releasing the EOs over time.

This combination of the mesoporous SiO_2 NPs and EOs was also tested as the principal component of a protective coating for stone surfaces. The promising synergic results show that this system could be of interest for inhibiting and preventing microbiological growth on stone surfaces, while also avoiding visible aesthetic impacts or color changes, being non-toxic for the environment or the operator, and preventing the EOs from evaporating holding them for gradual release.

References:

[1] K. Elert, C. Rodriguez-Navarro, Construction and Building Materials 2022, 330, 127226.
[2] F. Bartoli, Z. Hosseini, *et al.*, Coatings 2024, 14 (2), 163.
[3] M. Spada, O.A. Cuzman, *et al.*, International Biodeterioration & Biodegradation 2021, 163, 105280.

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ABC-OR-005

Pilot-scale raceway pond reactor for CEC removal from municipal WWTP effluents by iron biochar assisted solar photo-Fenton

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Addressing the urgent environmental challenge of contaminants of emerging concern (CECs) in wastewater, this study introduces a pioneering approach by employing the solar photo-Fenton process within raceway pond reactor (RPR), utilizing iron-functionalized biochar (FeBC) as a catalyst. This novel method aligns with stringent European regulations and the global commitment to Sustainable Development Goal 6, emphasizing the importance of clean water and effective sanitation for all [1]. The choice of RPR for this application is innovative, marking the first time such a system has been optimized with iron-functionalized biochar for the degradation of CECs like acetamiprid in municipal wastewater. The research focuses on optimizing operational parameters, including the precise concentration of hydrogen peroxide (H_2O_2) and the quantity of FeBC, to maximize the degradation efficiency of targeted pollutants. This setup leverages the generation of hydroxyl radicals under UV-A radiation, crucial for oxidizing complex organic molecules effectively [2]. By conducting both batch and continuous flow experiments in RPR, the study evaluates the process's scalability and its potential for integration into existing wastewater treatment frameworks. Continuous flow experiments are particularly valuable, providing insights into the system's performance under variable conditions typical of municipal wastewater treatment, thereby demonstrating its real-time applicability. This groundbreaking application of RPRs with iron-functionalized biochar for the solar photo-Fenton process offers a promising solution for enhancing reclaimed water quality. It not only meets environmental and regulatory demands but also paves the way for sustainable water management practices, particularly in the context of agricultural irrigation. Through this innovative approach, the study makes a significant contribution to the field, potentially setting a new standard for the treatment of CECs in wastewater. Remarkably, the application of this process in both batch and continuous flow configurations within an RPR has led to the removal of up to 99% of acetamiprid (with an initial concentration of 100 µg/L) from secondary effluent sourced from the El Toyo wastewater treatment plant in Almeria, Spain. These results underscore the efficacy of the optimized process in significantly reducing acetamiprid concentrations, showcasing its potential as a highly effective method for the treatment of wastewater containing CECs.

References:

[1] E. Gualda-Alonso, P. Soriano-Molina, J.L. Casas López, J.L. García Sánchez, P. Plaza-Bolaños, A. Agüera, J.A. Sánchez Pérez, App. Cat. B 2022, 319, 121908.

[2] A. Fiorentino, P. Soriano-Molina, M. J. Abeledo-Lameiro, I. de la Obra, A. Proto, M. I. Polo-López, J. A. Sánchez Pérez, L. Rizzo, . Environ. Chem. Eng. 2022, 10, 108777.

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ABC-OR-006

Biogeochemistry and bioaccumulation of toxic elements in freshwater ecosystems of Bosnia and Herzegovina

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Metals and metalloids are ubiquitous in the environment due to both natural and anthropogenic sources. As some of them can exert toxic effects on living organisms, their presence can hinder the environmental quality and determine bioaccumulation and damage in living tissues. Bioindicators are a very effective tool for assessing the environmental quality of an ecosystem, as these organisms tend to bioaccumulate contaminants in their tissues. The bioaccumulation in a living organism depends on its exposure and contact mechanisms with pollutants, but also on the specific interaction between the studied pollutant and the target organs.

Bosnia and Herzegovina is characterised by one of the widest variety of plants and animal species in the European continent, and this country is currently working towards the re-evaluation of its protected areas and species in line with European Union standards, to improve its biodiversity protection strategy.

This project focuses on the characterisation of aquatic habitats and protection of freshwater biodiversity, and the specific aim of the presented work is to assess the environmental quality and bioaccumulation in freshwater ecosystems located in the two target areas of the "NatureBosniaErzegovina: aree protette e sviluppo sostenibile" project (AID 012003), namely the Blidinje Natural Park and the Sutjeska National Park.

In particular, we determined the concentrations of essential and toxic elements in water and sediment samples, and we evaluated the bioaccumulation in selected animal (fish, crayfish) and plant (reed) species by means of Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Moreover, target organs were identified for both plant (roots, stem, leaves) and animal (muscle, liver/hepatopancreas, gills) species. Results show that contamination levels is variable between the studied ecosystems, and that bioaccumulation within the same habitat is both species-specific and organ-specific.

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ABC-OR-007

NANO-STRUCTURED EMULSIONS LOADED GEL FOR REMOVING UNDESIRED MATERIALS FROM STONE ARTIFACTS

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The conservation of the Cultural Heritage items is a common operation to maintain their original structure against degradation processes. Removing undesired and/or decayed products from the artworks represents an important and delicate step in the conservation process. There are many possible undesired materials (aged coatings, degraded materials, deposits of pollutants, grime or dirt, soil materials) to be removed from the surfaces of artifacts, and the challenge is to remove them without damaging their properties and affecting their original aspect[1]. Highly selective techniques must be applied for this purpose, in order to preserve the original nature and properties of the substrates. Hence, the present research study was mainly focused on studying the removing process of different undesired materials (e.g. decayed polymer coatings, graffiti, organic pollutants) from the stone surface by different cleaning tools. In particular, the effectiveness of nano-structured emulsions (NSE; surfactant with limited amount of organic solvents) supported on gels was investigated for the removal of an acrylic polymer (Paraloid B-72), common soil, and graffiti from a stone substrate (Marble, M).

For this purpose, three different gel materials were synthesized and characterized in the laboratory: (i) a synthetic gel[2] (HEMA-MBA/PVP copolymer: 2-hydroxyethyl methacrylate/N,N-methylenebisacrylamide with polyvinylpyrrolidone), (ii) a new bio-degradable gel: Xylan (X) treated with Polyvinyl alcohol (PVA), PVP, and sodium borate (SB), and (iii) Starch (S) treated with PVA, PVP and SB. All the considered gel materials were characterized using different techniques to comparatively assess their properties that are relevant for cleaning purpose: gel content, equilibrium water content, retention capability, morphology, and durability. The results indicated that both gels prepared by natural polymer (Xylan and Starch) have higher equilibrium water content (EWC ~93%) than the synthetic gel (HEMA-MBA/PVP, EWC ~81%). Consequently, the retention capacity has the same trend. NSE-loaded gels were applied in the cleaning of marble surface[1], and the results were comparatively evaluated to find out the gel materials more appropriate for removing the different undesired compounds.

References:

[1] M. L. Weththimuni, A. Girella, M. Ferretti, D. Sacchi, M. Licchelli, Sustainability, 2023, 15, 8117, 1-17.
[2] J. A. L. Domingues, N. Bonelli, R. Giorgi, E. Fratini, F. Gorel, P. Baglioni, Langmuir, 2013, 29, 2746-2755.

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ABC-OR-008

Life Cycle Assessment of a Catalytic Process for Methane Conversion to Hydrogen and Carbon Nanotubes using a Co-Precipitation Catalyst

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The rising cost and decreasing supply of fossil fuels have spurred the search for clean, alternative energy sources. Hydrogen holds promise as a clean fuel, but current production methods often generate significant CO_2 emissions[1]. The STORMING project, funded by the European Union's Horizon Europe program, aims to tackle this challenge. The project's team is developing a novel catalytic technology that converts methane gas (CH_4) into two valuable products: clean-burning hydrogen fuel (H_2) and carbon nanomaterials for batteries. Researchers from the University of Bologna, participating in the STORMING project, developed a catalytic process to convert methane using a catalyst obtained by co-precipitation.

In this study, a life cycle assessment[2] (LCA) is conducted to evaluate the environmental impact of the process. The analysis focused on two highly efficient catalysts, one containing copper (Cat 2) and one without it (Cat1), with and without a reduction step (NR) of the catalyst. For each of the 4 cases, environmental impacts were analyzed for the synthesis of 0.5g of catalyst and then for the production of 1g of carbon nanotubes considering their productivity. H_2 is credited as an avoided impact.

The assessment revealed that energy consumption, particularly during the laboratory-scale catalyst synthesis phase, mainly contributes to the process's environmental impact. However, this aspect can be significantly reduced during large-scale production. The study found that considering the catalyst production scenarios without the reduction during the pre-treatment step had a slightly lower environmental impact.

While the pre-treatment step seems to have a minimal impact on catalyst synthesis, it becomes more significant when considering the overall reaction with methane. This is because the pre-treatment also affects the catalyst efficiency. The study found that catalysts without the reduction step have the lowest environmental impact thanks to their higher productivity in converting methane to hydrogen and carbon nanomaterials.

The study has some limitations. Since it was based on a laboratory-scale process, energy consumption estimates might not reflect a fully optimized, large-scale production scenario. Additionally, some assumptions are made for some data and certain values related to productivity have been only predicted.

Overall, this LCA study provides valuable insights into the environmental impact of the methane conversion process and offers useful indications to develop a technology that is as sustainable as possible.

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References:

[1] Atilhan, Selma, et al. "Green hydrogen as an alternative fuel for the shipping industry." Current Opinion in Chemical Engineering 31 (2021): 100668.

[2] Curran, Mary Ann. "Life cycle assessment: a review of the methodology and its application to sustainability." *Current Opinion in Chemical Engineering* 2.3 (2013): 273-277.

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ABC-OR-009

Two-years analyses of beryllium-7 in the Antarctic region: use of beryllium-7 as a tracer of stratosphere-to-troposphere transport events

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Ozone is one of the most important greenhouse gases and a very hazardous atmospheric pollutant. In the troposphere, ozone is a secondary species produced by complex reaction mechanisms involving nitrogen oxides and VOCs. However, there is another source of ozone, which is the stratosphere to troposphere exchange whose mechanisms are not yet well understood especially in Antarctica.

In order to deepen the knowledge about such transports, their frequency and their intensities, an experimental facility was set up in Concordia Station, on the Antarctic plateau at Dome C, within the framework of STEAR (Stratosphere-to-Troposphere Exchange in the Antarctic Region) project. While greater attention is focused on stratospheric ozone, due to the recurrent ozone hole occurrence and its alarming fluctuations causing a globally recognized threat, tropospheric ozone, though well-known among scientists, is less popular than the former. The comprehension of ozone-related issues relies on the possibility of defining an accurate tropospheric budget of this gas, starting from the identification and subsequent quantification of stratospheric ozone contribution.

Beside direct observations of ozone, STEAR project is focused on the sampling and analysis of beryllium-7 (^{7}Be), a natural cosmogenic radionuclide[1] produced by spallation reactions of nitrogen and oxygen nuclei induced by cosmic rays in the stratosphere. Its presence in the troposphere is an established marker of stratosphere-to-troposphere exchange events[2]. While ^{7}Be data at coastal sites in Antarctica have been often object of research, this contribution aims to present the first high-resolution ^{7}Be time series in aerosol samples from the Antarctic plateau from January 2022 to date. The main novelties are not only the data time resolution (2–4 days) but mainly the coverage of winter-over periods, so far unprecedented, and the deployment at Dome C of a dedicated high-resolution γ-ray spectrometer, to allow the determination of the short-lived radiotracers on-site. This contribution will be therefore focused on the first results obtained, considering the two years-time series, the correlations found between ^{7}Be concentration and meteorological variables, and the evaluation of the source points by back-trajectory analysis.

References:

[1] L. Tositti, E. Brattich, G. Cinelli, D. Baldacci, 2014, Atm Env 87, 108-122.
[2] E. Brattich, H. Liu, L. Tositti, D. Considine, J. Crawford, 2017, Atm Chem and Phys, 17(2), 1061-1080

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ABC-OR-010

An Innovative Approach to disclose Paleolithic Stone Tools as Bio-Archives

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The recovery of starch grains from ground stone tools (GSTs) dating to the Late Pleistocene have provided evidence that *Homo sapiens* (HS) was mechanically grinding plant organs during its dispersal into Eurasia.[1] Starch is the reserve of polysaccharides accumulated in the amyloplasts of plants, and its high energetic value might have played a vital role for HS to survive a new environment (the Northern latitudes) and the harshening of the climate that occurred in the late Marine Isotopic Stage 3 (MIS 3, 60-25 ka BP). Starch grains are conventionally analyzed by means of optical microscopy with bright and polarized light after washing/sampling archaeological materials either by pipetting or sonicating the selected portion of the GST surface, or by mechanical remotion. Indeed, the identification and recognition of starch grains is challenging because on the one hand their removal from GSTs requires invasive procedures that can invalidate a proper physical-chemical characterization, and on the other, necessitate a comparative reference collection.

Within SMarT4BioArCH project[2] we propose an integrated methodology: from the extraction to the characterization of starch grains (but also of other biogenic residues) adhering to the archaeological GST surfaces, to testing different approaches for their extraction. Our approach relies on the combination of morphological and chemoprofiling analyses, and by comparing the archaeological data to a tailored reference collection that includes aged starch granules from relevant plants potentially available during the MIS 3. We aim to enhance the narrative on the exploitation of available resources by hominins thriving in a given territory through a multi-disciplinary approach.

References:

[1] G. Birarda, E. Badetti, C. Cagnato, G. Sorrentino, I. Pantyukhina, C. Stani, S. Dal Zilio, G. Khlopachev, S. Covalenco, T. Obada, N. Skakun, A. Sinitsyn, V. Terekhina, A. Marcomini, C. Lubritto, N. Cefarin, L. Vaccari & L. Longo, Scientific Reports 2023, 13, 21713.

[2] Ministero dell'Università e della Ricerca (MUR) of Italy, Project PRIN 2022 2022XX8BRT PNRR, "SMarT4BioArCH", CUP Master B53DZ3014020006, financed by the European Union – Next Generation EU, is gratefully acknowledged for financial support.

ABC-OR-011

Degradation of Nimesulide by Sunlight-Assisted-UVA irradiation: Kinetics and Reactive Species Generation[1]

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The investigation of Nimesulide (NIM) degradation, recognized as an emerging pollutant[2], was conducted through a hybrid approach combining free chlorine (Cl_2) and UVA irradiation (UVA/Cl_2)[3]. The primary objective was to elucidate the kinetics, generation of reactive species, and transformation mechanism implicated in the degradation process. Furthermore, the feasibility of utilizing natural sunlight as an illumination source was explored. Our findings unveiled NIM's limited reactivity towards hypochlorite (OCl^-) alone, necessitating complementary methods to expedite degradation. UVA irradiation facilitated the activation of the oxidizing agent, resulting in the degradation of 88% of NIM in 180 minutes (Figure 1).

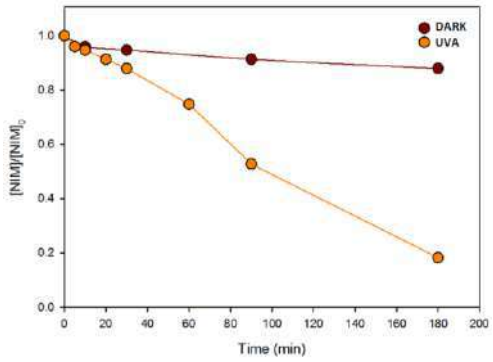

Figure 1: Nimesulide degradation in the presence of 0.5 mM of Cl_2 under dark and UVA.

Chemical probes were employed to assess the radical species generated during the process. High-performance liquid chromatography-mass spectrometry (HPLC-MS) analysis disclosed the presence of novel oxidation by-products, previously unreported.

Total organic carbon (TOC) analysis confirmed the substantial degradation of NIM during the UVA/ Cl_2 process, indicating efficient mineralization up to 60%. Additionally, the feasibility of employing natural sunlight as an alternative light source and application of the process to real wastewater was validated.

References:

[1] These studies were supported by AIPRAS Onlus (https://www.aipras.org/)
[1] D. Vasu, A.K. Keyan, P. Moorthi, S. Sakthinathan, C.L. Yu, T.W. Chiu, J. Environ. Chem. Eng. 2023, 11109055.
[2] N. Kishimoto, J. Water Environ. Technol. 2019, 17, 302 – 335.

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ABC-OR-012

Proposal for a remediation method for the "vinegar syndrome" in cellulose acetate-based motion picture films

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Motion picture films made of cellulose acetate (CA) are subjected to chemical degradation mainly due to the "vinegar syndrome". It concerns the cleavage of the ester bonds between the acetate group and the cellulose chain through ester hydrolysis (deacetylation), with the release of acetic acid, which acts as a catalyst for the reaction. By-products of deacetylation can promote, also, the hydrolysis of the glycosidic bonds of the cellulosic backbone. The consequent deformation and embrittlement of the films can strictly compromise their usability [1,2]. The most important goal of this project is to set up innovative, cheap, easy-to-produce and handle and possibly reusable chemical inhibitors. We proposed and characterized several systems based on two strategies: the use of sponge-like systems (1) made of polyethyleneimine (PEI) and/or (2) uploaded with metal oxide nanoparticles. The intent was to use free amino groups, in the first case, and inorganic nanoparticles, in the second case, to convert acetic acid into ammonium carboxylate and acetate salt, respectively, through an acid/base reaction. The evaluation of the efficacy of the above-mentioned systems in inhibiting the vinegar syndrome was performed both on real motion picture films on which the deacetylation process has been artificially induced with an innovative degradation protocol and on films naturally affected by the "vinegar syndrome". The different behaviors of untreated and treated films have been evaluated through an innovative multi-analytical protocol able to monitor the chemical alterations of the supports connected with the occurrence and the evolution of the "vinegar syndrome".

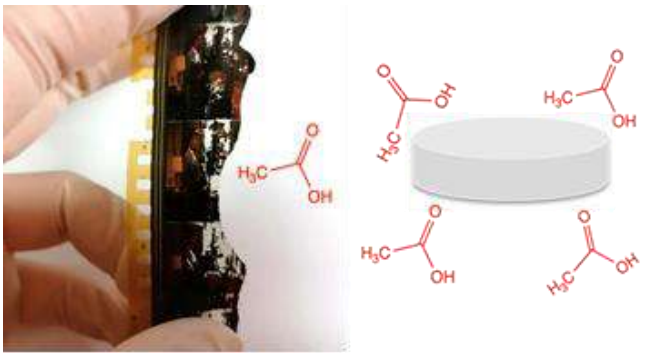

Figure 1: sponge-like inhibitor for the "vinegar syndrome" of CA-based motion picture films.

References:

[1] N. S. Allen, M. Edge et al., Pol. Degrad. Stab., 1987, 19, 379-387.
[2] M. McGath, S. Jordan-Mowery et al., Restaur, 2015, 36, 333-365.

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ABC-OR-013

Photochemistry of the antibacterial oxolinic acid in surface waters

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The production of farmed fish from aquaculture is significantly increasing, due to the raise of seafood demand from a growing world population and because of overfishing of world fish stocks. The expansion of aquaculture production is accompanied by an augmented use of veterinary medicinal products (VMPs), such as parasiticides and antibiotics, the application of which in aquaculture prevents and reduces the outbreak of fish diseases. However, this poses a potential environmental risk since VMPs can be released in water bodies from aquaculture effluents, despite the adoption of wastewater treatment procedures.[1] The presence of pharmaceuticals in water bodies is a worldwide environmental problem because, although their concentration values are very low, these contaminants of emerging concern (CECs) can have adverse effects on aquatic ecosystems, including the spread of antimicrobial resistance.

In water bodies, abiotic photochemical reactions play a role in the attenuation of the ecotoxicological risk posed by CECs, because the latter are usually photodegraded into compounds of lower environmental concern; however, photoproducts are sometimes formed that are more toxic than the parent contaminant.[2]

Oxolinic acid (OxA) is a quinolone antibiotic used in both fresh- and saltwater aquaculture, and is thus released in aquatic environments. The few studies published so far about the fate of OxA in natural waters showed that photoreactions would be important degradation processes.[3] However, the photoreactivity of OxA in surface waters has not been systematically investigated.

In this work, the photochemistry of the basic form of OxA (pK_a ~ 6) was studied. The direct photolysis quantum yield and the bimolecular reaction rate constants of OxA with relevant reactive transient species ($HO^\bullet$, $CO_3^{\bullet-}$, $Br_2^{\bullet-}$, $^1O_2$, and triplet states of dissolved organic matter) were determined by means of steady-state irradiation experiments and laser flash photolysis measurements. Despite high OxA photoreactivity, we observed that some photodegradation pathways are inhibited by phenol, here used as representative of antioxidant dissolved organic matter (AODOM). By considering measured reaction kinetics together with inhibition by AODOM, we could model the photochemical half-life time of OxA in surface waters.

References:

[1] I. de la Casa-Resino; M. T. Empl; S. Villa; B. Kolar; J. Fabrega; A. D. Lillicrap; X. N. Karamanlis; R. Carapeto-García. Environ. Sci. Eur. **2021**, 33 (1), 84.
[2] D. Vione; L. Carena. Environ. Sci. Technol. **2020**, 54 (9), 5328–5330.
[3] V.L. dos Louros; C.P. Silva; H. Nadais; M. Otero; V.I. Esteves; D.L. Lima. Sci. Total Environ. **2020**, 749, 141661.

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ABC-OR-014

Influence of the chemical environment on CO_2-sequestration by clathrate hydrates: a Raman study

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Clathrate hydrates (CHs) are nonstoichiometric solid compounds formed by cage-like crystalline structure of water molecules where a guest molecule is entrapped under proper conditions of temperature and pressure. CHs offers a solution for the sequestration of Carbon Dioxide (CO_2) in its structure as trapped molecule both in seawater and under the seafloor.[1] The formation conditions and a deeply investigation about the chemical properties of seawater, sediments and the environmental parameters are fundamental to understand the process and help the know-how for a technological solution for the CO_2 sequestration as CO_2-CHs.

Whitin the PRIN2022 project CO_2-RESTO, the water hydrates features were deeply investigated by Raman spectroscopy, since important information can be obtained from the observation of the -OH stretching bands of water that are present in CO_2-CHs. The Raman study has been performed by using lab-reproduction CHs with and without CO_2, in presence or in absence of salts and sediments. The in-depth analysis of Raman shifts showed that the presence of salt, as NaCl, influences the water structure decreasing the hydrogen bonds, but in the same conditions, in presence of sand, the latter limiting the inhibition effect of salts. Moving towards the CO_2-CHs test, using Raman spectroscopy the characteristic two peaks of CO_2, in the region 1200-1400 cm^{-1}, can be easily detected. Also in this case, the Raman bands of the water -OH stretching in the CO_2-CHs, showed useful information. At different temperature, the CO_2 hydrates showed a less ordered structure in the presence of sand but however, thanks to the interaction between water and silanol groups of sand particles, their stability was maintained with the variation of temperature, favoring the expansion of the cages that was highlighted by the Raman shifts of the CO_2 Fermi diad.[2] All the obtained experimental results will be used to the devolpment of a theoretical model applicable to the CO_2-CHs formation for their reproduction in lab-scale and for the technological solution as the CO_2-injection.

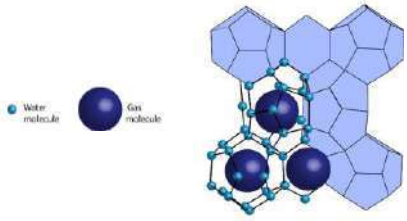

Figure 1: General structure of clathrate hydrates

References:

[1] A. Hassanpouryouzband, E. Joonaki, M. V. Farahani, S. Takeya, C. Ruppel, J. Yang, N. J. English, J. M. Schicks, K. Edlmann, H. Mehrabian, Z. M. Aman, B. Tohidi Chem. Soc. Rev. 2020, 49 5225-5309.
[2] R. Giovannetti, A. M. Gambelli, A. Rossi, B. Castellani, M. Minicucci, M. Zannotti, A. Nicolini, F. Rossi, J. Mol. Liq. 2022, 368, 120739.

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ABC-OR-015

Source apportionment of real-time ultrafine airborne particulate data in an urban center of a medium-sized mediterranean city during summer period.

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Introduction: Increase in human activities within urban centers in recent years has resulted in an increase in the number of individuals exposed to progressively higher levels of atmospheric pollutants such as particulate matter. An increasing number of studies demonstrates the significance, for public health scopes, of characterizing not only the total mass of particulate matter but also studying the size distribution of particles and attributing their sources. Although there have been efforts to normalize the particulate emissions in PM10 and PM2.5 fractions, little has been done for the ultrafine fraction, which constitutes the majority of total particle number concentrations (PNCs). The aim of this study is to characterize the emission sources affecting the urban center of Lecce (Italy), which is representative of medium-sized cities in terms of urban planning and climate, during the summer period.

Metodh: The sampling site is located at "Piazza Ludovico Ariosto"-Lecce, where the main sources of airborne particulate matter are vehicular traffic, biomass combustion from human activities, regional background, and dust transport from the saharan region. A total of 39 days were sampled using a real-time AQ-SMART 1000 (PALAS) station, which analyzes particles using an optical analyzer based on the Light Scattering principle (spectral analysis), wich can provide real-time particle number and size class distribution. Continuous 1-minute observations were obtained for each of the 64 size classes, covering a range from 0.175 µm to 20 µm, and mass concentrations of PM1, PM2.5, and PM10.

Results: The data were then processed to obtain daily averages of PM1, PM2.5, and PM10 masses and their respective ratios PM2.5/PM10, PM1/PM10, and PM1/PM2.5, which allowed us to identify a Saharan Dust event confirmed by back trajectories and satellite images, and some days characterized mainly by ultrafine particulate matter attributable to anthropogenic sources such as vehicular traffic. Next, data on the number of particles for different size classes were considered, and Positive Matrix Factorization (PMF)[1] was applied to confirm the emissive sources impacting the urban center of Lecce, including vehicular traffic, regional background, and Saharan dust.

Conclusion: Assigning a size range of atmospheric particulate matter to a specific source provides a helpful tool for decision makers, enabling them to implement effective and sustainable solutions to improve air quality and the health of urban residents.

References:

[1] Al-Dabbous, A. N. Source apportionment of airborne nanoparticles in a Middle Eastern city using positive matrix factorization. Environ. Sci.: Processes Impacts 17, 802–812 (2015).

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ABC-OR-016

Recycling of construction and demolition waste in the European Union: an environmental and economic assessment

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Although the recovery rate of construction and demolition waste in the European Union is at 89 %, it does not correspond to high-value material recovery but rather "poor" levels of circularity. The environmental impacts and costs of 12 construction and demolition waste material fractions relying on alternative pathways and treatment technologies are assessed by using a life cycle assessment. Important trade-offs in the transition towards the circular economy are found. Recycling of concrete, bricks, gypsum, and ceramics and tiles is the best environmental performance but also the most expensive pathway. Overall, recycling construction and demolition waste in the European Union with advanced technologies could save about 264 kg CO^2eq t^{-1} with a cost of 25 EUR t^{-1}. The maximum potential for recycling would correspond to a total reduction of about 33 Mt of CO_2eq in 2020. Concrete and bricks result as the fractions with the highest potential for improving current waste management practices in environmental terms. Economic and non-economic barriers for realising this potential at EU level are discussed in relation to the European Green Deal and the EU's circular economy objectives.

ABC-OR-017

Two-step pyrolysis biochar from industrial sludge and its application for removal of steroid hormones from wastewater

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The increasing prevalence of organic micropollutants (OMPs) from both industrial and domestic sources has significantly affected the quality of surface water and treated wastewater for reuse. Among these, pharmaceutical compounds pose a significant concern due to their widespread distribution and biological activity. Specifically, steroid hormones (SHs) have drawn growing interest in the scientific community for their disruptive effects on the endocrine system in aquatic organisms.[1] Wastewater treatment plants (WWTPs) are recognized as sources of these pollutants,[2] since they are not designed for their removal. Therefore, as recently remarked in a Proposal for an European Directive concerning urban wastewater treatment,[3] it is urgently needing to address the issue of OMPs in urban wastewater, especially for larger WWTPs. Among the technologies developed to remove OMPs from wastewater, physicochemical processes such as adsorption offer promising solutions due to their simplicity, eco-friendliness, and relatively low cost. As a potential adsorbent, biochar could represent a cost-effective and efficient solution. Furthermore, the biochar production from sewage sludge pyrolysis could represent a promising strategy to manage hazardous residues from WWTPs.

Based on the aforementioned considerations, this work used a two-step pyrolysis methodology to produce biochar on a bench-scale with improved adsorption stability by removing tar produced during pyrolysis and mineral components, that are intrinsic to this waste, so as to reach the highest removal of different categories of SHs. For this purpose, physicochemical properties of various biochars produced in our laboratory were investigated. The best material, subjected to a chemical and subsequent thermal treatment, provided a remarkable surface area (436 m^2 g^{-1}), together with a high environmental compatibility in terms of water leachable impurities. Maximum adsorption capacity (Q_m) for SHs were assessed in real wastewater matrices through kinetic and isotherm tests, using a commercial activated carbon (AC) as reference. Q_m values 2.5-1.1 lower than those of AC were observed, (except for Estrone for which Q_m values 1.5 higher). Additionally, different regeneration processes were evaluated to prolong the lifetime of sorbent reusability.

References:

[1] J.O. Ojoghoro, M.D. Scrimshaw, J.P. Sumpter, Science of The Total Environment 2021, 792, 148306.
[2] Q. Yu, J. Geng, Chemosphere 2019, 237, 124371.
[3] https://environment.ec.europa.eu/publications/proposal-revised-urban-wastewater-treatment-directive_en.

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Determination of oxidative potential on particulate matter filters of different origins: outdoor, indoor, and fixed-source emissions

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Exposure to atmospheric particulate matter (PM) has been linked to various adverse health effects such as respiratory, cardiovascular, and neurological disorders[1]. In most studies, the effects are linked to mass concentrations of PM or particle dimensions. An emerging hypothesis is that these toxic effects are caused by the oxidising activity of specific chemical components of PM, which lead to the formation of reactive oxygen species (ROS) that are harmful to our bodies[2]. The overall oxidative capacity has been proposed as a metric that is more closely related to the biological responses caused by PM exposure and thus may be more informative than particulate mass alone.

The oxidative potential (OP) of particulate matter is defined as the ability of PM to oxidise target molecules by generating ROS. Many methods have been developed to measure OP including cell-free in vitro assays, which have the advantage of being fast, inexpensive, and easier than cell-based assays[3]. Two popular acellular ones are the dithiothreitol (DTT) and the ascorbic acid (AA) assays. In both tests, the redox-active species present in the PM (heavy metals and quinones) oxidise the reagents and the oxidative potential is determined as the rate of reagent depletion; respectively, OP^{DTT} and OP^{AA}.

DTT and AA assays were performed on particulate matter samples of different origins: urban PM filters from the city of Milan collected during a one-year sampling campaign, indoor PM samples from the *Santuario della Beata Vergine dei Miracoli* in Saronno (VA), and PM deriving from fixed-source emissions, namely wood-fired pizza ovens. The results from the one-year sampling campaign on urban PM filters show that the samples are more responsive towards the AA assays than the DTT assay. The yearly trends are also different between the two: OP^{DTT} does not change significantly between the different seasons, whereas OP^{AA} is higher during summer. Results also show a similar oxidative capacity of indoor PM with respect to outdoors. Finally, compared to the other two types of samples, particles emitted from wood-fired pizza ovens are more responsive towards the DTT assays than the AA assays probably due to the lower metal-content and higher contribution of the organic fraction.

References:

[1] B. Brunekreef, S.T. Holgate, Lancet 2002, 360, 1233 – 1242.
[2] G.L. Squadrito, R. Cueto, B. Dellinger, W.A. Pryor, Free Radic Bio Med 2001, 31, 1132 – 1138.
[3] M.C. Pietrogrande, I. Bertoli, F. Manarini, M. Russo, Atmos Environ 2019, 211, 103 – 112.

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ABC-OR-019

Antibiotic resistance genes and antibiotic contamination in real water samples along the "water pathway": from wastewater to marine environment

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Antibiotics are compounds, either natural or synthetic, with bactericidal or bacteriostatic properties widely used in human and veterinary medicine. The massive use of such drugs has resulted in environmental contamination both through diffuse sources (intensive agricultural areas, industrial districts) and through point sources (livestock facilities, aquaculture, urban and hospital sewage discharges). Urban sewage discharges are considered among the main sources of antibiotic entry into the aquatic environment as wastewater treatment plants, as currently designed, are inefficient or barely efficient in their removal[1].

Currently, antibiotics are recognized as emerging pollutants, as they can represent dangerous contaminants for the ecosystems in which they are introduced and play a crucial role in the development of resistant bacteria and resistance genes (Antibiotic Resistant Gene, ARG)[2].

In this study, real samples of wastewater, both incoming and outgoing from the Servola treatment plant, and samples of seawater taken along the submarine discharge pipeline in the Gulf of Trieste were analyzed. Samples were taken at various depths to assess contamination along the water column, allowing for the evaluation of anthropogenic impact along the "water pathway," from the WWTP inlet to the coastal areas of the Adriatic Sea.

The contamination assessment was updated by integrating investigations on the contribution of some commonly used antibiotics (Fluoroquinolones, Sulfonamides, Macrolides) and their respective prototypes. Simultaneously, to assess ecological impact, the presence of antibiotic-resistant bacteria is investigated. Antibiotic resistance assays involve the search for three specific genes that determine resistance to sulfonamides, fluoroquinolones and macrolides (respectively sul2, qnrS, and ermB).

The results obtained from the first year of the campaign show a reduction effect attributed to the wastewater treatment plant for both the targeted antibiotics and antibiotic-resistant genes, as well as a significant seasonal effect.

References:

[1] A.Serra-Compte, M.G.Pikkemaat, A. Elferink, D. Almeida, J. Diogene, J.A.Campillo, M. Llorca, D.Alvarez-Munoz, D.Barcelo, S. Rodriguez-Mozaz, Environmental Pollution 2021, 271, 116313.
[2] V.Fonti, A. Di Cesare, J. Sangulin, P. Del Negro, M Celussi, Water 2021, 13, 3335.

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Quantification of Plastic Particles in Sewage Sludge via Py-GC-MS Analysis

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In recent decades, micro- and nanoplastics (MPs and NPs) have emerged as persistent contaminants of increasing concern to the environment. Nowadays, they have been found almost everywhere.[1,2]

While identification method for MPs has been optimized for different analytical techniques (e.g. spectroscopical and thermal), quantification remains challenging, mostly because of the heterogeneity of the matrices from which this class of contaminants must be separated.[3] Some methods have been validated for the quantification of MPs in water thanks to the simplicity of the matrix, but dealing with environment, it is not possible to overlook on its complexity. Moreover, not all the plastic particles (PPs) in the environment are categorised as MPs; fragments smaller than 1 µm generate even more concern due to their potential to interact at cellular level.[4]

In this study, sewage sludges (SS) were selected as complex matrices of environmental interest. Domestic and industrial activities generate N-MPs which can be collected in wastewater, then treated at the wastewater treatment plant (WWTP). Despite these plants are not designed for the abatement of emerging contaminants, MPs can be satisfactorily reduced probably accumulating in SS.[1] Subsequently, SS can be used in agriculture as soil conditioners, posing an indirect contamination source of MPs in soil. Therefore, the analysis of MPs in SS is of environmental significance to understand the extent of this contamination.

The present study proposes a method for the identification and quantification of PPs in the 0.3 µm – 0.3 mm size range (large NPs and small MPs) in SS. The organic and inorganic carbon content of the matrix was utilised as a criterion for both characterising the SS and optimising of the method for the separation of PPs. The proposed method involved the use of Fenton reagent to minimise the organic load, enabling the analysis by pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS), to detect PPs. After confirming the detection and chemical assignment of PP polymers, the study aimed to assess the matrix effect on the quantification of polymers. The standard addition method was used for the quantification of PPs and the results were compared with external calibration-based quantification. Findings revealed that the presence of the remaining organic matter differently affected polymer quantification. Finally, according to the previous outcomes, PPs were quantified in SS collected from WWTPs, to provide insight into the extent of N-MP contamination in agricultural soils resulting from the use of SS as soil improver.

References:

[1] Y. Li, Q. Liu, M. Junaid, G. Chen, J. Wang, TrAC Trends in Analytical Chemistry, 2023, 164, 117106.
[2] A. Thacharodi et al., Journal of Environmental Management, 2024, 349, 119433.
[3] J. La Nasa, G. Biale, D. Fabbri, F. Modugno, Journal of Analytical and Applied Pyrolysis, 2020, 149. 104841.
[4] A. Banerjee, W.L. Shelver, Science of The Total Environment, 2021, 755-2, 142518.

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ABC-OR-021

Testing the EU Safe and Sustainable by Design (SSbD) framework for chemicals and materials in specific fields: an example on innovative solutions for art restoration

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On December 2022 the EC recommended the Safe and Sustainable by Design (SSbD) framework, developed by JRC[1], as a voluntary approach to guide the innovation process for chemicals and materials. It is composed of five steps encompassing hazard assessment, risk assessment for human health and the environment as well as environmental, social and economic sustainability assessment. Currently, the framework is in a testing phase, with the aim to refine it and make it applicable to a wide variety of substances.

The HEU GREENART (GREen ENdeavor in Art ResToration) project has been included among the case studies for such testing phase as it aims to propose new materials and chemicals (i.e., cleaning systems, protective coatings and consolidants, packaging and sensors) for the conservation of Cultural Heritage (CH), which are demonstrated to be safe and sustainable. As initial step, EU REACH and CLP regulations were used to look at the intrinsic properties of the chemical or material in order to understand its hazard profile. All formulation ingredients were assessed for Human Health, Environmental and Physical Hazards, by consulting SDSs and/or the ECHA dossier. Then, they were classified (Levels 0 to 3) according to the SSbD criteria for assessing intrinsic hazard properties. These initial results were communicated to the formulation developers along with observations for each SSbD hazard level. Finally, a self-classification of the mixture in accordance with CLP guidance was performed. Based on the outcomes of this initial phase, developers had the option to modify the original formulation in order to minimize any potential risks, or they could choose to eliminate it altogether, if functionality could not be preserved. Steps 2 and 3 of the SSbD framework were then performed to evaluate human health, safety and environmental aspects in both production and final application phases. Finally, a semi-quantitative screening sustainability assessment was performed by integrating environmental, socio-economic and functionality aspects, which will be complemented, for the most promising solutions only, by Life Cycle Assessment (LCA) and Life Cycle Cost (LCC). Building on the results of the previous H2020 NANORESTART project[2], this work is expected to contribute to the development of criteria to support the application of the SSbD framework to the CH sector and beyond (e.g., cleaning systems in cosmetics).

References:

[1] C. Caldeira, R. Farcal, I. Garmendia Aguirre, L. Mancini, D. Tosches, A. Amelio, K. Rasmussen, H. Rauscher, J Riego Sintes, S. Sala. 2022, Publications Office of the European Union, Luxembourg, 1-118.

[2] E. Semenzin, Giubilato, E. Badetti, M. Picone, A. Volpi Ghirardini, D. Hristozov, A. Brunelli, A. Marcomini, Environmental Science and Pollution Research 2019, 26, 26146-26158.

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ABC-OR-022

Non-invasive analysis and Machine Learning methods for degraded copper-based artefacts characterisation

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The characterisation of degraded artefacts has specific complexity and needs, to be duly faced with a multi-analysis approach. Obtaining information about the alloys and corrosion products is very relevant to the study of Cultural Heritage both in terms of documentation and conservation. Corrosion products can consist of a great variety in composition and appearance of mineral phases, which must be investigated to define the most suitable restoration intervention. In particular, for copper-based artefacts, easy detection of active corrosion is a priority: also known as bronze disease, it is a dangerous form of corrosion disease caused by copper trihydroxychlorides. Several studies on this subject have recently been published using different analytical techniques[1] and also adopting spectroscopic methods and machine learning models[2 3].

This study employs colorimetry, Fiber Optics UV-Vis-NIR diffuse Reflectance Spectroscopy (FORS), Portable X-ray fluorescence Spectrometry (pXRF), μ-Raman Spectroscopy (μ-RS) and X-ray Powder Diffraction Analysis (XRPD). Machine learning clustering and classification models were adopted, trained using datasets comprising hundreds of measuring points from degraded copper-based artefacts from various museum collections. Non-invasive techniques results were integrated and re-interpreted in light of results also obtained by micro-invasive analyses to characterise the corrosion products and to classify different kinds of alloys.

The study identifies the colorimetric space regions that are most affected by certain types of corrosion and the spectral reflectance features of several mineral phases occurring in corrosion products. Furthermore, a method of easy identification of chlorine-based phases by Machine Learning classification of reflectance spectra is proposed. Finally, the study develops a classification model that accurately distinguishes between degraded Ptolemaic-era bronze coins according to their minting period. This model can accurately predict the periods of coins that are no longer legible and, therefore, cannot be studied numismatically.

References:

[1] D. Porcu, S. Innocenti, M. Galeotti, J. Striova, L. Dei, E, Carretti, R. Fontana, Heritage 2022, 5, 3548 – 3561.
[2] F. Liggins, A. Vichi, W. Liu, A. Hogg, S. Kogou, J. Chen, H. Liang, Heritage Science 2022, 10, 142.
[3] Q. Hu, W. Liu, S. Liu, J. Chen, Journal of Cultural Heritage 2023, 59, 49 – 56.

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Phytoremediation potential of epiphytic Tillandsia (Bromiliaceae): evaluation of removal efficiency of Formaldehyde

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The exploration of indoor plants' role in the abatement of airborne pollutants concentration and, as a result, in improving indoor air quality (IAQ) has recently become a matter of interest within the international scientific community [1-3]. Formaldehyde (FA) is a priority pollutant for the proven potential adverse effects on human health; it is an ubiquitous chemical compound inside indoor environments, emitted by building materials and products or generated by human activities (e.g., smoking cigarettes). Epiphytic Tillandsia species show to uptake compounds directly from the gas phase via their leaf trichomes for sustainment and growth, therefore they may play a key role in the removal of airborne pollutants including FA. The present study was performed with the main objective to investigate whether two Tillandsia species e.g., *Tillandsia Velutina* and *Tillandsia Ionantha* can efficiently adsorb FA and remove it from the gas phase. Static experiments with and without plants were carried out inside a test chamber under controlled micro-environmental conditions and lighting (natural or artificial). Temporal variation of gas-phase FA concentration was monitored by means of FA-selective high-temporal resolution detector (*Formaldemeter Htv-M, PPM Tecnologies*). In order to deepen the effect of FA absorption on plant cellular metabolism, investigations onto Tillandsia leaves, e.g., glutathione and soluble protein contents measurements, pre- and post- exposure to FA were additionally carried out. Experimental outcomes demonstrated that Tillandsia species were able to remove FA with a high efficiency. FA removal was promoted when artificial lighting was applied, suggesting that a controlled lighting in a selected spectral range result in a stimulated plant metabolism. The extent of FA removal was shown to be related with plant dimensions: the removal capacity increased with the increase in leaf surface and number of absorbing trichomes. FA, probably due to a fast metabolism and reutilization, was not accumulated in the leaves as the glutathione content significantly decreased (suggesting the occurrence of oxidative stress) and the content of soluble proteins simultaneously increased.

In conclusion, the experimental outcomes obtained in the present study combining test chamber investigations, e.g., monitoring of FA concentration into the gas-phase, with foliage investigations suggested that *Tillandsia Velutina* and *Tillandsia Ionantha* were both capable of absorbing FA via the specialized trichomes located onto the leaves' surface. Moreover, the absorbed FA is likely to be quickly metabolized and used for plant growth.

References:

[1] Kim K.J. et al., 2018. Phytoremediation of volatile organic compounds by indoor plants: a review. Horticulture, Environment and Biotechnology 59, 143-157.
[2] Ravindra K. and Mor S., 2022. Phytoremediation potential of indoor plants in reducing air pollutants. Frontiers in Sustainable Cities 4, 1039710.
[3] Li P., Pemberton R., Zheng G., 2015. Foliar trichome-aided formaldehyde uptake in the epiphytic Tillandsia Velutina and its response to formaldehyde pollution. Chemosphere 119, 662-667.

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ABC-OR-024

Near-infrared hyperspectral imaging to map collagen content in prehistoric bones for radiocarbon dating

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Many of the rarest prehistoric bones found by archaeologists are enormously precious and are considered to be part of our cultural and historical patrimony. Preserving the integrity of rare prehistoric bones while accurately determining their age is crucial for cultural and historical studies. Traditional radiocarbon dating, although effective, poses limitations due to its destructive nature[1]. Recently, NIR-HSI has been applied to obtain spectral maps that reveal the collagen distribution in large bones[2]. However, this method offers only an estimation of the distribution of collagen. Moreover, the pretreatment used in this study was not the same as the one used in radiocarbon laboratories.

In this study, we propose a non-destructive approach utilizing near-infrared spectroscopy (NIR) coupled with a camera with hyperspectral imaging (HSI) to quantify collagen presence in ancient bones and to localize its distribution. Combining the acquisition non-invasive approach with a multivariate partial least squares (PLS) regression model, we obtained chemical maps of the collagen distribution. This model quantifies the collagen at every pixel and thus provides a chemical mapping of collagen content, correlating the relative collagen amount and NIR absorptions. The proposed approach allows for precise collagen quantification and localization within bone samples, facilitating the selection of optimal regions for subsequent radiocarbon dating analysis.

Our findings promise significant contributions to the study of human evolution by minimizing bone material destruction, thereby safeguarding our cultural heritage and providing accurate chronological context to valuable artifacts.

References:

[1] Talamo et al., Sci. Technol. Archaeol. Res., 2021, 7, 62–77.
[2] Lugli, F. et al., Talanta, 2021, 226, 122126.

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ABC-OR-025

PARCA - Advance in Proteomics and Analysis of dyes and Recovery of Charred and Aged textiles

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Archaeological textiles are invaluable relics from ancient cultures, cherished for their historical and cultural significance. However, their high delicate state of preservation and the degradation processes they have been subjected to require the use of highly sensitive analytical tools to conduct thorough studies.

The PARCA project is dedicated to examining both components of ancient wool textiles, dyes, particularly anthraquinone ones, and keratins (IFs) and keratin-associated proteins (KAPs), devising an innovative protocol that combines dye and protein analysis in a single extraction, thereby minimizing the number of samples while maximizing the information obtained.

Beginning with madder-dyed wool mock-ups, proteins and dyes were simultaneously extracted using either the recent TCEP/CAA method or a modified urea method. Following extraction, various clean-up methods, such as µ-SPE, stage tips, dLLME[1] or paramagnetic beads (such as SP3[2]), were employed to isolate both components, assessing their application wouldn't result in losing the analytical sensitivity for both. Proteins were digested with trypsin, either in-solution or on beads, and subsequently desalted using C18 SPE/C18 stage tips. Peptides were separated using ThermoScientific Acclaim PepMap 100 trap and analytical columns at 300 nL/min, while dyes were separated using a Waters BEH Shield RP18 column with an Ultimate 3000 system at 200 uL/min. Both were detected on an Orbitrap Elite mass spectrometer. The methodology was further tested on laboratory samples subjected to a progressive thermal ramp, from 200°C to 300°C at different times, thus trying to simulate the conditions of charred archaeological samples to determine the survival threshold of proteins and dyes at the various thermal aging steps. These data are correlated to FTIR and SEM information, to establish a correspondence between non-destructive and proteomics analyses. Preliminary results of the application of such methodologies on wool samples from Vesuvian area are presented.

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References:

[1] Bosi, G. Peruzzi, A. Ciccola, I. Serafini, et al. Molecules. 2023, 28, 5290.
[2] T. P. Cleland, T. P. Journal of Proteome Research, 2018, 17, 3976−3983.

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ABC-OR-026

Fabrication of SERS sensors based on recycled paper for Cultural Heritage applications: advancements for the SAMOTHRACE project

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We will present a technology for fabricating sustainable Surface-Enhanced Raman Spectroscopy (SERS) sensors based on paper substrates, for Cultural Heritage (CH) applications. Silver nanostructured thin films were deposited via pulsed laser ablation[1] onto flexible cellulose fiber substrates reclaimed from waste sources. Several typologies of paper structures were tested. By optimizing deposition conditions, SERS efficiency was maximized for the rough, porous paper textures. Samples were characterized by UV-Vis absorption spectroscopy and SEM to evaluate deposited films morphologies. SERS performance was evaluated for model analyte Rhodamine 6G at concentrations from $10^{\wedge -2}$ to $10^{\wedge -10}$ M using a portable Raman system with 785 and 835 nm lasers. The lowest detectable concentration achieved for Rhodamine 6G was $10^{\wedge -10}$ M (Fig. 1).

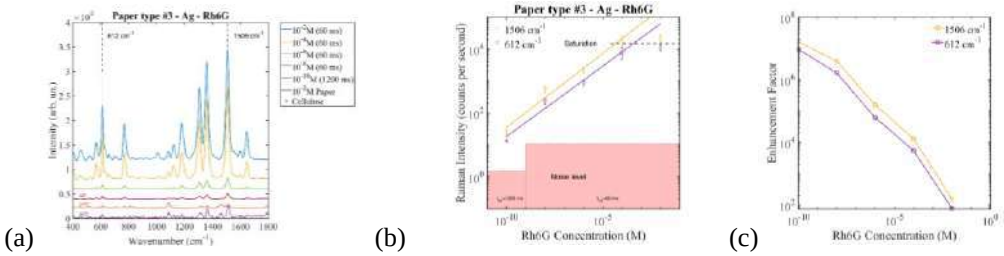

Figure 1: (a) Spectra acquired on Paper#3 at different Rh6G concentration; (b) Calibration curves obtained from the intensities of the 612 and 1506 cm^{-1} Raman peaks vs Rh6G concentration. (c) Behaviour of the Enhancement Factor.

This procedure demonstrates strong performance for CH materials characterization, diagnostics, and preservation applications, through trace chemical detection. Some real-world case studies will be presented, involving materials from archaeological sites and museum. This work has been funded by NextGeneration EU, through the MUR-PNRR project SAMOTHRACE (ECS00000022).

References:

[1] S. Trusso, G. Festa, C. Scatigno, G. Romanelli, A. Piperno, R. C. Ponterio, Neutron sensing at spallation neutron sources by SERS, Applied Surface Science, Volume 651,2024,159186, https://doi.org/10.1016/j.apsusc.2023.159186.

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Green composites obtained by PCL melt blending with Diatomaceous Earth

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In recent years, the development of eco-friendly composites using biodegradable polymers and natural materials has gained significant attention to mitigate environmental pollution effects.

Here, we explore diatomaceous earth (Diat) as a filler for polycaprolactone (PCL) to obtain composites useful for environmental applications. Both components are biocompatible materials with relevant adsorption capacities towards inorganic and organic pollutants. Diat, well known for its non-toxicity and eco-friendliness, possesses high absorption capacity, low thermal conductivity, and low density due to its high porosity. Derived from the amorphous silica cell walls of dead diatoms deposited on marine sediment, Diat is composed of silicon dioxide (>90%), alumina and trace iron oxides, with particle sizes ranging from 3 to 200 μm[1]. Its unique structure makes Diat suitable for diverse applications, including drug delivery systems, environmental remediation, and polymer reinforcement[2].

In this study, composites were prepared by blending different Diat amounts (5, 15 and 50 wt%) with molten PCL. We present here the promising viscoelastic and thermal properties of these composites.

Dynamic Mechanical Analysis (DMA) was employed to assess the viscoelastic characteristics of PCL/Diat hybrids, while Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA) were used to determine the thermal properties. Incorporating Diat within the polymeric matrix improved PCL elasticity at temperatures below its melting point, with a more evident effect in composites with higher Diat content. DSC results showed that Diat can act as a nucleating site for PCL crystallization, resulting in enhanced melting and crystallization enthalpies. On the other hand, the melting and crystallization temperatures of the polymer were slightly affected by the filler concentration. Notably, mixing with Diat generated relevant effects on the PCL thermal stability, as evidenced by TGA data, due to the filler's barrier effect.[3]

Overall, the results obtained by thermal analysis methods highlighted the interfacial compatibility between PCL and diatomaceous earth. Melt blending of PCL with Diat emerges as an easy and efficient strategy to obtain biocompatible composites with enhanced properties, compared to the pure polymer. Such composites hold promise for various applications, including air pollutant remediation in museum environments.

References:

[1] P.Aggrey et al., RSC Adv. 2021, 11, 31884–31922
[2] A. Semenkova et al., J. Radioanal. Nucl. Chem. 2020, 326, 293–301
[3] I. Zglobicka et al., Materials 2022, 15, 6210

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Natural Clays for the Removal of Inorganic and Organic Pollutants from Leachate of Waste Collection Centers

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Billion metric tons of municipal solid waste (MSW) are annually generated worldwide, raising concerns about potential exposure to human health and the environment from hazardous substances that may result during their storage. Indeed, MSW are often stored in waste collection centers in open-top containers placed in open-air yards, being exposed to various weather conditions, including rainfall, which can lead to the release of high concentrations of pollutant. To decrease the exposure towards these hazardous substances, according to the corresponding Italian legislation, wastewater must be collected, routinely monitored through periodic sampling, and treated before the final discharge. Among the different methods for removing pollutants from wastewater, clays have garnered increasing attention worldwide due to their availability, low cost, and excellent adsorbent properties. In wastewater resulted from waste collection centers, metals, in particular iron, aluminium, and zinc, are among the primary pollutants. In this context, this work aims to identify the most suitable type of clay, or a combination of them, that allows the best removal capacity of Fe^{3+}, Al^{+3}, Zn^{2+}, Cd^{2+} and Pb^{2+} in aqueous medium. The capability of bentonite, chabazite, kaolinite, and clinoptilolite in adsorbing the single metals and the competition for the adsorption sites given by their simultaneous presence were evaluated. The effects of the experimental conditions - initial concentrations, contact time, adsorbent mass, solution pH, and ionic strength - were investigated in the study. Moreover, considering that these metals are commonly employed for intercalation into the interlayers of clay minerals[1] to create new adsorption sites that enhance the adsorption of organic molecules[2], the adsorption capacity of an emerging organic pollutant was also studied. This involves evaluating if the co-adsorption of organic and inorganic pollutants could increase the removal efficiency of the different tested clays compared to their starting materials.

References:

[1] A. Dhar, Himu H., Bhattacharjee M., Mostufa M., Parvin F., Environmental Science and Pollution Research, 2023, 30(3), 5440-5474.

[2] H. Mabrouki, D. E. Akretche., Desalination and Water Treatment, 2016, 57.13, 6033-6043.

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Archaeometry and Artificial Intelligence: an Interdisciplinary Study for the Chemical Analysis of Burnt Soils and Stones from the Hearths at the Riparo Mochi Paleolithic Site

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This research's main concern is the characterisation of findings from one of the most important prehistoric sites in mediterranean Europe, i.e. Riparo Mochi in Ventimiglia (Imperia - Italy), with the final goal of obtaining a reliable representation of the original combustion structures at the site. The results of the study will allow the researchers to go deeper in the understanding of the use and management of fire by humans in the Upper Palaeolithic period. Archaeological materials from the site (heated stones and soils, ashes, bones, reddened earths, and possibly pigments) have been characterised using a wide range of analytical techniques, both in laboratory and in-situ. Specifically, electron microscopy coupled to X-ray micro-probe (SEM-EDXS), X-ray Diffraction (XRD), porosimetry, Fourier Transform Infrared (FTIR) and Raman spectroscopies, colorimetric and visible reflectance techniques, in addition to density measurements [1] have been employed. The use of portable instruments, e.g. systems for Raman, FTIR and visible-NIR spectroscopies, which are acknowledged to be suitable for the characterisation of these materials, made it possible to perform the analyses of the archaeological finds effectively and in a totally non-destructive manner on the site. The results emerging from the chemical analyses have been post-processed through Artificial Intelligence (AI) strategies. In particular, the results from the different chemical characterisation techniques will be brought together to enhance both the sensitivity and selectivity of predictive models. Specific parameters/markers, hereafter named as ARchaeological Markers (ARMs), have been identified to determine the concentration of the studied materials. For example, the presence of natural or artificially made hematite, specific silicates or botanical and biological residues were significant. Neural network-based algorithms have been trained through a set of selected datasets coming from reference chemical species' mixtures with known compositions of ARMs and their efficacy have been tested by the outcomes' validation sets. Both training and validation sets have initially been made up exploiting single-ARM and, thereafter, multiple-ARM samples, encompassing, therefore, the effects of possible cross-sensitivities in the model-identification step. The identification and validation path also considered the inherent uncertainty of input data, particularly focusing on the contributions due to repeatability/reproducibility of the chemical analyses and calibration methods.

References:

[1] F. Santaniello., A Berloffa., S.Grimaldi, S.Maffei, A.Pedrotti, S.Gialanella, J. Cult. Heritage, 2020 47, 117-122

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Modelling the photodegradation of acetaminophen, carbamazepine, bentazone and clofibric acid in a river under water scarcity conditions

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Wastewater treatment plants (WWTPs) are known to behave as point sources of pollution for surface waters as rivers, introducing a) extra amounts of nutrients and b) contaminants of emerging concern (CECs) that are not completely removed by the wastewater treatment processes. After reaching the water body, CECs can undergo a range of transformations. These include photochemical reactions triggered by sunlight, which may either achieve the degradation of the compounds into products with lower ecotoxicity, either generate more harmful intermediates that threaten the health of the aquatic ecosystems.[1]

During drought periods, the frequency and the duration of which is expected to increase in the near future, the impact of WWTPs on riverines ecosystems may be exacerbated due to the decreased dilution capacity of the watercourse.[2] Beside this, the photochemical reactions occurring in water may be affected, as the alterations of water flow and flow velocity may reflect on the photochemical fate of pollutants released by the WWTPs.[3]

In this work, the photochemical transformations of four contaminants (acetaminophen, carbamazepine, bentazone and clofibric acid) were modelled as a function of water chemistry and hydrological conditions (water depth and flow velocity) measured in a one-year sampling campaign on the Stura di Lanzo river, a 3rd order stream belonging to the Po basin and located in Piedmont, NW Italy. The samplings were carried out upstream (U), at the discharge point (W) and downstream (D) of a local WWTP during the year 2022, which was characterised by a severe drought provoking water scarcity conditions in many Italian basins. Using the software Apex (*Aqueous Photochemistry of Environmentally-occurring Xenobiotics*), the steady-state concentrations of the photochemically produced reactive intermediates (PPRIs; i.e., $^{\cdot}OH$, $CO_3^{\cdot-}$, $^1O_2$ and triplet states of dissolved organic matter) were predicted, along with the kinetics of direct and indirect photolysis of the investigated compounds. The results showed that, beside the expected seasonal trends (lowest phototransformation during winter months), the effluent discharge from the WWTP in the Stura di Lanzo river affected the photochemistry of the contaminants in terms of PPRIs involved in their photodegradation.

References:

[1] X. Wuang, A.Y. Lin, Environ Sci Technol 2012, 46(22), 12417–12426.
[2] S. Castelar, S. Bernal, M. Ribot et al. Urban Ecosyst 2022, 25, 1313-1326.
[3] D. Vione, A. Ecinas, D. Fabbri, P. Calza. Chemosphere 2018, 198, 473-481.

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Hyperspectral imaging and multiblock chemometric strategies for the study of multilayered paintings

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A urgent issue in cultural heritage investigation consists of the need for acquiring information regarding the in-depth distribution of organic and inorganic components, without any invasive sampling. To address this requirement, a new analytical set-up, able co-register VNIR, SWIR, and XRF spectral data, was exploited in combination with a multivariate and multiblock data processing strategy, for the analysis of multilayered paintings.

The instrument simultaneously records X-ray fluorescence (XRF,1.4-40 keV) data, together with visible & near-infrared (VNIR, 380–1100 nm) and short-wave infrared reflectance (SWIR, 1100–2500 nm) spectra, obtaining elemental and molecular information from superficial to subsurface layers across the investigated area. Data from these three spectral ranges were co-registered, thus inherently saved with high spatial coherence.

The chemometric strategy applied efficiently reduced data and extracted valuable information from the three different spectroscopies. For an effective data visualization and inter-correlation assessment, the approach combined principal component analysis (PCA), brushing, correlation diagrams, and maps within and between spectral blocks, using both low-level and mid-level data fusion. Correlation diagrams and maps are particularly useful for reconstructing a stratigraphic structure without sample collection. They account for inter-correlations among data variables, characterizing possible component combinations at the same depth level. The strategy was applied for the multi-level characterization of a complex painting reproduction study and of the painting of San Sebastiano attributed to Raffaello Sanzio (1483-1520) and exhibited at the Accademia Carrara (Bergamo, Italy).

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Materials and methodologies for the conservation of outdoor contemporary mural paintings

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Outdoor public art and painted murals, in particular, can improve the city's environment, bring communities together and deepen public understanding of community identity and culture[1]. Due to this important social role, murals are subjected to conservative actions through various and still under discussion methodologies since these artworks are not juridically defined as cultural heritage and, therefore, subjected to the current guidelines for traditional mural paintings. These interventions lead to different results regarding many variables: the painting techniques, the substrate layer typology, the environmental conditions, the materials used for the interventions, etc. This research aims to investigate the durability of conservative interventions, particularly for surface protection and consolidation, carried out with different materials and applied methods on murals located in urban, rural and mountain environments and prepared with various painting materials and techniques. Crossing these data allows us to individuate the best procedures for the different scenarios and, eventually, to modify the properties of already used materials to make them more suitable for specific situations. Non-invasive *in situ* surveys and analyses, such as optical microscope, Raman spectroscopy and multi-spectral analyses, are used [2] to evaluate the current state of conservation of the murals and a database has been built to collect all the information, including the climatic conditions after the interventions in each case study analyzed.

Thanks to the collaboration of municipalities, foundations, and restorers involved in the maintenance and valorization of modern murals, it has been possible to collect a lot of information and access numerous case studies in very different environmental conditions[3,4,5] and contribute to the suitable and durable preservation of this most important kind of art.

References:

(1) Cadetti, A. *Conservare La Street Art. Le Problematiche Del Muralismo Contemporaneo in Italia*; edifir - Edizioni Firenze, 2020.
(2) Zendri, E.; Falchi, L.; Izzo, F. C.; Morabito, Z.M.; Driussi, G. A review of common NDTs in the monitoring and preservation of historical architectural surfaces, *in* Int. Jour. Arch. Herit., 2017, vol. 11, pp. 987-1004
(3) Grandi, P.; Grandi, F. *#MURODIPINTODOZZA MURALES*; 2017; Vol. XXVI Biennale Muro Dipinto di Dozza.
(4) Fondazione Štěpán Zavřel; Ferri, A. *Tra i Borghi Incantati Di Sàrmede - L'eredità Di Štěpán Zavřel*; I AM Edizioni, 2018.
(5) Zuccon, A., Coltro, P., Cibiana di Cadore. I «murales» raccontano la sua storia, 2003, Vianello Libri Ed.

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ABC-PO-001

Rare Earth Elements And Trace Elements Concentrations in Geothermal Waters: Implications for Resource Exploration and Water-Rock Interactions

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The Rare Earth Elements (REEs) hold promise as tracers in geothermal systems, yet progress has been hindered by the scarcity of data on REE behavior in thermal waters, as well as on REE mineral solubility and complex stability under high temperatures and pressures. Major and trace element geochemistry of geothermal waters is crucial for sample classification and for comprehending subsurface mass transport during groundwater circulation.[1]

A better understanding of the behavior of REEs in thermal waters could have significant implications for geothermal resource exploration and the investigation of water–rock interactions in geothermal systems. Consequently, the main objective of this study is an evaluation of REEs concentrations in waters sourced from different continental geothermal systems.[2]

The matrices under investigation are analytically complex, requiring pre-treatments to eliminate interferences resulting from high saline content before instrumental analysis via inductively coupled plasma-mass spectrometry (ICP-MS). Each sample, after acidification with high-purity grade HNO_3, was divided into two aliquots: one underwent filtration while the other was analyzed as is. Corrections for isobaric oxide interferences were implemented for BaO on Eu and Sm, PrO on Gd, and NdO on Tb, with In serving as an internal standard. A comparison between filtered and unfiltered aliquots was conducted to discern the form in which REEs are present within the sample, both in solution and as suspended particulates.

Approximately 70 samples of thermal waters from two Italian regions, Campania, and Veneto, were analyzed, with temperatures at the source ranging from 22.7°C to 86.4°C. In addition to REEs, minor and major elements such as Ag, Al, As, B, Ba, Ca, Cd, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sb, Se, Sr, Rb, Tl, V, and Zn were analyzed using ICP-MS with Y and In serving as internal standards. Fluoride, chloride, bromide, nitrate, sulfate, and phosphate were determined using ion chromatography.

In both fields, trace element concentrations are higher in the geothermal waters than in the cold waters. Rb/Cs ratio in the geothermal waters was evaluated, as an indicator of water–rock interaction.

The REE concentration distributions were normalized to chondrite and to the European shale composition, with particular attention to Ce and Eu, whose anomalies in the patterns may be used as an indicator of rocks in the water circulation environment.

References:

[1] A. Scott, W.M. Wood, et al., Rare-earth elements in geothermal waters from Oregon, Nevada, and California, Journal of Solid State Chemistry, Volume 171, Issues 1–2, Pages 246-253, ISSN 0022-4596, **2003**.

[2] M. Wang, X. Zhou, et al., Major, trace and rare earth elements geochemistry of geothermal waters from the Rehai high-temperature geothermal field in Tengchong of China, Applied Geochemistry, Volume 119, 104639, ISSN 0883-2927, **2020**.

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ABC-PO-002

Determination of trace elements for the evaluation of the exposome: the ExpoMap project

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The determination of essential and toxic chemical elements in environmental, biological and food matrices is nowadays of considerable importance as an indispensable tool for the assessment of risk factors for human health, as well as for the drafting of consequent standards and legislation.

The living environment substantially determines an individual's state of well-being or illness, and the environment-health pair is now considered inseparable. Water, food, air, and soil are examples of pathways through which individuals are exposed to pollutants that may affect their health. Men and their state of health can be considered essential indicators of the environmental state, evaluating the presence of contaminants within biological matrices[1]. Each biological matrix retains a different pollution trace capable of being conserved for variable times[2]. Urine, in particular, matrix represents the biological matrices of choice for clinical and forensic investigations. This is 'stable' matrix since it has less variability than other matrices, for example, nails and hair, which are subject to sources of external contamination. Main objective of this work is the evaluation of the environmental exposure of subjects residing in two different areas of the Campania region: Land of Fires and Sele Valley. The volunteers recruited for this purpose are, in fact, healthy boys and girls aged between 18 and 22, with body mass indexes and homogeneous lifestyles. To evaluate the environmental exposure of the subjects of interest, the concentrations of trace elements (Hg, Li, Be, Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Cd, Sn, Sb, Te, Ba, Pb, U) and alkali and alkaline-earth elements (Na, K, Ca, Mg) have been evaluated in different biological fluids in order to evaluate the bioaccumulation of these elements in the human body. For the determination and quantification of these trace elements, analytical methods have been implemented and validated for the different biological matrices using the ISTISAN 15/30[3]. report as a starting point and the subsequent instrumental determination by inductively coupled plasma mass spectrometry (ICP-MS) and microwave-generated plasma-coupled atomic emission spectrometry (MP-AES).

References:

[1] Moffat, A.; Osselton, M.; Widdop, B. *Clarke's Analysis of Drugs and Poisons.* **2011**, 4th ed. Pharmaceutical Press, United Kingdom.

[2] Di Nunzio, A.; Giarra, A.; Toscanesi, M.; *et al. Comparison between Macro and Trace Element Concentrations in Human Semen and Blood Serum in Highly Polluted Areas in Italy*. *IJERPH* **2022**, Vol. 19 (18), 11635.

[3] Alimonti, A.; Bocca, B.; Ruggieri, F. *Metodo di riferimento per la determinazione degli elementi chimici in matrici biologiche umane: prestazioni analitiche e incertezza del dato*; Rapporti ISTISAN; Istituto Superiore di Sanità; **2015**; p 47.

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Recovery and quantification of polymer debris in wastewater treatment plants located in South Italy

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Contamination of water with polymer micro- and nano-metric debris (PDs) is an emerging issue in environmental chemistry and public health. Polyolefins (such as polyethylene (PE) and polypropylene (PP)) and polydimethylsiloxane (PDMS) find a wide range of practical applications in everyday life and are thus the most abundant PDs in wastewater (WW). They have densities lower than water and are typically isolated by flotation. A novel procedure to recover and quantify PE and PDMS in wastewater treatment plants (WWTPs) has been developed and herein described.[1] The analytical protocol, based on quantitative NMR analysis, has been applied to a real case study (50 samples) from two campaigns of sampling in WWTPs located at Tavernola (Battipaglia (SA), Italy) and Punta Gradelle (Vico Equense, (NA), Italy) where different approaches to the WW treatment are used, namely the bed adhered biomass (MBBR) and membrane bioreactor (MBR) technologies[2], respectively. Samples of influent, intermediate stage and effluent WW were collected, the PDs isolated by flotation, filtration and finally analyzed by solution ^{1}H nuclear magnetic resonance spectroscopy (^{1}H NMR) in 1,1,2,2-tetrachloroethane-d_2 solution. Assessment of the PDs concentration at a limit of quantification (LOQ) of 1 mg/m^3 level has been successfully obtained, whereas their presence is typically reported in the current literature as a number of microparticles per volume of water. As expected, PDs of PE are the most abundant, and PE concentrations of 1.80 ± 1.10 g/m^3 (Tavernola Plant) and 3.48 ± 2.70 g/m^3 (Punta Gradella Plant) were actually determined with this novel method after sampling the effluent water twice a week. In the same samples, PDMS concentrations of 257 ± 236 mg/m^3 and 498 ± 613 mg/m^3 were found in the Tavernola Plant and Punta Gradella Plant, respectively. The abatement of PE in both plants was also investigated. Higher removal yields and greater efficiency were found in the Punta Gradelle plant equipped with the MBR technology. The Punta Gradella Plant showed filtration efficiency of 97.5± 2.5% for PE and 87.8 ± 7.9 % for PDMS; by contrast, the Tavernola Plant showed values of 94.9 ± 0.7 % for PE and 67.3 ± 17.8% for PDMS. The proposed method has achieved unprecedented simplicity, rapidity and sensibility of analysis. Moreover the study of microstructure and molecular weights of the PDs allowed drawing some hypothesis of the origin of these pollutants.

References:

[1] J. Sun, X. Dai, Q. Wang, M.C.M. Van Loosdrecht, B.J. Ni, Microplastics in wastewater treatment plants: Detection, occurrence and removal. Water Res (**2019**) *152*, 21–37.

[2]J. Bayo, J. López-Castellanos, S. Olmos, Membrane bioreactor and rapid sand filtration for the removal of microplastics in an urban wastewater treatment plant. Mar Pollut Bull (**2020**) *156*, 111211.

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The role of hydrogen peroxide and thermally activated persulfate in phenol removal

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This study investigates the effectiveness of a novel approach that combines hydrogen peroxide (H_2O_2) with thermally activated persulfate (T-PDS) for the removal of phenolic contaminants from wastewater. Diverging from previous research, this investigation adopts a comprehensive chemometric strategy, utilizing both Response Surface Methodology (RSM) and Principal Component Analysis (PCA) to fine-tune the treatment process parameters, including temperature, pH levels, and the concentrations of H_2O_2 and $S_2O_8^{2-}$. The investigation pinpointed the most effective conditions for the degradation process: a temperature of 70°C, a pH level of 5, and a molar ratio of H_2O_2 to $S_2O_8^{2-}$ at 1:6, with concentrations set at 50 mg/L for each compound. Under these parameters, the degradation efficiency of phenol (PhOH) was observed to be around 89%, reducing its concentration to 1.2 mg/L (initial concentration 10 mg/L). Kinetic studies illustrated a nonlinear reduction in PhOH levels, suggesting a multifaceted reaction mechanism. A significant drop of approximately 38% in PhOH levels was recorded within the initial 15 minutes, followed by an additional 15% decrease over the next quarter-hour, indicating a brisk pace of reaction. The reaction rate then slowed, with PhOH levels plateauing between 75 and 120 minutes, potentially due to the depletion of oxidants or the accumulation of intermediates. The consumption and reactivity patterns of $S_2O_8^{2-}$ and H_2O_2 were found to differ, underscoring their distinct roles in the reaction mechanism. The accuracy of the model was confirmed by high R^2 values of 0.99 for both PhOH and $S_2O_8^{2-}$, and RMSE (Root Mean Square Error) values of 0.017 and 0.033, respectively. Hydrogen peroxide exhibited a slightly lower R2 value of 0.98 and a higher RMSE of 0.046. These results highlight the potential of the H2O2/T-PDS system for efficient and scalable phenol removal from wastewater, providing a solid foundation for its application in industrial settings. The findings underscore the significance of employing H_2O_2/T-PDS in broader pollutant management strategies, advocating for environmentally sustainable treatment solutions.

References:

[1] L.W. Matzek, K.E. Carter, Activated persulfate for organic chemical degradation: A review, Chemosphere 151 (2016) 178–188

[2] J. Wang, S. Wang, Activation of persulfate (PS) and peroxymonosulfate (PMS) and application for the degradation of emerging contaminants, Chemical Engineering Journal 334 (2018) 1502–1517.

[3] J.J. Pignatello, E. Oliveros, A. MacKay, Advanced Oxidation Processes for Organic Contaminant Destruction Based on the Fenton Reaction and Related Chemistry, Critical Reviews in Environmental Science and Technology 36 (2006)

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ABC-PO-005

Degradation of chloramphenicol and acid orange using nanoparticles of Fe^0

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Worldwide water pollution has become one of the most prominent problems over the past decades. The so-called contaminants of emerging concern (CECs) are a broad group of anthropogenic pollutants detected in the environment, that cannot be properly removed by conventional wastewater treatment plants and tend to accumulate ubiquitously in ground and surface water, causing damage to the ecosystems and human health[1]. The use of zero valent iron (Fe^0) has been proposed to remove a wide range of recalcitrant pollutants[2]. In this work, the removal of two CECs, a chlorinated nitroaromatic antibiotic (chloramphenicol succinate sodium salt, CAP) and an azo dye (Acid Orange 7, AO7) by Fe^0 has been investigated, also evaluating the effect of initial pH on degradation. Additionally, ecotoxicity surveys were carried out on samples after the treatment using *Artemia franciscana*, as indicated by the Italian regulatory authorities for wastewater monitoring[3].

In each test, 100 mL of CAP or AO7 solution (20 mg/L) were treated with a certain amount of Fe^0 (0.1125 g/L, 0.225 g/L,0.45 g/L, and 1 g/L). Each test lasted 80 minutes and samples were collected at regular intervals. CAP or AO7 residual concentration was monitored through UV-Vis spectroscopy, by following the intensity of their characteristic peaks at 275 nm and 484 nm, respectively. The degradation of both contaminants improved with increasing Fe^0 dosage, allowing to reach removal rates up to 50%, 75%, 93%, and 95% for CAP and 25%, 43%, 65%, and 96% for AO7. In both cases, the degradation kinetic can be divided in two stages: a rapid discoloration happened in the first 10-15 minutes of treatment, then the reaction slowed, reaching a plateau. The efficiency of the contaminants' removal was also evaluated adjusting the starting pH to ≈3 or ≈9, using 0.225 g/L of Fe^0. In both cases Fe^0 efficiency was higher at acidic pH, achieving up to 87% and 84% removal of CAP and AO7, respectively. In alkaline conditions, the reactions yielded similar results to natural (≈7) pH. Untreated CAP and AO7 solution caused 100% of mortality in all life stages of *A. franciscana*. The treatment with Fe^0 greatly reduced the toxicity of the starting solutions, decreasing the mortality of ~65-85%. The residual toxicity observed can be ascribed to the Fe^0 that remained in the effluents.

References:

[1] S.J. Olusegun, T.G.F. Souza, G.O. Souza, M. Osial, N.D.S. Mohallem, V.S.T. Ciminelli, P.N. Krysinski, Journal of Water Process Engineering 2023, 51, 103457.
[2] X. Liu, Z. Cao, Z. Yuan, J. Zhang, X. Guo, Y. Yang, F. Hec, Y. Zhaod, J. Xua, Chemical Engineering Journal 2018, 334, 508 – 518.
[3] L. Albarano, S. Serafini, M. Toscanesi, M. Trifuoggi, V. Zupo, M. Costantini, D.A.L. Vignati, M. Guida, G. Libralato, Water 2022, 14, 1594.

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Photochemical fate of benzene and phenol as polystyrene degradation products, in a surface water – atmosphere two-phase compartment

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Micro- and nanoplastic particles are a considerable emerging problem in the environment, because their small size facilitates interaction with living organisms with harmful effects. Exposure of water-suspended plastics to sunlight may cause fragmentation, which is a source of microplastics and nanoplastics, but it may also induce formation of dissolved compounds [1]. The latter phenomenon is interesting because it could end up in eventual removal of plastic particles from environmental waters, thus its details deserve investigation. We have previously shown that exposure of polystyrene aqueous suspensions to sunlight produces a range of aromatic and aliphatic compounds that could derive either from the polymer skeleton, or from additives and plasticisers [2]. This presentation will introduce an approach to predict the fate of two toxic/carcinogenic photodegradation products of polystyrene, i.e., benzene and phenol, using a two-compartment model that considers both surface waters and the atmosphere.

Most benzene produced by irradiation of aqueous polystyrene would end up in the gas phase, where it would react with the hydroxyl radical ($^{\bullet}OH$); phenol is the main product of the reaction between benzene and $^{\bullet}OH$ in both water and air. In water, phenol would mainly react with the triplet states of chromophoric dissolved organic matter ($^{3}CDOM^{*}$) [3]. In the gas phase, the main removal pathways of phenol would be reaction with $^{\bullet}OH$ in daytime and with the nitrate radical ($^{\bullet}NO_3$) during the night [4].

The reaction between phenol and $^{\bullet}NO_3$ yields nitrophenols, which can undergo partitioning to atmospheric waters (e.g., cloud water), whence they could reach surface-water environments by precipitation (especially, 4-nitrophenol and 2,4-dinitrophenol). This scenario was modelled by considering a gas-water partitioning equilibrium, as described by the Henry's law constants (K_H) and by the volume fraction of liquid water in the atmosphere ($f_W = 5\times10^{-7}$) [4]. We could thus model the time evolution of aqueous phenol from benzene + $^{\bullet}OH_{(w)}$, followed by phenol degradation with $^{3}CDOM^{*}_{(w)}$, as well as phenol formation in the gas phase followed by liquid-water partitioning and precipitation of its transformation products.

References:

[1] S. Allen, D. Allen, V.R. Phoenix, G. Le Roux, P. Durántez Jiménez, A. Simonneau, S. Binet, D. Galop, Nature Geosciences 2019, 12, 339–344.
[2] A. Bianco, F. Sordello, M. Ehn, D. Vione, M. Passananti, Science of the Total Environment 2020, 742, 140413.
[3] S. Canonica, M. Freiburghaus, Environmental Science & Technology 2001, 35, 690-695.
[4] US-EPA, 2021. Estimation Programs Interface Suite™ for Microsoft® Windows, v. 4.11. https://www.epa.gov/tsca-screening-tools/epi-suitetm-estimation-program-interface.

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ABC-PO-007

Development of chemical organogels and sponges for modern and contemporary artworks cleaning

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Polydimethylsiloxane (PDMS) organogel sponges were prepared and studied in order to understand the role of pore size in an elastomeric network on the ability to uptake and release organic solvents. PDMS organogels sponges have been produced according to sugar leaching techniques by adding two sugar templates of different forms and grain sizes (a sugar cube template and a powdered sugar template), in order to obtain materials differing in porosity, pore size distribution, solvent absorption and liquid retention capability. These materials were compared to PDMS organogel slabs that do not contain pores. The sponges were characterized by Fourier Transformed Infrared spectroscopy in the Attenuated Total Reflectance mode (FTIR-ATR) and compared with PDMS slabs that do not contain pores. Scanning Electron Microscopy (SEM) provided information about their morphology. X-ray Micro-Tomography (XMT) allowed us to ascertain how the form of the sugar templating agent influences the porosity of the systems: when it was in the form of cubes, the porosity was 77% and the mean size of the pores was ca. 300 μm; when it was in the form of powder, the porosity decreased to ca. 10% and the mean pore size was reduced to ca. 75 μm. These materials, porous organic polymers (POPs), are able to absorb many solvents in different proportions as a function of their polarity. The absorption capacity, as measured by swelling of eight solvents, covering a wide range of polarities, was investigated. Rheology data established that solvent absorption did not have an appreciable impact on the gel-like properties of the sponges, suggesting their potential for applications in cultural heritage conservation. Application tests were conducted on the surfaces of two different lab mock-ups that simulate real painted works of art. They demonstrated further that PDMS sponges are a potential innovative support for controlled and selective cleaning of works of art surfaces.

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New modified alginate gels for the cleaning of cultural heritage items

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In the field of cultural heritage conservation, the cleaning of artworks has become an essential practice as part of preservation processes, because artefacts are often affected by different unwanted materials. Cleaning of cultural heritage items usually concerns the removal of substances deriving from natural pollution (e.g., surface dirt, grime, and soil) as well as from past non-original treatments (e.g., polishing treatments, adhesives, and decayed varnishes).

Following previous research works, we focused our attention on gel materials as cleaning tools for the cultural heritage. Gels were introduced by the pioneering works of Wolbers at the end of 1980s as cleaning systems to remove dirt and degraded materials from different substrates such as metals, stones, and paper.[1]

Generally, the gels were prepared from different polymers loaded with solvents, including water, or organic solvent/water mixtures (e.g. emulsions). More recently, "green" gels have been prepared from natural polymers, although the rather complicated structure and composition of these matrixes may induce a more difficult control of some gel properties such as mechanical features and water content. Commonly used water-containing natural gels (hydrogels) are based on agar, gellan gum, xanthan gum, and chitosan. The hydrogels based on these natural polymers have been considered as cleaning tools by conservators over the last few decades.[2, 3]

The present study is focused on the preparation and characterization of new gels based on the natural polysaccharide alginate, whose structure was chemically modified in order to control the properties of the resulting hydrogels. In particular, different crosslinking materials were used to prepare a series of hydrogel characterised by different mechanical properties and water content values. The control of water content (and water release) of hydrogel is expecially important when the cleaning of potentially water-sensitive substrates is considered. Functionalization of alginate was performed by using as much as possible "green conditions", aiming to develop highly sustainable materials. A multi-analytical approach was used to characterize the structure and the properties of hydrogels. The tuning of alginate properties by its chemical modification opens the opportunity to use the corresponding gels for the surface treatment of different substrates like wood, stones, and paper.

References:

[1] R. Wolbers, Cleaning Painted Surfaces: Aqueous Methods; Archetype Publications: London, UK, 2000.
[2] C. Lee, F. Volpi, G. Fiocco, M. Weththimuni, M. Licchelli, M. Malagodi, Materials 2022, 15, 1100 - 1117
[3] S. Thakur, B. Sharma, A. Verma, J. Chaudhary, S. Tamulevicius, V.K. Thakur, J. Clean. Prod. 2018, 198, 143–159.

ABC-PO-009

The anthropic impact on Antarctica: a biennial study on emerging contaminants' occurrence

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Human activities influence (often negatively) the environmental processes. The most visible consequences occur in highly-impacted regions, where industries and residences are more abundant. Still, even small settlements in remote areas can have an impact on the surroundings, like the Mario Zucchelli Italian research Station (MZS) in Terra Nova Bay (Antarctica). The PNRA (National Research Program in Antarctica) project called 'MATISSE' (Emerging contaminants in the Ross Sea: occurrence, sources and ecotoxicological risks) is devoted to assess such an impact[1]. In this work, the results of the samplings performed in the outlet of the MZS's wastewater treatment plant (WWTP) and the surrounding Road Bay seawaters (where the WWTP discharges) during two consecutives campaigns (37th and 38th Italian expedition in Antarctica) were compared. Samplings were carried out by following two approaches: (i) spot sampling and consequent solid-phase extraction and (ii) passive sampling (exploited by the first deployments of Polar Organic Chemicals Integrative Samplers – POCIS –in this remote region for 2-3 weeks), which encompasses an in-situ pre-concentration during the sampling itself. The final extract of each sample processed was properly diluted and analysed by LC-MS/MS, targeting approximately 40 emerging contaminants, belonging to various classes and presenting different physico-chemical properties. The first campaign involved an intensive sampling, which was reorganized during the second one according to the obtained results[1]: the processing method was slightly modified to increase the recovery of the most polar analytes, and the sampling point at Road Bay was moved closer to the WWTP outlet to reduce the seawaters' dilution effect. This allowed to double the number of compounds detected in marine samples, while the analytes within the WWTP effluent were more or less the same from one year to the following one. Detected substances included food- and recreational activities-related compounds (methylxanthines, artificial sweeteners, taurine, nicotine), pharmaceuticals (non-steroidal anti-inflammatory drugs, β-blockers, β-agonists…), hormones, UV-filters and industrial additives (like PerFluoroAlkyl Substances and BisPhenol-A) at concentrations ranging from dozens of ng L^{-1} to dozens of µg L^{-1}. During the two campaigns, most of these analytes were quantified at comparable levels. In order to get a more comprehensive evaluation and interpretation of the results, both principal components analyses and correlation matrices were implemented, highlighting the relations among the compounds and those with the number of personnel in the base, as well as between the two sampling approaches, whose quantifications resulted correlated for many compounds[1].

References:

[1] H. MacKeown, C. Scapuzzi, M. Baglietto, B. Benedetti, M. Di Carro, E. Magi, Science of The Total Environment, 2024, 925, 171755.

ABC-PO-010

Life Cycle Assessment of a process for the removal of contaminants of emerging concern by advanced oxidation process enhanced by UVC irradiation

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Life cycle assessment (LCA) is applied in this study to evaluate the Global Warming Potential (GWP) of a system[1] that use advanced oxidation processes (AOPs), such as photo-Fenton enhanced by UVC light[2], for the degradation of 1 mgL^{-1} of acetaminophen, as an example of contaminant of emerging concern (CEC), under different conditions[3]. Results showed in Figure 1 depicts the GWP of acetaminophen removal under different scenarios. This indicate that energy is the most important factor to be taken into account in order to reduce the overall greenhouse gases emission. This analysis confirmed the results obtained in the previous study since photo-Fenton process is the best as it is the fastest and emits the least kg CO_2-eq. Finally, in future works the study will be extended to treat larger volumes in order to approach a WWTP.

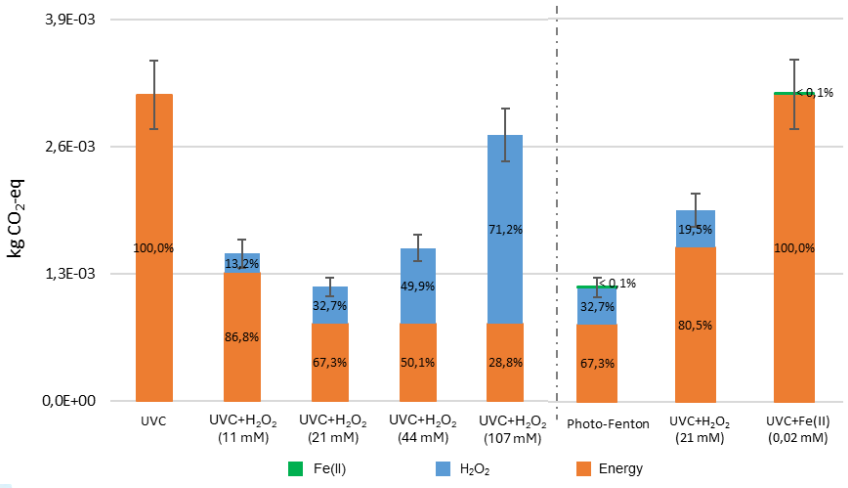

Figure 1: GWP of acetaminophen removal under different conditions.

References:

[1] ISO, 2006b. Environmental Management — Life Cycle Assessment — Principles and Framework, ISO 14040:2006.
[2] D. Li, Z. Feng, B. Zhou, Sci. Total Environ 844 (2022) 157162.
[3] R. López-Timoner, M. Mora, E. Zuriaga, Water. 15 (2023) 882.

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Biopolymer membranes as a sustainable alternative to chemical biocides in Built Cultural Heritage: a preliminary study

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Nowadays, outdoor built cultural heritage is particularly affected by degradation phenomena threatening the conservation of the stone elements because of the changes in environmental conditions (e.g. increase in the air pollution, climate changes) along with predisposing factors linked to the intrinsic characteristics of the material (porosity, composition, etc.). These changes have resulted in an acceleration of degradation processes, including those of biological origin. The Baroque monuments of eastern Sicily, built in local limestones, represent a significant conservation challenge since physical, chemical decay and biodeterioration are easily observable. In this context the attention to the environmental issue encourages the definition of more sustainable conservative strategies[1] focused on safer and cheaper alternatives to traditional chemical biocides. The objective of this research is to synthesize biopolymeric membranes as controlled-release systems for natural biocides, to test on Modica, Ragusa and Comiso stones widely used in the Sicilian Baroque. The main compositional and physical features of the limestones were previously and opportunely determined to assess the efficacy of the developed polymeric systems.

In this study, a biopolymeric membrane based on Polylactic acid (PLA) and combined with limonene was synthesized and characterized using analytical techniques[2] such as Fourier-transform infrared spectroscopy (FTIR) and nuclear magnetic resonance spectroscopy (NMR). FTIR analysis enabled the identification and interpretation of molecular interactions between limonene and the PLA matrix through vibrational band analysis, while NMR highlighted the presence of limonene in the membrane. The next steps foresee to prepare membranes with different amounts of limonene and to evaluate their biocidal efficiency in biological tests conducted on limestone samples undergone biocolonization in laboratory-controlled environment.

References:

[1] M. Cirone, A. Figoli, F. Galiano, M.F. La Russa, A. Macchia, R. Mancuso, M. Ricca, N. Rovella, M. Taverniti, S.A.Ruffolo, Innovative Methodologies for the Conservation of Cultural Heritage against Biodeterioration: A Review. Coatings 2023, 13, 1986.

[2] M. P. Arrieta, J. López, S. Ferrándiz, M. A. Peltzer, Characterization of PLA-limonene blends for food packaging applications, Polymer Testing 2013, 32, 760-768.

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Neural Network Modeling of Nanobubble Characteristics in Venturi Tube-Assisted Hydrodynamic Cavitation for Organic Chemicals Degradation

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Hydrodynamic cavitation has been shown as a suitable technology to remove organic contaminants from water, especially in the presence of nanobubbles. Nanobubble generation has been investigated using devices, including Venturi tubes, showing a strong correlation between nanobubble characteristics (e.g., diameter, Zeta potential, and size distribution) and the Venturi tube's geometry. However, building and testing different designs can be resource and time-consuming; therefore, three neural network models were developed to estimate nanobubble characteristics from Venturi tube configuration parameters in this study.

A design of experiment (DoE) approach was employed to select the most relevant Venturi tube configurations considering throat diameter (Dt), throat length (L1), divergence length (L2), and divergence angle (α°). In detail, 10 out of the 30 considered designs were built and tested in a cavitation system to obtain the data needed to train and validate the neural networks. Dynamic light scattering (DLS) analysis was used to measure the size and zeta potential of the produced nanobubbles. The neural networks were trained and tested to estimate nanobubbles' diameter, zeta potential, and size distribution. Considering the limited range of each design factor (L1, L2, Dt) caused by technical limitations, the model shows good prediction efficiency based on the regression coefficient (R-value), error histogram, and goodness-of-it. The Venturi tube showing the best results regarding nanobubble generation was manufactured from steel and tested inside a semi-pilot cavitation system (4 bar pressure, 13.6 liters of water) to degrade Methylene Blue dye (96% of degradation in 20 min at pH = 3.3). The neural networks developed in this study will facilitate the advancement of Venturi tubes by accommodating various design factor configurations and enabling thorough investigations into their performance.

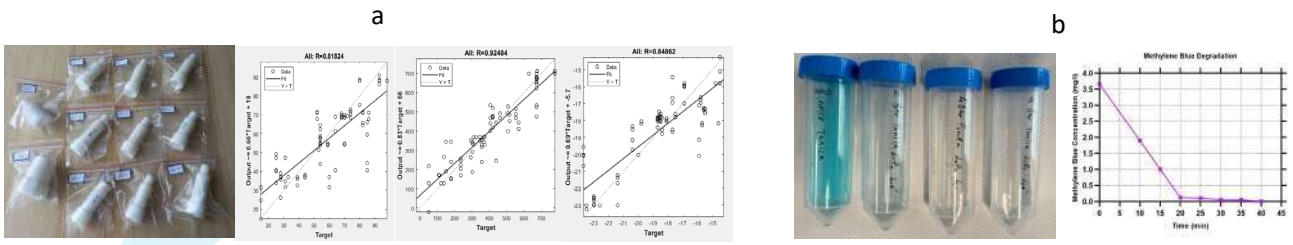

Figure 1: Venturi tube design and neural network models (a) Methylene Blue degradation test (b)

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Safe by design assessment of a multi-component nanomaterial embedded in a cement mortar for photocatalytic NO_x degradation

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Within the European Green Deal, the Chemicals Strategy for Sustainability (CSS) identified several actions to reduce negative impacts to human health and the environment related to chemicals, materials, products and services in the European Union (EU). The EU CSS action plan envisions the development of a framework to define Safe and Sustainable by design (SSbD) criteria for chemicals and materials with the aim to reduce greenhouse gas emissions by 55% by 2030 from 1990 levels. Therefore, according to a SSbD framework developed by the Joint Research Centre, the safety assessment of the SiO_2@ZnO multi-component nanomaterial (MCNM) embedded into a cement mortar for NO_x degradation was performed, defining specific safety criteria highlighted here below. First, in line with step 1 of the framework, the hazard assessment of the MCNM was carried out by i) investigating the physico-chemical identity of both the individual NMs and the MCNM, ii) assessing the hazard of the precursors for the MCNM synthesis and iii) evaluating the cytotoxicity of both the individual components and the MCNM through *in vitro* testing. Physico-chemical characterization showed that the mesoporous SiO_2 core present an incomplete coating of a thin layer of ZnO, did not impacting on the overall SiO_2 size, but reducing the surface area covering the surface pores. As far as the hazard assessment of MCNM precursors is concerned, while SiO_2 NM powder was considered a non-hazardous substance according to the present classification, $ZnAc_2 \cdot 2H_2O$ showed both health and environmental hazards, (i.e., acute toxicity, serious eye damage and long-term chronic aquatic hazard). Moreover, the *in vitro* hazard screening using THP-1 cells to inform the early innovation stages suggested the hazard of the MCNM was comparable to ZnO NM. Afterwards, according to step 2 of the framework, human health and safety aspects of the MCNM-based material were also investigated. Starting from the very early stage of the design phase, a questionnaire-based standard industrial hygiene survey showed that a release of nanoscale particles into the workplace air could not be excluded during synthesis. This required an occupational exposure assessment of three different exposure scenarios selected through the survey, i.e., material synthesis, calcination and MCNM-based mortar formulation. The results showed that particles concentration was always lower than the recommended limit values (Recommended Benchmark Level – RBL, or nano reference values – NRV) proposed by international bodies. Lastly, as proposed in the final application/use phase of step 3 of the framework, an environmental exposure assessment was carried out, investigating the potential release of inorganic elements constituting the MCNM-based mortars in ultrapure water, following ISO 2812:2018 for mortars' immersion conditions and EN 12457-3:2004 for leaching evaluation. No or negligible release of Zn and Si was recorded, indicating that their potential exposure is unlikely once the MCNM is embedded into the mortars. In conclusion, the safety assessment of this MCNM through the SSbD framework helped in identifying safety criteria, providing useful information on their risk profile for future assessment of their sustainability.

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New materials with low environmental impact for the protection of Cultural Heritage

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In recent years it has become increasingly important to identify new materials to be used for the protection of Cultural Heritage in place of long-chain perfluoroalkyl compounds (PFAS), highly efficient products[1] but with a high environmental impact, and therefore currently under restriction in EU. In the last decade, new materials have been designed for the protection of degraded, non-varnishable wooden artifacts, but also applicable in other cases, for instance stone based items, where the maintenance of the aesthetic characteristics of the treated object is essential.

Recently, interesting results have been obtained on wood using various fluorinated products, prepared by reacting different oligoamides and a diethylenetriamine with a C6 fluorinated chain epoxide[2]. All these compounds have low molecular weights and therefore non-film forming properties, the presence of polar groups makes them similar to polar materials such as wood while the fluorinated chain gives hydrophobicity and stability to light, but above all they are soluble or easily mixable in eco-sustainable solvents such as 2-propanol. In view of a further probable extension of the restriction to the use of C6 fluorinated chemicals, other products with a shorter fluorinated chain (C4) have been also synthetized.

Systematic tests on wood samples have been done to evaluate and compare these products using a diagnostic protocol developed for this specific application field. The optimal application method has been evaluated for each product. To verify the actual variation in surface wettability with no or minimal alterations to the surface color, contact angle and colorimetric measurements have been carried out. Furthermore, the second part of the diagnostic protocol has been developed to test the resistance of these protective materials to natural and artificial photoinduced aging, as well as the resistance to mild abrasion, both on fresh and aged samples, to simulate the effects of manipulating the artefacts. Tests on stone samples have confirmed the potential of these new materials as protective agents.

Best results both in terms of protective efficacy and stability to various types of stress were obtained with the C6 derivatives, demonstrating the criticality in the use of products with a too low fluorine content.

Fluorine-free derivatives are being also studied as alternative protective agents for Cultural Heritage.

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References:

[1] Y. Cao, A. Salvini, M. Camaiti, Mater. Des. 2018, 153, 139 –152.
[2] Y. Zhang, L. Vespignani, M. G. Balzano, L. Bellandi, M. Camaiti, N. Lubin-Germain, A. Salvini, Coatings 2022, 927, 1 – 25.

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Pollution by polycyclic aromatic hydrocarbons in the Mediterranean Sea: the *Caretta Caretta* turtle as a bioindicator

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Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous pollutants that can be detected quite often in marine and coastal environments. PAHs are highly toxic, mutagenic, carcinogenic, teratogenic, and immunotoxicogenic to various life forms. One of the main targets of PAHs in marine environments is sea turtles. They are at the top of the marine food chain and, despite being migratory, are good indicators of marine contamination. The loggerhead turtle C. caretta (Linnaeus, Cheloniidae) is the most common sea turtle species in the Mediterranean Sea and it often uses the Italian coasts for nesting and feeding ground. The Mediterranean Sea represents an area where conservation efforts are of paramount relevance due to historic release from former industrial sites, and current commercial release from cargo, tanker, and passenger transportation. Caretta caretta, diving into deep and cold water and returning in surface for breathing, rest or rewarm are highly exposed to hydrocarbon pollution from both seabed and surface [1].

This study aimed to determine the 16 priority PAHs, in different organs and tissues of loggerhead turtles, stranded along the coasts of the southern Tyrrhenian Sea, Italy, from 2019 to 2021. The 16 EPA's priority PAHs were determined by gas chromatography coupled with mass spectrometry (GC-MS).

The first results showed the prevalent presence of naphthalene and represented 90.0% and 93.7% of the ΣPAHs in the different organs. A very interesting and little-studied thing is the presence of PAHs in the salt gland, whose concentrations are sometimes higher than in other organs. Furthermore, an overall higher bioaccumulation of NAP is observed in the salt glands of female and adult individuals. Data of PAHs richness highlighted a potential risk of neoplastic disease development and that anthropogenic activities may seriously impair healthy state conditions of C. caretta. populations in southern Tyrrhenian Sea [2].

References:

[1] Pasanisi, E., Chimienti, M., Blasi, M.F., Maffucci, F., Hochscheid, S., 2022. Ocean highways in the Western Mediterranean: which are the areas with increased exposure to maritime traffic for loggerhead turtles? Front. Mar. Sci. 9, 924532 https://doi.org/10.3389/fmars.2022.924532.

[2] Arienzo, M., Toscanesi, M., Esposito M., Iaccarino D., Di Nocera F., Canzanella S., Ferrara L., Di Natale G., Trifuoggi M., 2023. Comparative study of polycyclic aromatic hydrocarbons (PAHs) in salt gland and liver of loggerhead turtle Caretta caretta (Linnaeus, Cheloniidae) stranded along the Mediterranean coast, Southern Italy. Ecotoxicology and Environmental Safety, 2023, 263, https://doi.org/10.1016/j.ecoenv.2023.115355.

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Nano-engineered solutions for safeguarding frescoes: innovative formulations against microbial deterioration

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Microbial colonization poses a significant challenge to the longevity of mural paintings[1, 2]. Despite efforts to combat microorganisms using various biocides, their long-term effectiveness remains limited, accompanied by high toxicity and corrosive side effects[3]. The recent advances in nanotechnology are opening great opportunities for the conservation of cultural heritage, changing the approach paradigm. This study centres on developing ground-breaking nano-engineered formulations, merging noble metal nanoparticles with natural biopolymers, to assess their potential as microbial inhibitors on frescoes. Tailored synthesis of nanoparticles with specific physical-chemical attributes enhances antimicrobial efficacy. Upon achieving desired properties, mock-ups are meticulously crafted for preliminary performance evaluations. The formulations exhibit minimal colour variation, non-glossy surfaces, favourable hydrophobicity, water vapour permeability, and chemical stability post-artificial and natural aging.

Testing various concentrations screens the in vitro antimicrobial activity to identify the most promising formulation. Remarkably, these formulations substantially limit fungal colonization of frescoes and reduce bacterial growth by up to 99%. Further assessment involves observing biofilm formation and evolution on chitosan-nanoparticle-treated frescoes mock-ups post-aging in climatic chambers, supported by electron microscopy and XPS analyses.

These experiments underscore the efficacy of highly innovative composite formulations in inhibiting microbial growth on mural paintings, signalling their readiness for application to Cultural Heritage materials.

References:

[1] L. Zucconi, F. Canini, D. Isola, G. Caneva, 2022, 12, 2988.
[2] L. Randazzo, G. Montana, R. Alduina, P. Quatrini, E. Tsantini, B. Salemi, 2015, 16, 838 - 847.
[3] I. Franco-Castillo, L. Hierro, M. Jesús, A. Seral-Ascaso, S. G. Mitchell, 2021, 7, 629 - 669.

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Mesostructured silica-based materials as sorbents and catalysts for pollutant removal and CCU technologies

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Introduction

In recent years, the concerns surrounding heavy metal pollution and the increasing CO_2 levels contributing to global warming have intensified. This study focuses on the synthesis and functionalization with aminosilanes of mesostructured silicas (MCM-41, MCM-48) for the development of amine-silica sorbents with potential applications in Cd^{2+} removal from aqueous solutions and in Carbon Capture and Utilization (CCU) technologies. Thanks to their highly ordered mesoporous structure, the donation of lone pairs by amines to Cd^{2+} and the amines' high affinity for CO_2, amine-silica sorbents are suitable for such applications. Moreover, mesostructured silica-based composites have been developed by impregnating MCM-41 with oxidic phases of copper, zinc, and zirconium (CZZ), for a prospective application in the catalytic hydrogenation of CO_2 to methanol.

Materials and Methods

Mesostructured silica was synthesized via the sol-gel technique employing a templating agent, a siliceous alkoxide precursor and two distinct solvent systems: water alone (yielding MCM-41) and a combination of water and ethanol (yielding MCM-48). Various amine-silica sorbents were obtained from post-synthesis grafting with aminopropyltriethoxysilane and tested for Cd^{2+} removal and CO_2 capture. To lower both environmental and economic impact of the grafting procedure, an eco-friendly solvent (*i.e.* butanol instead of toluene) was used. The CZZ@MCM-41 composites were prepared through auto-combustion. Moreover, for the development of cadmium sorbents and CZZ-based catalysts, mesostructured silica from an industrial waste (hexafluorosilicic acid, FSA) was also tested. All sorbents were characterized by XRD, TEM-EDX, TEM, N_2-physisorption, thermogravimetric-analysis and ATR-FTIR.

Results and discussion

MCM-48 was obtained by adding ethanol as co-solvent, keeping all the other experimental conditions equal to the MCM-41's synthesis, confirming its key role among others synthesis parameters in tuning the mesophase. The replacement of the alkoxide precursor with FSA allowed the production of MCM-41 with comparable textural properties, reducing environmental and economic impacts for CZZ-catalysts' support. The same amino groups' concentration (~2 mmol/g) was obtained for MCM-41 functionalized with either toluene or butanol. Amino-silica sorbents were tested for Cd^{2+} sorption showing a removal percentage of 99% and adsorbed amount of cadmium q_e=46 $mg_{Cd(II)}/g_{sorb}$ at pH 5. This preliminary study suggest that amine-silica sorbents have the potential to remove significant amounts of cadmium ions from aqueous solutions.

The use of butanol instead of toluene in the grafting procedure led to a decline in CO_2 adsorption performances (968 $\mu molCO_{2ads}/g_{sorb}$ *vs.* 480 $\mu molCO_{2ads}/g_{sorb}$), indicating the need to improve functionalization process. Nevertheless, a comparison revealed that toluene-functionalized MCM-41 is more efficient than SBA-15, emphasizing the crucial role of the support's surface area.

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An integrated approach for the site-specific identification of emerging contaminants in water resources

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The implementation of Water Safety Plans (WSPs) promoted by World Health Organization (WHO) aims to ensure safe drinking water supplies by identifying and assessing potential site-specific risks as well as developing mitigation strategies to prevent and minimize impacts on human health and the environment. One of the crucial steps in applying the WSP approach is the identification of chemicals of concern, especially those not regulated or monitored. In this study, we developed and tested an integrated approach applying on both desk-based and experimental methodologies to identify such chemicals in the deeply industrialized Province of Vicenza (Veneto Region, Italy) where significant aquifers historically subjected to severe contamination are used for water supply. The first methodology involved the use of publicly available databases (e.g., European CHemical Agency (ECHA) database) and information on the geographical distribution of the industrial plants present in the study area. We obtained a list of 46 non-regulated chemicals of concern that were further prioritized based on their Persistence, Mobility, and Toxicity (PMT) characteristics, and the quantity of wastewater associated with their use based on information retrieved from the local water utility. The second methodology involved the sampling of surface and wastewater collected within the study area followed by analysis using liquid chromatography coupled with high resolution mass spectrometry (LC-HRSM, qTOF Bruker Compact) to qualitatively assess the presence of chemical of concern. The mass spectroscopy data and retention time was compared with libraries containing information (e.g., parent ion exact mass, isotopic pattern) on more than 2000 substances including pesticides, pharmaceuticals, and illicit drugs. The analytical results showed that the highest number of chemicals was detected at the outlet of wastewater treatment plants, with pharmaceuticals being the most present class of compounds. Moreover, several of the 46 substances identified through the first methodology, including venlafaxine, diclofenac, and valsartan, were also detected during the screening analysis. The proposed approach effectively identified site-specific chemicals of concern highlighting the importance of integrating information on industrial activity with experimental data. In fact, all substances identified in this work will be further investigated through quantitative analysis to better understand their occurrence in the examined water supply area.

ABC-PO-019

Exposure assessment of plant protection products in the Northern Adriatic Sea: emission inventory and environmental modelling

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Plant protection products (PPPs) are formulations mainly used to keep crops healthy and prevent them and their products from being destroyed by diseases and/or infestations, thus contributing maintain high levels of food production. These products include fungicides, herbicides, insecticides, plant growth regulators, and pest repellents. The toxicity of these chemicals towards humans and animals is quite lower with respect to that against target organisms, but there are still direct and indirect toxic effects on non-target organisms that are not fully understood yet. Moreover, the monitoring of the most recently developed PPPs in the environment is still limited, especially for coastal waterbodies. The use of predictive exposure models has been identified as a complementary, cost-efficient tool to support the investigation of the behaviour and environmental fate of these contaminants and the assessment of associated risks.

The Northern Adriatic is a narrow and shallow sea, where the variety of temperature, salinity, and sedimentation patterns leads to the presence of different and unique habitats for marine species. This area is also subjected to pollution loads from both point and diffuse source. In particular, agricultural activities can affect water and sediments quality due to both nutrients and chemical pollutants loads.

The aims of this work, developed within the iNEST project, are: (i) to develop an emission inventory of several PPPs in the study area, (ii) to use state-of-the-art modelling tools to investigate the environmental distribution and fate of these contaminants in the Northern Adriatic Sea, with particular attention to the processes involved in their natural attenuation, and (iii) to define a risk-based priority list of contaminants specific to the case study area, taking into consideration the overall mass balance of the target pollutants.

The emission inventory was developed by integrating PPPs sales data obtained from Regional authorities within the Northern Adriatic drainage basin with river flow, land-use and geographical information through statistical data treatment and GIS-based spatial analysis. In addition, a preliminary modelling exercise was carried out by applying the newly-developed ChemicalDrift model[1], a chemical transport module part of the open-source Lagrangian framework OpenDrift.

References:

[1] M. Aghito, L. Calgaro, K.-F.F. Dagestad, C. Ferrarin, A. Marcomini, Ø. Breivik, et al., Geosci. Model Dev., 2023, 16, 2477–2494

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ABC-PO-020

Mulching Films: Plastic Additives Release into Soil and Crops

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Mulching, a widely practiced technique in agriculture, involves laying a protective layer of material over the soil's surface [1]. This is typically achieved using films derived from polyethylene (PE), known for containing additives such as phthalates. These additives are recognized for their ability to disrupt endocrine functions, thereby posing environmental and health risks through the potential transfer of chemicals to the soil and crops.

Biodegradable plastic mulches could represent an alternative to reduce plastic waste and the costs associated to the PE films removal. However, concerns exist regarding the release of substances from these mulches, impacting biodiversity and human health. To assess contaminants transport, a field experiment was conducted with strawberries by mulching the soil with four different film materials: PE, biodegradable PE (PE-BIO), polypropylene (PP) and polybutylene adipate terephthalate (PBAT)/starch. Soil and strawberry samples were analysed by GC-MS for phthalates and other plastic additives such as acetyl tributyl citrate, di-n-butyl sebacate and tris(2-ethylhexyl) phosphate.

The Kruskal-Wallis test showed significant differences in the total concentration of phthalates between the control soil and soils mulched with PE-BIO ($p=0.033$) and PP ($p=0.002$). Furthermore, a significant difference was also observed between the soil mulched with PE and that mulched with PP ($p=0.048$). However, no statistically significant differences were found between the controls and the soil mulched with PBAT-starch and PE ($p=1$). Regarding dibutyl sebacate and acetyl tributyl citrate, the statistical tests did not show any significant differences among the treatments ($p>0.143$).

Data from strawberry samples are currently being analysed and will be presented at the conference.

The results will help determine the risks posed by mulches to agricultural soils and whether differences exist in contaminant transport among different mulching materials.

References:

[1] B. Chen, J. Cui, et al. Journal of Cleaner Production, 2022, 359, 132011. https://doi.org/10.1016/j.jclepro.2022.132011

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ABC-PO-021

Enhancing permanence of corrosion inhibitors inside acrylic protective coatings for outdoor bronze statues using green nanocontainers

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Outdoor bronze statues face daily exposure to weathering and reactive compounds present in the atmosphere which can interact with the surfaces of the artworks. To avoid these phenomena, one of the most exploited methods is the application of coatings including corrosion inhibitors. However, the most employed acrylic coating, Incralac®, contains benzotriazole (BTA) which is toxic and considered a suspected carcinogen.[1] The development of safe and reliable long-term methods and strategies for the conservation of these artworks is nowadays a mandatory prerequisite, since the currently exploited hazardous materials need to be replaced.[2] The idea behind this work arose from the attempt to improve the poor permanence over time of two corrosion inhibitors chosen to formulate new acrylic coatings for outdoor bronzes.[3] Cyclodextrins were selected to host corrosion inhibitors, due to their capability of giving rise to complexes embedding small organic molecules. Cyclodextrins are water-soluble macrocyclic oligosaccharides, made of at least six α-D-glucopyranose units linked via α-(1–4)-glycosidic bonds. CDs are among the most widely used host molecules thanks to their unique structure that creates an internal cavity less hydrophilic than the external aqueous environment and therefore able to accommodate a large variety of hydrophobic molecules inside it.[4]

In this work, Methyl β-Cyclodextrins (Me-β-CD) were investigated as nanocontainer of 5-ethyl-1,3,4-thiadiazol-2-amine (AEDTA) for enhancing its permanence inside acrylic coatings. First, the compatibility of the nanocarriers inside the acrylic systems was assessed. Then complexes of Methyl β-Cyclodextrin and AEDTA were prepared and the formation of the inclusion complex was proved by FTIR and XRD. Three types of acrylic coatings were prepared at different concentration of Me-β-CD/AEDTA system. The coatings were applied on both inert supports and bronze polished mock ups. The so-prepared samples were aged inside an oven at 80 °C and monitored every 24 hours by Fourier Transformed Infrared Spectroscopy, either in transmission or in reflection mode according to the support. During the first 72 hours, SPME-GC/MS and py-GC/MS analyses were also performed to assess the volatilization of the corrosion inhibitor. The obtained results were compared with the corresponding data for pure AEDTA films and Incralac®. The outcomes from the experiments are encouraging, highlighting that Me-β-CD/AEDTA complexes might be considered as serious candidates for the formulation of novel coatings, exhibiting increased stability and longer retention of AEDTA over time.

References:

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ABC-PO-022

Arsenic and chromium contaminated groundwaters: from geochemical analysis to treatment

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The presence of toxic elements in water is becoming a serious concern, also when it is not due to pollution related to human activities, but to the natural interactions occurring between water and rocks. In fact, this type of water contamination is usually underestimated with respect to that linked to industrial productions; however, its impact on human health is also significant, since the concentration of toxic species in groundwater is often higher than the imposed limits. In last years, an increase of the awareness for natural contaminated groundwaters has grown. In particular, in this work, the approach followed within the PNNR project (CUP B83C22003980006) to manage groundwaters contaminated by arsenic and hexavalent chromium is reported and discussed. Starting from a map of geochemical characteristics of groundwaters present in the Sila and Pollino massif areas (Southern Italy), it was possible to obtain information useful to identify the most suitable technology to treat the water, in order to obtain a stream which meets the threshold values (25 µg/L and 10 µg/L for chromium and arsenic, respectively). In this respect, membrane operations, like nanofiltration, showed interesting performance in terms of removal efficiency and purified water production.

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ABC-PO-023

Development and evaluation of an air cleaning system for prolonged antifungal and antibacterial activity for indoor cultural heritage spaces

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Biological air contamination inside cultural heritage indoor spaces is a frequent problem that needs to be solved since microbial deposition on artistic surfaces causes mechanical biodeterioration and the impossibility of a complete appreciation of the artwork. To prevent those mechanisms, it is helpful to reduce the microorganisms present in the air by introducing an air-cleaning system. The starting point of this project is the work of a research group from the *Universitat Politècnica de Valencia* that has already applied tea tree essential oil cold diffusion as an active air cleaning system for this purpose at a small space in *Los Santos Juanes* Church in Valencia [1]. In this research work, the tea tree essential oil has been encapsulated inside the pores of mesoporous silica support to elongate the period of activity of the oil and enhance its performance. To obtain the simplest device, it has been designed to be a part of a passive-release air cleaning system.

The silica mesoporous support has been characterized through diffuse/specular reflectance, attenuated total reflectance infrared (ATR-IR) and Raman spectroscopies, electron scanning microscopy coupled with X-ray microprobe (SEM-EDX), porosimetry and X-ray diffraction (XRD) whereas the amount of the charged essential oil has been evaluated through thermogravimetric analysis (TGA) [2].

In addition, this innovative air cleaning system has been tested in test rooms and compared with the free-oil system. The complete air monitoring control (temperature, relative humidity, microbial assay, and particulate matter) performed in these rooms showed that the essential oil encapsulated in the microparticles (as a passive release system) keeps its biocidal activity for a longer time than the oil-free one, especially after the third week for the bacteria and after the fourth for the fungi. The new cleaning system has also been applied in vitro [3].

These promising results are the beginning of future research projects that will focus on combining the microparticles and the essential oil to have a high immediate and long-term biocidal effect, for example, applied in an air filtration system.

References:

[1] J. Díaz-Alonso, A. Bernardos, J. L. Regidor-Ros, R. Martínez-Máñez, and P. Bosch-Roig, 'Innovative use of essential oil cold diffusion system for improving air quality on indoor cultural heritage spaces', *Int. Biodeterior. Biodegrad.*, vol. 162, p. 105251, Aug. 2021, doi: 10.1016/j.ibiod.2021.105251.

[2] A. Bernardos *et al.*, 'Antifungal effect of essential oil components against Aspergillus niger when loaded into silica mesoporous supports', *J. Sci. Food Agric.*, vol. 95, no. 14, pp. 2824–2831, 2015, doi: 10.1002/jsfa.7022.

[3] A. Winkler, T. Contardo, V. Lapenta, A. Sgamellotti, and S. Loppi, 'Assessing the impact of vehicular particulate matter on cultural heritage by magnetic biomonitoring at Villa Farnesina in Rome, Italy', *Sci. Total Environ.*, vol. 823, p. 153729, Jun. 2022, doi: 10.1016/j.scitotenv.2022.153729.

ABC-PO-024

Upcycling of industrial membrane wastes and their reuse as sorbent of emerging contaminants in drinking water

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Drinking water purification from Emerging Contaminants (ECs), which include pharmaceuticals, personal care products, additives, and dyes, in a current main global challenge. To this aim, the development of innovative, sustainable, cheap, versatile and efficient technologies is urgently needed.[1]

In this communication, I will report innovative materials deriving from industrial scraps of polysulfone (PSU) and polysulfone-graphene oxide (PSU-GO) hollow fiber membranes industrial production, and their validation as sorbent materials for ECs in tap water.[2-3]Mechanical grinding was employed to convert scraps into PSU and PSUGO granules and cartridges filled with these materials exhibited superior adsorption capacities than Granular activated carbon (GAC), the industrial benchmark sorbent.[3] Notably, PSU-GO granules showed over 2 times higher adsorption capacities for diclofenac (DCF), a drug, and perfluorooctanoic acid (PFOA), and over 10 times higher on lead (Pb).[4] Molecular dynamics simulations provide insights on adsorption mechanisms, revealing the key role of graphene oxide (GO) in enhancing the adsorption performance.[5] The obtained materials were exploited under tap operational conditions (4 L/min, 2 bar) and the leaching of GO was excluded by Surface-enhanced Raman spectroscopy analysis of treated water.

Figure 1. a) Hot wire industrial membrane processing for commercial ultrafiltration modules, b) granular sorbent materials and cartridges obtained by scraps grinding , c) adsorption capacity of granules on lead, compared to GAC.

References:

[1] D. Cserbik, P.E. Redondo-Hasselerharm, M.J. Farré et al., npj Clean Water 2023, 6, 16
[2] S. Khaliha, M. Zambianchi, A. Bianchi et al, Journal of Membrane Science 2022, 120707
[3] M. Zambianchi et al., Advanced Sustainable Systems 2017, 1,1700019
[4] S. Khaliha, F. Tunioli et al, Water Research and Technology 2024, in press
[5] S. Khaliha, T.D. Marforio, A. Kovtun et al., Flatchem 2021,100283

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Novel and sustainable materials based on chitosan for the protection of metal surfaces of artistic and cultural interest

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Metal objects of cultural and artistic values are detrimentally affected by corrosion processes, which induce changes in the aesthetic and structural properties of precious surfaces. To hinder degradation and to preserve the artefacts, protective coatings are usually applied on metal objects. Traditional protective coatings are based on petroleum-derived materials and require harmful solvents for their application, representing a serious threat for both conservators' health and the environment. Recently, an increasing research interest has been addressed to the development of sustainable and effective protective materials for cultural heritage applications[1].

In the framework of the European GREENART project, research activities, aimed at the development of new solutions for the sustainable conservation of cultural objects, are currently ongoing. One of the main goals is the formulation and validation of polymeric coatings, starting from renewable sources and waste materials, to ensure a reliable and long-term protection of metal surfaces.

To achieve these challenges, we focused on coatings based on chitosan, an eco-friendly biopolymer derived from crustacean shells (as waste of fishing industry). Chitosan was used to prepare and optimize highly transparent and removable anticorrosive coatings. Water-based formulations were produced and applied on different metal surfaces, such as polished and patinated bronze and silver substrates, with the aim of studying the coating/metal interactions. To this purpose, both accelerated corrosion tests and long-term treatments reproducing natural indoor environments were performed and the structural and chemical properties of the coatings before and after the tests were deeply investigated. Results pointed out that chitosan show excellent protective properties toward different metal substrates. The coatings behaviour during the tests strictly depends on the composition of the metal surfaces and on the duration of the aging, proving that both accelerated and long-term treatments are required to evaluate the polymer/metal interactions as they provide complementary information[2]. The alteration of the films observed after a prolonged exposure to uncontrolled environmental conditions was used to optimize the formulation and enhance the long-term stability of the coatings.

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References:

[1] C. Giuliani, M. Pascucci, C. Riccucci, E. Messina, M. Salzano de Luna, M. Lavorgna, G. M. Ingo, G. Di Carlo, Progress in Organic Coatings 2018, 122, 138 – 146.

[2] F. Boccaccini, C. Giuliani, M. Pascucci, C. Riccucci, E. Messina, M. P. Staccioli, G. M. Ingo, G. Di Carlo, International Journal of Molecular Sciences 2022, 23(22), 14454.

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Bronze disease: synthesis and characterization of new recycled polystyrene-based coatings

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Polystyrene (PS) is one of the most used and worthwhile plastic materials: millions of tons of PS are produced every year for applications in several aspects of modern life, from packaging to construction and automotive. However, high production volumes imply high procession costs, making recycling a central goal for end-life PS plastics. Hence, the development of low-cost strategies aimed at converting waste plastics into new valuable materials is of paramount importance to minimize the environmental and health impact of this kind of waste. In particular, the PS conversion can match the need to develop new materials suitable for protecting outdoor bronze artifacts, also complying with circular economics goals (*e.g.* the European Green Deal).

To this aim, a new protocol for PS upcycling was developed, based on a study by Kurbanova.[1] Expanded PS was functionalized with an increasing feed of maleic anhydride (MA, 5 to 25% mol) *via* Friedel-Craft acylation reaction. The functionalization results in the formation of carboxylic pendant moieties, which could both (i) improve PS performances as a coating due to the interactions of the newly formed moieties with the bronze surface and (ii) act as a protecting group for the copper alloy.

The library of newly established materials (PS-MA) was analyzed by proton nuclear magnetic resonance (^{1}H NMR), attenuated total reflection Fourier transform infrared (ATR-FTIR), size exclusion chromatography (SEC), and differential thermogravimetry (DTG).

Application tests were carried out by laying PS-MA on bronze substrates. Coating thickness was measured by Optical Coherence Tomography (SD-OCT) before and after artificial aging treatment.[2] The tested samples have shown promising performance in terms of corrosion resistance, color, thickness, and adhesion.

Overall, the PS-MA library represents optimum candidates for the development of new and effective coating materials. Moreover, this novel class of end-life polystyrene materials could be further modified with target molecules to introduce additional anti-corrosive agents for cultural heritage aims and scopes.

References:

[1] R. A. Kurbanova, R. Mirzaoglu, G. Akovali, Z. M. O. Rzaev, I. Karatas, Journal of Applied Polymer Science 1996, 59, 235 – 241.
[2] D. Porcu, S. Innocenti, M. Galeotti, J. Striova, L. Dei, E. Carretti, R. Fontana, Heritage 2022, 5, 3548 – 3561.

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Changes in the magnetism of nanoakageneite as probe for adsorption phenomena of arsenate

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Iron oxi(hydroxi)des are known to be efficient sorbents toward arsenic species, thanks to the formation of complexes of the inner sphere, through ligand exchange of surface -OH_2 and -OH^- with the arsenic species in the coordination sphere of the structural Fe atoms.[1] Recently, we compared the sorption ability of different iron oxi(hydroxi)des, namely akaganeite (β-FeOOH), ferrihydrite (referred to as $Fe_5HO_8{\cdot}4H_2O$), and maghemite (γ-Fe_2O_3, as bare and silica-based composite) toward arsenate/arsenite species in spiked aqueous solutions.[2] Akaganeite was proved to be the best sorbent for arsenate anions (89 mg g^{-1} at pH_0 3, 52 mg g^{-1} at pH_0 8) and also an efficient one for arsenite species (91 mg g^{-1} at pH_0 3–8), thanks to its high positive surface charge (measured by Electrophoretic Light Scattering, ELS, ≈30 mV) and high surface area (determined by N_2 physisorption, ≈200 m^2 g^{-1}). To investigate the adsorption process and the interaction between arsenate/arsenite and akageneite, different methods, such as powder X-ray diffraction (PXRD), infrared spectroscopy (FTIR-ATR), transmission electron microscopy also in high resolution (HRTEM) and coupled with chemical probes (EDX-EELS), X-ray photoelectron spectroscopy (XPS), X-ray absorption (XAS), and DC magnetometry were adopted. None of these techniques were able to detect any changes in the sorbent properties upon adsorption, but FTIR-ATR and DC magnetometry. In particular, the interaction between akageneite and arsenate species was found to produce a distinctive change in the magnetism of the sorbent, with the appearance of a second band in the temperature profile of the magnetisation, whose associated intensity increased with increasing adsorbate amount. This work demonstrates the high sensitivity of DC magnetometry in exploring surface phenomena in iron-bearing materials.

References:

[1] A. Jain, K. P. Raven, R. H. Loeppert, Environ. Sci. Technol. 1999, 33, 1179–1184.
[2] M. Sanna Angotzi, V. Mameli, A. Fantasia, C. Cara, F. Secci, S. Enzo, M. Gerina, C. Cannas, Nanomaterials 2022, 12, 326, 1-22.

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Green nanostructured composites for the consolidation and protection of Street Art: formulation, characterization, and application

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Street art is increasingly influencing world artistic production, but its conservation is challenging due to constant exposure to environmental conditions such as light, pollution, temperature, and relative humidity fluctuations. Furthermore, biological agents are non-negligible in urban art degradation[1]. Unlike traditional wall paintings, graffiti are made with synthetic organic paints on inorganic substrates such as concrete, brick walls, and mortars. Therefore, it is necessary to study the degradation processes and develop appropriate conservation products and methods.

Organic-Inorganic Hybrid Materials (OIHM) can be an effective strategy for the formulation of protective coatings that can act both as a barrier layer and a consolidating product, considering the physicochemical properties of urban art materials.

Chitosan (Chs) is an abundant, and sustainable biopolymer obtained by partial deacetylation of chitin from the industrial waste processing of marine shells and crustaceans. It has been selected as the organic component for its good film properties as it forms mechanically resistant and semi-permeable films. Additionally, it shows good optical, and antimicrobial properties, it is non-toxic, and it has already been studied as a new biopolymeric treatment on porous limestones in historic architecture to inhibit the crystallization of hazardous salts[2].

The main objective of this project is to develop a hybrid coating that combines Chs and nano-silica (NS) to improve the compatibility and the adhesion of the coating to the inorganic substrate. The new formulation would act as a barrier layer and a consolidating product by introducing innovative green materials that can best mitigate the degradation effects on Street art. The hybrid formulation was designed and investigated by ATR-FTIR, SEM, DLS, and zeta potential analysis. Alkyd and acrylic spray-painted concrete mockups were prepared to mimic street art techniques.

Chemical stability, color and gloss variations, water vapor permeability, and hydrophobicity are evaluated on the mockups before and after the application of the Chs-NS-based coating, and its long-term stability is assessed through accelerated aging tests.

References:

[1] L. Pagnin, N. Guarnieri, F.C. Izzo, S. Goidanich, L. Toniolo, Coatings 2023, 13, 2044.
[2] M. Bassi, E. Sassoni, E. Franzoni, Frontiers in Materials 2021, 8, 583112

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ABC-PO-029

HIGH TEMPORAL AND SPATIAL RESOLUTION MONITORING OF INDOOR AIR QUALITY IN AN ITALIAN BASILICA

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In recent years, people spend most of their time in indoor environments as working places, public or private transportations, homes and schools which are frequently more contaminated than outdoors one[1, 2]. In fact, in addition to outdoor pollutants penetrating through windows and doors and affecting the indoor air quality (IAQ), indoor pollutants sources as building materials, furniture, cleaning and combustion processes (heating, cooking and incense or candles burning) can deeply worsen the air quality in closed environments. Among indoor sources linked to combustion processes, cooking or cigarettes smoking has been deeply characterized in contrast to incense burning emissions [3]. Anyway, over recent years, incense burning is attracting ever more interest because it was found to be the significant source of large amounts of particulates, heavy metals, polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) [4]. In a poorly ventilated environments as the churches where a large number of people gathers and incense is commonly burned, high concentrations of harmful chemical pollutants could affect IAQ and, thus, the human heath of exposed people. Therefore, this study aims to investigate the time profiles of pollutants concentration in an Italian basilica during the liturgical celebrations. An high-time and spatial resolved monitoring campaign was carried out from 1st November 2023 to 2nd April 2024 inside an basilica that covers an area of about 23000 m^2. The real time measurements of PM, TVOCs, CO_2 and microclimatic parameters as temperature and humidity were provided by integrated systems consisting of low-cost sensors named NOSE (Beefrest srl) located in eight different points inside the basilica. In addition, the real time concentrations of total polycyclic aromatic hydrocarbons (TPAHs) were monitored by a photoionization analyzer (PAS2000 - EcoChem Analytics) installed bottom of the church altar in a beeline with the first lines of pews.

The preliminary results highlighted relevant increments of PM10 (maximum value: 216 $\mu g/m^3$), PM2.5 (maximum value: 184 $\mu g/m^3$), TVOCs (maximum value: 3.9 ppm) and TPAHs (173 ng/m^3) concentrations, especially, at the sites nearest the altars and during liturgical celebrations linked to Christmas, Lent and Easter when incense was burned. These peak concentrations as well as PM10 and PM2.5 daily mean concentration values registered during Christmas and Easter days were significantly higher than the daily limit value established by Italian law for the PM10 outdoors concentrations (Legislative Decree 155/10).

References:

[1] IARC, (2013). Outdoor air pollution a leading environmental cause of cancer deaths.
[2] M. Manigrasso et al., (2019). Science of the Total Environment, 653, 1192–1203.
[3] Saraga et al, Science of The Total Environment, 900, 20, 2023, 165744
[4] Sadrizadeh et al., Journal of Building Engineering 57 (2022) 104908

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Contaminants screening in *Procambarus clarkii* and environmental matrices from three wetlands in Sicily (Italy)

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The aquatic environment is a reservoir of pollutants of natural or anthropogenic origin. Pollution and the invasion of exotic species are recognised as major factors in the loss of biodiversity[1] and are known to have a negative impact on ecosystems and trophic networks. Monitoring is therefore necessary, including chemical investigations to assess contamination of environmental and biological matrices. *Procambarus clarkii* is one of the most widely introduced freshwater animal species in the world, raising concerns about its impact on native aquatic biota[2]. Despite the important nutritional properties of freshwater decapods and their potential use as a source of bioactive molecules, there are potential health risks associated with their consumption due to their ability to accumulate contaminants[2]. In the present work, three representative Sicilian aquatic ecosystems were selected for the collection of *P. clarkii* specimens and environmental samples (water and sediment). The analytes selected for determination in the muscle and exoskeleton of *P. clarkii*, as well as in water and sediment, were trace elements (TEs), pesticides, per- and polyfluoroalkyl substances, phthalates, antibiotics and cyanotoxins. Except for TEs, all samples showed concentrations below the detection limit for all contaminant classes. Bioaccumulative potentials and TEs contamination profiles differed significantly between sites and matrices, confirming the suitability of *P. clarkii* as a biomonitor of environmental contamination. The levels of TEs found in the biological matrices were similar or lower than those reported for other sites in different parts of the world[3] and below the limits set by current European environmental and food safety legislation. However, these results should be contextualised to the selected sites, time of sampling collection and contaminants, and desirably confirmed by further periodic sampling and analysis.

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Monitoring of indoor air quality and preventive conservation: the case study of the King's Apartment, Royal Palace of Turin

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A conservation project that aims to preserve an artwork in the best possible way must adopt an analytical approach, developing methodological strategies to gain exhaustive knowledge of the object and the environment that hosts it.
Identifying the composition of materials not only enhances understanding of an artist's technique and may provide evidence of authenticity, but it is crucial for directing restoration interventions and identifying past ones, shedding light on the conservation history of the object. In fact, the study of the state of conservation of historical and artistic heritage assets also takes into account the composition of alteration products and the processes leading to their formation. It is therefore necessary to consider environmental factors such as temperature, humidity and air quality, as they can lead to alterations and chemical, mechanical and biological degradation.[1]
In the King's Apartment of the Royal Palace of Turin, monitoring of microclimatic conditions, air quality and aerobiological particulates is currently underway with the aim of identifying the environmental risks in the apartment in its current state of disuse and in view of its possible future use for exhibition purposes. Moreover, the study aims to identify possible sources of pollution, external or internal to the apartment, and any correlations between air quality and the state of conservation of the artworks currently present in the apartment.
The contribution presented here reports some preliminary results on air quality emerging from the processing of data collected in the first five months of monitoring. In particular, the monitoring involves the continuous detection of particulate matter (PM1.0, PM2.5 and PM10) and volatile organic compounds (TVOC), measurements of formaldehyde concentration and detailed analysis of organic emissions through solid phase microextraction coupled to gas chromatography/mass spectrometry (SPME-GC/MS).

Figure 1: Views of some rooms of the King's Apartment at the Royal Palace of Turin.

References:

[1] H. Sharif, B. Abu-Hijleh, 2018, Building and Environment, 143, 186-195.

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ABC-PO-032

Their Dark Materials: Discovering the Black Shades of the Naselli Sarcophagus

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In the framework of a conservation intervention -promoted and supported by the Superintendence of Cultural Heritage of Ragusa, the Prefecture of Ragusa and the Diocese of Ragusa-, the opening of a 15th Century sandstone sarcophagus, conserved in the Church of San Francesco all'Immacolata in Comiso, revealed a set of precious findings: several bones were found, belonging to twelve human bodies, among adults and children, along with various textiles. These were likely part of the grave goods of deceased members of Naselli nobles; however, they have been dated to the 16th Century, one hundred years after the sarcophagus.

Among these, several textile fragments showed technical features of luxurious goods, representing important evidence for the history of costume. In particular, three textile fragments, likely representative of a gown and a pair of trousers, captured the attention of the anthropologists for the preciousness of both fabric and colours. The brown and the black of these silk samples evidenced a refined manufacturing, while the complexity of dyeing processes for obtaining dark shades[1] and the issues related to their conservation[2] pushed the conservators to investigate the composition of these ancient matrices by means of an empowering collaboration with scientists and anthropologists, aimed to reconstruct the history of the ancient Naselli sarcophagus.

In this study, we present the results of an extended diagnostic campaign on these textiles, which exploited a multi-analytical approach covering dating, microscopic and spectrometric techniques. A particular focus was dedicated to Raman scattering, through the combination of the most solid and the newest strategies of this spectroscopy[3]. The achieved data allowed for an insight, helpful in unveiling the palette of ancient dyes used to colour the garments of this ancient Sicilian family in the darkest shades.

References:

[1] I. Joosten, M.R. Van Bommel, R.H. De Keijzer, H. Reschreiter, Microchimica Acta 2006, 155, 169–174.
[2] N.O. Saez, I. Vanden Berghe, O. Schalm, B. De Munck, Conservar Patrimonio 2019, 31, 115–132.
[3] G. Peruzzi, A. Ciccola, A. Bosi, I. Serafini, M. Negozio, N.M. Hamza, C. Moricca, L. Sadori, G. Favero, V. Nigro, P. Postorino, R. Curini, Gels 2023, 9, 1–13.

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ABC-PO-033

Artificial ageing methodology for the assessment of a new cutin-based polyurethane coating for bronze

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Innovative, eco-friendly coatings allow to implement sustainable treatments with low impact on the environment and operators[1]. Their efficacy can be assessed via accelerated ageing tests that simulate outdoor exposure conditions. In order to decrease discrepancies between the predicted behaviour of protective treatments and their performance in real conditions, the chosen environmental parameters should reflect current environmental conditions.

Two sets of bronze coupons, coated and uncoated, underwent artificial ageing in order to assess the anti-corrosion properties of an innovative cutin-based polyurethane coating. The cutin used in its production is extracted from tomato peels and reused, consistently with a circular economy approach[2].

The quaternary bronze G-85 or UNSC83600 was chosen to produce the coupons, as this alloy is commonly used in cultural heritage for artistic casting. Two kinds of substrates were considered: unaltered i.e. the new, non-degraded material, and pre-aged i.e. patinated bronze. The second substrate was used to test the coating on an oxidized metal surface, with chemical and morphological features similar to those met during a realistic conservation treatment. Patinated bronze was obtained by cyclical immersion of the bronze coupons in a synthetic rain solution with pH = 4,2 for 30 days.

The artificial ageing phase was carried out in two subsequent steps to systematically observe the effects of rainwater, both in stagnant[3] and runoff[4] conditions, and then of other environmental parameters such as temperature, relative humidity and solar radiation. In order to recreate conditions as representative as possible of real ones, the chosen environmental parameters were based on environmental monitoring data. Specifically, pH and ionic concentration values for the synthetic rain solution reflect rainwater composition data gathered in various locations in southern Europe and northern Italy in the last decade[5]. Moreover, T, RH and UV parameters chosen for the climatic chamber aimed to simulate combined day-night and seasonal conditions, alongside average irradiance on a clear day in southern European regions.

Following a multi-analytical approach, the coupons were characterized by scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDS), infrared spectroscopy, micro-Raman spectroscopy, UV-Vis spectrophotometry for colour analysis, and electrochemical impedance spectroscopy (EIS). The analyses were performed before ageing and were repeated after each step of the ageing procedure in order to observe the evolution of the degradation processes. Moreover, the solutions in contact with the coupons were sampled throughout the ageing period and later analysed by microwave plasma atomic emission spectroscopy (MP-AES) in order to know the concentrations of ions coming from the substrates, whose presence is diagnostic for the corrosion process.

After the first step of the ageing procedure, colour changes were characterized by $\Delta E<5$ (i.e. the threshold for acceptable colour change in cultural heritage) for coated coupons and uncoated patinated bronze, while pristine bronze showed $\Delta E>20$ as it underwent oxidation. Raman analyses indeed showed cuprite in various stages of formation. SEM-EDS analyses on pristine bronze after ageing also showed, as expected, a decrease of Cu due to the decuprification process occurred, alongside a relative enrichment of Sn at surface level. This

ABC-PO-034

Studying the degradation of egg proteins in polychrome layers by MS-based proteomics

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Egg was widely used in the tempera technique thanks to its good resistance and stability to aging[1]. The present study aimed to investigate the effect of artificial aging on egg white proteins to better explore the process of protein degradation in polychrome artworks. According to the literature, the most common protein events in historical samples are the oxidation of serine, phenylalanine, and cysteine as well as the deamidation of asparagine and glutamine[2]. In many cases, inorganic pigments may accelerate the binder's degradation as several studies claim[3,4].

Mock-up samples made of beaten egg white, egg white each mixed with hematite and calcium carbonate, applied, and dried on glass microscope slides, were analyzed as such and after artificial aging with a solar lamp (300 W, 230 V, 280-2000 nm) at 50 °C for a maximum of 864 hours and relative humidity between 60 and 75%. Three types of enzymes (trypsin, GluC and AspN) were employed to enzymatically digest the freshly prepared samples as well as the ones subjected to 30, 72, 144, 288, 576 and 864 hours of aging. Trypsin was chosen as the conventional enzyme for bottom-up proteomics while AspN and GluC were selected for a middle-down approach. ATR-FTIR (attenuated total reflectance – Fourier-transform infrared spectroscopy) analysis was performed on microscope slides, while reversed-phase liquid chromatography with electrospray ionization-mass spectrometry (RPLC-ESI-MS) and matrix-assisted laser desorption/ionization-time of flight MS (MALDI-TOF-MS) were used to investigate the enzymatically digested samples. Regardless of the enzyme employed, the number of no specific peptides increased with artificial aging time, suggesting a protein structural degradation. This was also confirmed by the peptide mass fingerprinting (PMF) in MALDI-MS showing a progressive decrease of the S/N ratio with aging especially for heavier peptides. In this communication, the main results will be presented and discussed.

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References:

[1] A. Fanost, L. de Viguerie, G. Ducouret *et al.*, Angewandte Chemie, 2022, 134, 1–5.
[2] G. Leo, I. Bonaduce, A. Andreotti *et al.*, Analytical Chemistry, 2011, 83, 2056–2064.
[3] C. Duce, L. Ghezzi, M. Onor *et al.*, Analytical and Bioanalytical Chemistry, 2012, 402, 2183–2193.
[4] L. Ghezzi, C. Duce, L. Bernazzani *et al.*, Journal of Thermal Analysis and Calorimetry, 2015, 122, 315–322.

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Photo-/Electro-chemical CO_2-recycling: from disposal to resource

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The most distressing task of Anthropocene is to find an effective process to convert renewable feedstocks of otherwise disposable materials into exploitable, cheap fuels and chemicals via sunlight-driven processes. This project targets the production of small, transportable molecules with high energy content, starting from CO_2 as raw material. The overarching goal is to simultaneously target the mitigation of climate change and the principles of circular economy.

The strategy is based on the synergistic action of orthogonal photo- and electro-catalysts able to drive the photoelectrochemical (PEC) conversion of CO_2. In particular, an array of metal-coordinating porphyrin-derivatives with appended amine groups has been synthesized and tested in homogeneous phase as plausible electrochemical (EC) catalyst,[1] whereas organometallic Mo-/Mn-based complexes bearing terminal amino moieties have been tested as photosensitizers (PS).[2]

A screening of the selected porphyrins showed a promising EC behaviour. Cyclic voltammetry data exhibit values of standard reduction potential (E°) for these molecules between -1.155 and -0.097 eV, i.e., compatible with CO_2 reduction. Further, the photochemical and photophysical characterization of the substrates suggests the possibility to exploit both catalysts simultaneously without facing electron transfer (ET) processes.

These preliminary results suggest the possibility to covalently link the tested molecules on an inert matrix in order to perform heterogeneous catalysis in view of a further optimization and scalability of the system.

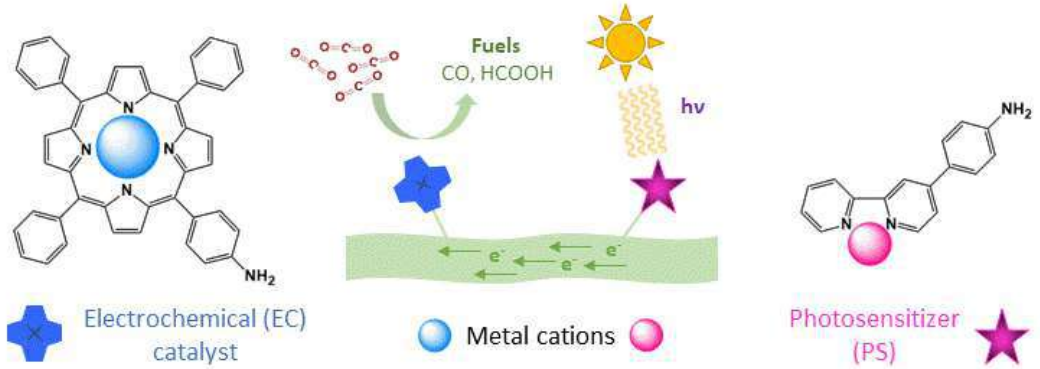

Figure 1: schematic representation of the selected molecules envisaged for targeting CO_2 reduction.

References:

[1] Z. Liang, H. Wang, H. Zheng, W. Zhang and R. Cao, *Chem. Soc. Rev.*, **2021**,50, 2540-2581
[2] J. Bonin, A. Maurin and M. Robert, *Coord. Chem. Rev.*, **2017**, 334, 184-198

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Ecclesiastic heritage safeguarding: a monitoring campaign in the Saronno Sanctuary

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Ecclesiastic heritage is a tangible testimony of artistic vocations among history. Despite hosting such masterpieces, churches' purpose differs from museums' one; thus, controlling microclimatic and pollutant levels can be challenging. Monitoring is essential to possibly suggest improvement measures[1].

Here is presented a monitoring campaign in the "Beata Vergine dei Miracoli" Sanctuary in Saronno (VA), which hosts frescoes and wood works from some of the most relevant 1500's artists of northern Italy. Temperature and relative humidity were measured by a 6 low energy Bluetooth nodes network, innovative in the power supply systems, ranging from vibrations to light. Particulate Matter (PM) was measured with a custom start-go-stop energy-saving GPRS system placed near the "Last Supper" woodwork. The application of innovative sensors allowed to guarantee the less-invasive setup, from the visual, acoustical and operator-dependent point of view. The monitoring campaign was performed between February and October, 2023.

Temperature and RH followed seasonal trends, and, comparing results with the normative suggestions[2], the values were in conformity mainly in spring and autumn. Besides absolute values, source of concern rises from the variation from the "historical microclimate" of the artworks[3]. There weren't problems with temperature, while, regarding RH, a mechanical-stressing 10% 24-hours variation (more than doubling the limit) was frequently observed during all the seasons, yet variations up to 35% were observed in summer. PM showed a season-dependent baseline with significant peaks related not only to worshippers' presence but rather to specific indoor sources as the use of incense, which acutely exposes the artworks to soiling and future chemical stress, as PM2.5 and PM1 were 90 and 70% of PM10 mass. Interestingly, peak correlation could be observed between RH and PM values all along the year. RH peaks could be thus linked to people presence, and it was possible to distinguish between celebrations with a lot of or a few people and with or without the use of incense.

This study will be crucial for the Sanctuary to better understand its point of weakness, to adopt corrective actions and to cut future restoration costs. It contributes to the awareness of the safeguarding theme, also by underlining the respectfully approach the scientific research has towards churches purpose.

References:

[1] T. de Rubeis, I. Nardi, M. Mutillo, D. Paoletti, Journal of Cultural Heritage, 2020, Vol. 43, 186 – 203.
[2] UNI 10829:1999.
[3] UNI EN 15757:2010

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Development of a new biomimetic biosensor based on Molecularly Imprinted Bio-Polymers coupled with Surface Plasmon Resonance for the detection of amelogenins

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Amelogenins are structural proteins of the dental enamel matrix, playing a key role in archaeological and forensic fields due to their relative abundance and relevance for sex determination. Currently, the detection of amelogenins mainly relies on liquid chromatography (LC) and tandem mass spectrometry (MS/MS)[1] and only few studies have involved immunoassays based on antibodies[2], but the application of fast, reusable and cost-effective biomimetic systems has not yet been explored. We present an innovative biosensor based on Molecularly Imprinted Bio-Polymers (MIBPs) coupled with Surface Plasmon Resonance (SPR), capable of detecting and binding amelogenins from standard solutions and protein extracts from human teeth samples. The protein sequence was studied by machine learning methods to select suitable peptide sequences to be used to molecularly imprint polynorepinephrine (PNE). The imprinting efficiency of the PNE-based biosensor was evaluated by performing single cycle kinetic (SCK) analyses, allowing the characterisation of the system in terms of kinetic rates and binding affinity parameters, towards both the peptide template and protein. The demonstration of the applicability in real cases was achieved optimising a suitable extraction protocol and performing measurements of extracts from human dental enamel. The results prove the effectiveness of the biosensor, which was specifically tailored on the target protein sequence and requires a quick and simple preparation process involving natural, 100% green, and biodegradable reagents. The application of state-of-the-art MIBPs offers a low-cost, highly effective, and environmentally friendly alternative to the use of antibodies in the development of label-free detection systems that allows the possibility to select and design the epitope to be printed with high precision, therefore deciding the protein capture target.

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References:

[1] M. Cintas-Peña et al., 2023, Sci Rep, vol. 13, no. 1, 9594.
[2] B. Shaw et al., 2023, iScience, vol. 26, no. 11.

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Effects of iso- and hetero-valent substitutions in Egyptian Blue on color and luminescent properties

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The interest in the ancient pigment Egyptian blue $CaCuSi_4O_{10}$ (cuprorivaite) increased dramatically after its discovery in frescoes of Raphael in the Villa Farnesina by non-invasive mapping [1]. This pigment has also been shown to have luminescent properties. In order to study the effect of possible impurities on the color and luminescent properties of the cuprorivaite phase, we prepared two series of samples corresponding to (1) isovalent substitution of Ca by Ba, (2) heterovalent substitution of Ca by La and Si by Al (Fig. 1). The samples were obtained by liquid sintering method in the presence of Na_2CO_3 (2%) at 1000ºC. Solid solutions based on cuprorivaite containing Ba are characterized by a monotonic increase in lattice parameters. The substitution of Ba by Ca in $BaCuSi_4O_{10}$ doesn't occur. The formation of solid solutions with successively increasing parameters has been proven in the case of heterovalent substitution. In both cases, the formation of solid solutions leads to a change in color from blue to violet in (1) and to steel bluish-green in (2). The effect of dispersion on the color is studied. A change in IR luminescence upon substitution in series (1) and (2) is shown.

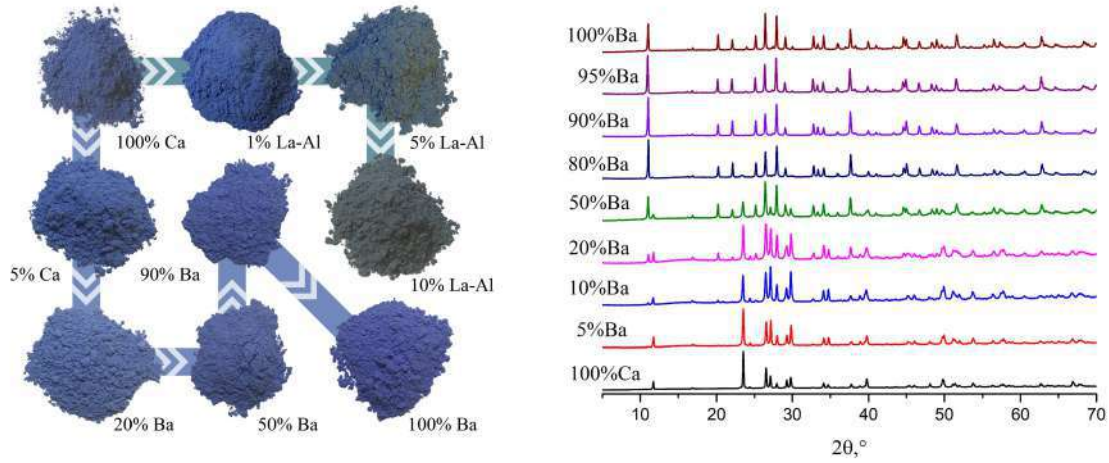

Figure 1. The color changes in series (1) and (2) (left) and powder XRD diffraction data for series (1) (right)

References:

[1] C. Anselmi, M. Vagnini, C. Seccaroni, M. Azzarelli, T. Frizzi, R. Alberti, M. Falcioni, A. Sgamellotti, Rendiconti Lincei. Scienze fisiche e naturali 2020, 31(4), 13-917

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ABC-PO-039

Less analyte, less impact: hydrogel extraction for ultra-sensitive dye characterization, protecting artifact integrity and the environment

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Dye analysis represents an invaluable repository of historical knowledge, while also shaping future strategies for cultural heritage conservation. However, characterizing dyes within complex matrices presents challenges, particularly when aiming for minimal or non-invasive analyses, due to potential interferences. Optimal techniques in this regard include high-performance liquid chromatography coupled with mass spectrometry (HPLC-MS), capable of separating components in mixtures and identifying them individually, and surface-enhanced Raman spectroscopy, providing ultrasensitive high-throughput vibrational information[1,2]. Nevertheless, achieving fingerprint characterization requires the removal of paint or thread fragments. Moreover, traditional approaches often involve high temperatures, strong acids, and significant amounts of organic solvents to extract various dye classes with varying solubility from the sample.

In the proposed methodology, a direct hydrogel extraction technique is introduced, tailored for minimal dye quantities, able to facilitate SERS and HPLC-MS characterization while preserving artifacts integrity. This approach utilizes agar, a green polysaccharidic compound forming a hydrogel upon interaction with water. Agar gel loaded with an ammonia aqueous solution was employed to gently extract dyes without the need for organic solvents[3].

To maximize the use of minimal analyte quantities extracted for multi-technique characterization, a clean-up strategy, known as dispersive liquid-liquid microextraction (dLLME), was tailored. DLLME purifies and preconcentrates low concentrated analytes, reducing organic solvent volumes while maintaining effectiveness.

Following successful results on laboratory mock-up, the gel was rescaled until it could be applied using a Pasteur pipette tip, to prevent any visible markings. The methodology was applied to real study cases in collaboration with the Berlin National Museums. The results highlight the effectiveness of the developed workflow in enabling fingerprint dye characterization using minimal analyte quantities while minimizing visible impacts on artifact surfaces.

References:

[1] E. Geddes da Filicaia, R. Evershed, D. Peggie, Analytica Chimica Acta 2023, 1246, 340575
[2] M. Aceto, Archaeological and Anthropological Sciences 2021, 13, 159
[3] G. Germinario, A. Ciccola, I. Serafini, L. Ruggiero, M. Sbroscia, F. Vincenti, C. Fasolato, R. Curini, M. Ioele, P. Postorino, Microchemical Journal 2020, 155, 104780

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ABC-PO-040

Performic acid pre-treatment of poplar biomasses from green remediation to obtain fine-products

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Lignocellulosic biomass is the most abundant and cheap carbon-based feedstock on earth and is the main candidate for the purchasing of bioderived added value compounds namely biofuels and biochemicals. The valorisation of the lignocellulosic biomasses generally occurs through bio-chemical transformations of polysaccharides (cellulose) into simple soluble sugars (glucose). The use of enzymes (cellulases)[1] has proven to be more advantageous, thanks to the higher specificity towards the substrate which leads to the selective production of glucose. To make the enzymatic processes more efficient a pretreatment is necessary to destroy the complex structure of hemicellulose and lignin that act as shields for cellulose by preventing its hydrolysis[2].

In this research work a sustainable pre-treatment for the valorisation of a poplar matrix (pruning residues) recovered with Plant-Assisted BioRemediation (PABR) technology was studied[3]. Pre-treatment was carried out using mixtures of formic acid and hydrogen peroxide to make the lignocellulosic structure simpler to make cellulose more available for the consequent enzymatic process. The synergic action of formic acid and hydrogen peroxide was greatly efficient and yields a solid phase enriched in cellulose (56% of cellulose) with a total recovery equal to 70–80% of the starting cellulose. The recalcitrant molecules such as hemicelluloses and lignin, potential platform molecules for biorefinery[4], were almost completely recovered in the liquid phase.

The resulting biomass was subjected to enzymatic hydrolysis through a commercial cellulase (from Trichoderma reesei): the enzymatic digestibility was proven to be already effective on samples pre-treated with 3.5 M performic acid at 55 ◦C since the cellulose in the residual biomasses was completely hydrolysed in glucose. The produced monosaccharide was then used as feedstocks to produce levulinic acid in presence of $AlCl_3 \cdot 6H_2O$ (1%) and sulphuric acid (0.5%) at 150 ◦C for 45 min. A final yield of 68.2% of levulinic acid and 4.8% of HMF was obtained. These results are comparable to those obtained with other heterogeneous[5] and homogeneous catalytic systems[6] reported in more extreme operative conditions.

References:

[1] A.S. Jatoi, S.A. Abbasi, Z. Hashmi, A.K. Shah, M.S. Alam, Z.A. Bhatti, G. Maitlo, S. Hussain, G.A. Khandro, M.A. Usto, A. Iqbal, Biomass Convers. Biorefinery, 2021 1, 1–13.
[2] Y.L. Loow, T.Y. Wu, K.A. Tan, Y.S. Lim, L.F. Siow, J. Md Jahim, A.W. Mohammad, W.H. Teoh, J. Agric. Food Chem., 2015, 63, 8349–8363.
[3] A. Angelini, E. Scelsi, V. Ancona, G. Aimola, C. Pastore, J. of Clean. Prod., 2022, 369, 133346.
[4] S. Peleteiro, A.M. Lopes, G. Garrote, R. Bogel-Łukasik, J.C. Parajo, Ind. Crop. Prod., 2015, 77, 163–166.
[5] C. Liu, X. Lu, Z. Yu, J. Xiong, H. Bai, R. Zhang, Catalysts, 2020, 10(9), 1006.
[6] D.B. Bevilaqua, M.K.D. Rambo, T.M. Rizzetti, A.L. Cardoso, A.F. Martins, J. Clean. Prod., 2013, 47, 96–101.

ABC-PO-041

Technological and compositional characterisation of Chinese Tang-style pottery

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The so-called *mingqi* figurines are Chinese funerary glazed or painted pottery statuettes. They became highly popular during the Tang dynasty (618-907 AD), a golden age of Chinese art, depicting peculiar characters such as coloured horses, foreign servants, and Bactrian camels [1]. Then, from around the 1910s, *mingqi* figurines began to attract Western collectors, and modern reproductions began to proliferate in the art market [2,3]. However, little provenance information is available, and authenticity is often uncertain. In addition, Tang-style finds have never been subject to systematic investigation.

As part of the PhD research project in *Technologies for Cultural Heritage*, 30 figurines from the Museo delle Civiltà in Rome, Museo di Arte Orientale in Venice, and Museo delle Culture in Milan have been analysed using non- and micro-invasive methods. In this study, the focus was set on the first chemical examination of their ceramic bodies. The comprehensive chemical characterisation of 30 pottery fragments from the inner cavities of the statues was carried out. More specifically, the samples were examined by colourimetry (Munsell colour system), μ-Raman/μ-FTIR spectroscopies and X-ray powder diffraction (XRPD) to assess the mineralogical patterns, Backscattered (BS) Scanning Electron Microscopy (SEM) to characterise the shape of the inclusions, SEM coupled with Energy Dispersive X-ray Spectrometry (SEM-EDS) to verify possible classifications based on the compositional analysis.

The employed multi-technique approach provided compositional, morphological, and structural information, with a possible comparison and cross-checking of the results. The early results allowed us to check for a first classification of modern Tang-style production from the major Chinese collections in Italy, and a comparison of the technological features with those of authentic Tang figurines from Chinese archaeological sites. The systematic investigation using the illustrated methodology might offer valuable information for further authentication and provenance studies of all the Tang-style artefacts stored in Western contexts.

References:

[1] S. Rastelli, Ceramica cinese. Evoluzione tecnologica dal Neolitico alle Cinque Dinastie, Libreria Editrice Cafoscarina, Venezia, 2004, 118-122.
[2] D. K. Strahan, A. Boulton, Studies in Conservation 1988, 33 (1), 149-154.
[3] C. Hentze, W. P. Yetts, Chinese Tomb Figures. A Study in the Beliefs and Folklore of Ancient China, ed. E. Goldston, London, 1928.

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ABC-PO-042

Novel Entities in the Earth System: highlighting impacts on Coral Reefs through new monitoring strategies

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Based on the framework developed by Rockstrom et al. [1], planetary boundaries (PBs) are defined as biogeochemical and physical thresholds that could have severe consequences for the Earth System (ES) if crossed. Chemical pollution has been included in the list of PBs since the first release of the PBs framework, and has recently been renamed to novel entities (NEs) to encompass "new substances, new forms of existing substances and modified life forms" [2]. At present, the assessment of the amount of NEs that can be tolerated by ES before irreversible shifts remains a challenge. Coral reefs are a hotspot of the current ecological crisis and human-driven ES changes: reef-like structures have existed on Earth for over 500 million years, but now their existence appears threatened by a combination of anthropogenic stressors such as higher water temperatures, ocean acidification, and chemical pollution. To collect data in these delicate environments and establish the contribution of NEs to large-scale bleaching events, we are currently developing new monitoring strategies based on the application *in vivo* of solid-phase microextraction and advanced mass spectrometry techniques [3]. Our work focuses on detecting different classes of contaminants including persistent organic pollutants (POPs), contaminants of emerging concern (CECs) [4], heavy metals and radionuclides, micro and nanoplastic (MPs and NPs) [5], and at the same time secondary metabolites to be used as markers of ecological system integrity [6]. By identifying the primary stressors that lead to irreversible changes, the marine pollution mitigation actions are then correctly prioritized, and the effectiveness of restoration plans is accurately evaluated.

References:

[1] J. Rockström, W. Steffen, K. Noone et al. *Nature* 2009 461 (7263), 472–475.
[2] Steffen et al. *Science* 2015, *347* (6223), 1259855
[3] F Saliu, S Montano, BW Hoeksema, M Lasagni, P Galli *Analytical methods* 2020 12(14), 1935-1942
[4] V Isa, A Becchi, IE Napper, PG Ubaldi, F Saliu, S Lavorano, P Galli *Chemosphere* 2023 327, 138509
[5] F Saliu, S Montano, B Leoni, M Lasagni, P Galli Marine pollution bulletin 2029 142, 234-241
[6] F Saliu, G Biale, C Raguso, J La Nasa, I Degano, D Seveso, P Galli, ...Science of The Total Environment 2022, 819, 152965

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Hydrogels for controlled release of glucosinolates extracted from *Brassicaceae* – A sustainable treatment for agricultural soils

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The extensive use of synthetic pesticides in agriculture has a significant environmental impacts and poses severe health risks to living organisms, including the human population. Hence, exploring effective alternatives to current pesticide practices is one of the main research goals in agrifood chemistry. A potential solution lies in the controlled release (CR) of bioactive compounds. In the frame of the Profood-IV Project (PON ARS01:0755), the use of two biocompatible and biodegradable polymers, i.e. sodium alginate and sodium carboxymethylcellulose (CMC), was investigated to synthesize crosslinked hydrogel beads for encapsulating and releasing glucosinolates-rich extracts from Brassicaceae. Glucosinolates are secondary metabolites of plants, which can be hydrolyzed by the mirosinase enzyme to isothiocyanates, a class of compounds with a renowned biocide activity towards fungi, bacteria and insects. The physicochemical properties of the developed CR systems was performed using several analytical techniques, including Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) spectroscopy, thermogravimetry (TGA), Differential Scanning Calorimetry (DSC), and rheometry. The encapsulation efficiency was assessed and the release kinetics was analyzed both in water and in a model soil. Preliminary microbiological tests were conducted to evaluate the efficacy of this approach, both in laboratory and on field. These systems represent a cost-valuable, sustainable and scalable alternative solution to the use of traditional pesticides, which exploits the by-products of the agrifood industry in agricultural practices.

Figure 1: Alginate (left) and CMC (right) hydrogel beads loaded with *Brassicaceae* extracts, rich in glucosinolates.

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Chemical characterization of atmospheric depositions at two sites subjected to different emission sources: the case of study of urban site in the city of Lecce and suburban site near the city.

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Atmospheric depositions are the process by which particulate matter, aerosols, and atmospheric gases from both anthropogenic and natural sources reach the ground in the form of precipitation and dry deposition. The combination of these two components is referred to as BULK depositions. In this study, two sampling sites were chosen: one representing an area in the urban center of Lecce affected by vehicular traffic (Arpa site, DAP Lecce), and one representing a suburban area influenced primarily by regional background (Ecotekne site within the university campus).

Sampling and determination of pollutants in BULK depositions were carried out on a monthly basis in accordance with Legislative Decree no. 155/2010, following UNIEN standards 15980:2011 for the determination of organic micro-pollutants and UNI EN 15841:2010 for the determination of inorganic parameters. Specifically, water-soluble inorganic species were analyzed using HPIC, heavy metals in the filtered aqueous sample were determined with ICP-MS, and the filters used for filtration were analyzed with ICP-AES. Additionally, PAHs were analyzed using GC-MS.

Applying source apportionment techniques such as multivariate statistics and PMF (positive matrix factorization), common sources between the two sites were identified. It was observed that the urban site had more samples characterized by exhaust emissions from traffic, while in the suburban site, samples showed a greater contribution from crustal sources.

This study suggests the application of source apportionment techniques on samples of atmospheric depositions to identify differences between sites impacted by anthropogenic activities compared to less impacted suburban sites, in order to provide useful information for decision-makers regarding public health management and air quality in cities.

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Nanostructured MgB_2 for the conservation of Archival and Librarian Materials

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The conservation of archival and librarian objects represents a continuous challenge especially for what concerns the protection of paper and parchment from bacterial and fungal biological attacks.

The development of biocidal materials produced using green techniques or associated with circular-economy processes represent a unique opportunity to safeguard these goods.

The synthesis of MgB_2 nanostructured through microwave techniques has shown the possibility of exploiting this material as a biocide in biomedical and, in this case, cultural heritage contexts.

The use of inorganic nanomaterials is definitely an advantage over traditional antibiotics, due to the low cost of production and the chemical inertia towards organic media to be preserved [1, 2].

The advantage resides in their different mode of action comparatively to antibiotics, therefore, the chemotherapeutic effect of NM is driven by processes that take place at the interface and two major lethal groups of interdependent mechanisms are presented in literature [3]: (i) disruption/damage of membrane integrity and potential [4]; (ii) production of Reactive Oxygen Species (ROS) [5], far away from an optimum level reached during the cellular metabolism. At low doses, ROS can cause severe DNA damage and mutations, while at higher concentration, ROS lead to the imminent cell death, caused by the severe oxidative stress and macromolecules modification via lipid peroxidation, alteration of proteins, inhibition of enzymes, and RNA and DNA damage

The results of in vitro, in vivo and in situ application of MgB_2 and MgB_2 - fulleren doped nanocompounds in the contrast of mycetes and cellulositic bacteria or that attack collagen fibers in parchment will be presented here.

References:

[1] P. Badica, N.D. Batalu, M.C. Chifiriuc, M. Burdusel, M.A. Grigoroscuta, G. Aldica, I. Pasuk, A. Kuncser, M. Enculescu, M. Popa, L.G. Marutescu, I. Gheorghe, O. Thamer, C. Bleotu, G. Gradisteanu Pircalabioru, L. Operti, V. Bonino, A. Agostino, M. Truccato, Journal of Materials Research and Technology, 2021, 12, 2168:2184,
[2] S. Padhi, X. Liu, M.C. Valsania, L. Andreo, A. Agostino, A. Alessio, L. Pastero, A. Giordana, Z. Wu, G. Cravotto, M. Truccato, Nano-Structures and Nano-Objects, 35, 2023, 101016
[3] A.M. Grumezescu, Nanobiomaterials in antimicrobial therapy, applications of nanobiomaterials, 2016, 6. UK: Elsevier,
[4] R.Y. Pelgrift, A.J. Friedman, Adv Drug Deliv Rev, 2013, 65:1803e15,
[5] L.H. Madkour,Pharma Sci Analytical Res J, 2019, 2:180023

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ABC-PO-046

Porcelain and Magnesian Mortars: an update on the traditional mortar formulations

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The preservation and restoration of architectural heritage has recently re-evaluated the role of traditional mortars due to their high compatibility with ancient masonry. Their use has therefore increased in recent years, as has the research and development of new formulations in improving their durability and resistance to deterioration. The focus of this research relies on the study of two past mortar formulations, called "porcelain mortars" and "magnesian mortars" whose documentation, even if lacking in numbers, still highlights their noticeable setting and hardening properties even in high humidity environments. Porcelain mortars are characterized by a mixture of sand and natural lime with metakaolin, nowadays known as a supplementary cementitious material (SCM) used often by the Portland cement industry as an additive to enhance the compressive strength and pozzolanic properties of cement[1,2,3,4,5]. Magnesian mortars are based on magnesian lime, composed by $CaCO_3$ and $MgCO_3$ (~30% in volume), able to produce a rather durable material capable to harden even within 2 or 3 days while immersed in water[6]. This project wants to deepen the knowledge about the aforementioned mortar formulations mixed with different percentages of metakaolin to evaluate its influence on both physical and mechanical properties as well as their freeze-thaw and salt decay resistance. Two sets of samples were produced, traditional and magnesian lime-based mortars with variable lime/sand ratios and variable quantities of metakaolin. The study paid particular attention to the rheological aspect of fresh mock-ups and the consequent influence of the different binder/inert ratio and additive on properties such as spreading, specific weight and workability. From the analysis of fresh mortars, no noticeable differences were found between the different percentages of added metakaolin, but magnesian lime appeared more useful for the application on inclined surfaces than the traditional ones due to its texture and thixotropy. The formulations were studied in their behavior with water through the analysis of capillary absorption and water vapor permeability. The presence of metakaolin seems to not modify in an evident way the behavior of these mortars, even though, for what concerns the compression test, good results were obtained for mortar formulations containing metakaolin. Research is ongoing to test the influence of traditional and innovative additives on these mortars.

References:

[1] B. Sabir, S. Wild, J. Bai, Cement and Concrete Composites, 2001, 6, 441-454.
[2] A. Tironi, M. Trezza, E. Irassar, A. Scian, Procedia Materials Science, 2012, 1, 343-350.
[3] J. M. Khatib, et alii, Waste and Supplementary Cementitious Materials in Concrete, 2018, 493-511.
[4] Z. Khaled, A. Mohsen, A. M. Soltan, M. Kohail. Ain Shams Engineering Journal, 2023, 14(6).
[5] L. J. Vicat, 1837. Mortars and Cements (J. Weale, Ed.) 1837. Donhead Publishing Ltd.
[6] J. C. L. de Sismondi, Storia delle repubbliche italiane nel Medioevo, Avanzini e Torraca, 1968 [1838].

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The influence of pigment-medium interactions in the manifestation of selective degradation phenomena on modern white oil paints

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The presence of selective degradation patterns in modern oil paintings, depending on the colored area considered, has been the starting point of this research: indeed, random, unconnected cracks, sharper edges, and protrusions, can be found beside vertical cracks of a semi-connected network within the same painting. The aim of this study was to understand the causes that led to such differential degradation phenomena by understanding the physical, chemical, and mechanical mechanisms involved in the damage patterns.

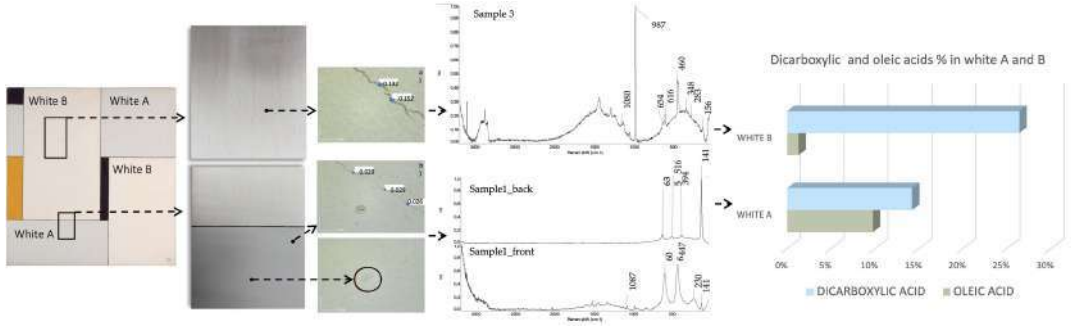

Figure 1: Multi-analytical approach carried out on *Composition dans le cône avec couleur orange* by G. Vantongerloo.

The case study (Fig.1) allowed to understand that the interactions between the composition of pigments, the nature of the binding media and the products resulting from the film formation processes were the mainly responsible for the ongoing degradation phenomena. A hybrid experimental approach based on non-invasive analysis (such as OM and multiband imaging analyses) were coupled with μ-Raman, ATR-FTIR and GC–MS analysis. The results highlighted that: random cracking and protrusions in white A areas were due to zinc soaps migrated from the preparatory layer; in white B areas, semi-combined cracking network was related to the interaction between lithopone and the lipidic binder causing the significant formation of dicarboxylic acids. This research bridges the gap between the chemical knowledge of artist's material choices and their degradation processes: it does not merely describe the morphology of cracks, but focuses on the role played by the pigment-medium interaction in the film formation processes of XX century commercial oil paints.

References:

[1] F.C.Izzo, M.Gnemmi, et al., Heritage Science, 2024, 92.
[2] M.F.Mecklenburg, P.Kekicheff, et al., From Soft Matter to Biophysics 2023, Book of abstract, p.29.

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ABC-PO-048

Green strategies to conserve the past and preserve the future of cultural heritage (GoGreen)

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The GoGreen project, funded by Horizon Europe (2022-2026), aims at introducing a green revolution in conservation by implementing both preventive and remedial strategies anchored in sustainable principles.

In the field of preventive conservation, we are developing new damage assessment tools for a variety of materials including glass, metal, ceramic, oil paintings, limestone, and lime-based plaster wall paintings. The goal is to support decision-making processes, allowing for the adoption of more flexible environmental controls within collections, ultimately reducing the carbon footprint. Additionally, artificial intelligence (AI) is employed to detect early signs of damage, thereby enabling the formulation of preventive conservation strategies. On the remedial side, the project aims to develop new eco-friendly solutions for cleaning paintings and metals, as well as sustainable stabilisation materials for metals and glass objects. These advancements draw inspiration from historical recipes, bioprocesses, and green chemistry. We are, for instance, producing electrospun nonwoven mats, made from either recycled polymers or bio-based compounds, combined with greener solvents for the removal of aged varnishes from paintings. These mats utilize micro- and nano-porosity to facilitate capillarity, ensuring varnish removal without the need for mechanical action. Similar technologies and bio-based methods are applied for treating tarnished metals (silver, copper and iron), using green chelating agents. Moreover, a water-based synthesis process at room temperature has been developed to produce silica-gel nanostructures for the stabilization of glass. Biosorption and biomineralization processes are also studied for the stabilisation of copper and iron artefacts. To validate the effectiveness of these materials and methods, GoGreen develops specialized and cutting-edge analytical procedures for surface and volume assessment. A key goal of GoGreen is to empower the conservation community to embrace sustainable practices. This is being achieved through the development of a digital web-app and decision model designed to assist conservators in designing and implementing green preventive and remedial treatments. Moreover, educational initiatives are being organized to instill a green mindset within the conservation field, aligning future practices with the objectives of the Green Deal.

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ABC-PO-050

Removal of nitrogen fraction in livestock farm wastewater using an electrochemical reactor for sustainable reuse.

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Spreading wastewater generated in the agro-zootechnical field to the soil is among the sources of total nitrogen in the environmental matrices. Wastewater is rich in ammonium nitrogen, which is transformed into nitrate by aerobic bacteria spontaneously present in the soil. Nitrate is highly soluble in water and leaches into the soil, surface water and groundwater, leading to environmental, humans, economic and social risks; for example, it could compromise the DOP brand of buffalo mozzarella. Therefore, removing ammonium nitrogen is crucial. Traditionally, ammonium nitrogen is removed from wastewater by biological and chemical approaches, but nitrate generation is carried out in this case. This research proposes an innovative approach based on electroxidation (EO). The research started with the design of the reactor and continued with its operation to intensify the electrochemical process and evaluate its engineered application. Applying electric current EO allows the transformation of ammonium nitrogen into gaseous nitrogen, avoiding nitrate and nitrite generation[1], and without sludge production, which contribute to the pollution of the environmental matrices. The tests were performed by using an advanced flat reactor made of titanium oxides (20*22.5 cm^2), operated to investigate the effect of applied current, after 3 hours. Preliminary investigations were conducted with a synthetic matrix, an initial concentration of NH_4Cl of 50 mg L^{-1} and NaCl of 250 mg L^{-1} in Milli-Q water; the initial pH was 6. This study also combines the ethical and application principles of sustainable development, Agenda 2030[2], and circular economy thanks to the recovery of wastewater.

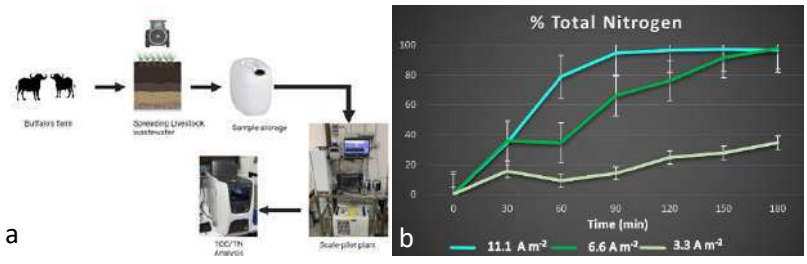

Figure 1: a) Flow chart of the research to removal of total nitrogen in livestock wastewater; b) EO results

References:

[1] P. Iovino et al. 2023, Molecules 2023, 28.
[2] ASVIS, Sustainable Development Agency, https://asvis.it/

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ABC-PO-051

Life Cycle Assessment of landfill leachate treatment

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The landfill remains one of the most frequent final destinations for the end-of-life of waste today at the national level (20% of MSW and 51% of industrial waste)[1]. Wastes permanence in landfill generates a heavily polluted liquid fraction (leachate) that, if not collected and treated, could constitute a threat to local superficial and subsoil water with consequential environmental and human health concerns[2]. A comprehensive examination of a full-scale facility that treats landfill leachate was conducted. The plant is composed of a chemical-physical treatment and a biological treatment designed for the abatement of nitrogen (90.3%), COD (92.2) and SS (95.1%), heavy metals and other pollutants. The precipitated sludges are centrifuged and sent to landfill. The study of the environmental impacts has been performed by applying the principles of the Life Cycle Assessment (LCA) techniques using ReCiPe 2016 [3] as the assessment method. $1m^3$ of leachate entering the plant is used as a functional unit (FU). Twelve impact categories have been analysed including in the system boundaries of the study the production and transport of the chemical used in the process, the electricity production and distribution, maintenance of the plant, sludge disposal and the law-compliant discharge of the clarified residues into seawater (including PFAS). The results show that chemicals, in particular sodium hydroxide (NaOH) and phosphoric acid (H_3PO_4), and electricity are major contributors in most of the impact categories while regarding eutrophication categories the discharge of the final clarified is by far the most impacting one. The next advancements will concern a focus on the PFAS removal efficiency of the plant and a life cycle assessment (LCA) including this removal in the functional unit (FU).

References:

[1] ISPRA: Catasto Nazionale Rifiuti, anno 2022, https://www.catasto-rifiuti.isprambiente.it/index.php?pg=gestnazione&advice=si

[2] F. Di Maria, F. Sisani, A life cycle assessment of conventional technologies for landfill leachate treatment, Environmental Technology & Innovation 8 (2017) 411–422.

[3] Huijbregts, M.A.J., Steinmann, Z.J.N., Elshout, P.M.F. et al. ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. Int J Life Cycle Assess 22, 138–147 (2017). https://doi.org/10.1007/s11367-016-1246-y.

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ABC-PO-052

Toxins of freshwater microorganisms, from bio- to chemodiversity

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Cyanobacteria are prokaryotic microorganisms that are present in all freshwater environments. A certain number of cyanobacterial species have the ability of producing toxic secondary metabolites. The massive growth (or bloom) of toxigenic cyanobacteria can lead to high concentrations of toxins in the water, thus posing a threat to human health. Eutrophication is the main driver of cyanobacterial blooms, but ongoing climate changes can exacerbate the problem. Cyanobacterial toxins (cyanotoxins) are secondary metabolites with a huge chemical diversity due to the high flexibility of their biosynthetic pathways.[1]

Research conducted in the last fifteen years at Fondazione Edmund Mach has revealed that the biosynthetic pathways are common to all toxigenic cyanobacteria, but that the resultant toxic molecules are very dependent on the species.[2] For instance, the cyanobacteria *Planktothrix rubescens* and *Microcystis aeruginosa* (among the most frequent responsible of toxic blooms around the world) both have the same gene cluster of the hepatotoxic microcystins (MC), but they synthetize different variants of MC. Moreover, the same set of MC are produced in different ratios by different strains of *P. rubescens*. These examples show how an integrated biological and chemical approach can be very effective in studying toxigenic cyanobacteria. This approach has demonstrated to be very useful in addressing the toxic potential of populations of cyanobacteria in different natural lakes.[3]

The presence of cyanotoxins in freshwaters is a matter that is taken into consideration by legislation in most countries and specific monitoring programs are routinely carried out by sanitary/environmental agencies. An emerging issue that is not yet considered by legislation is the presence of toxic cyanobacteria attached to different types of substrates (rocks, stones, vegetation) on the shores of lakes and rivers. Our recent studies revealed that some potent neurotoxins (anatoxins) can be produced in very high quantities by cyanobacteria growing in these environments. Such "biofilms" can constitute a relevant sanitary problem, considered that they can be easily accessed by people and animals walking on the shores.[4]

References:

[1] J.M. O'Neil, et al, Harmful Algae 2012, 14, 313 – 334.
[2] L. Cerasino, N. Salmaso, Advances in Oceanography and Limnology 2020, 11, 11 – 21.
[3] N. Salmaso, et al., Microbiology Resource Announcements 2023, 12, 11, 1 – 3.
[4] M. Zupancic, et. al, Toxins 2021, 13, 133.

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FAR-MD-01

The fascinating discovery of two antiviral drugs Raltegravir and Grazoprevir: the relevance of the scientific method and serendipity in drug discovery

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In drug discovery, the scientific method and serendipity are always key elements of the successful story. The presentation is a journey in the antiviral drug discovery and development process of the author related to two drugs, Raltegravir[1,2] (Isentress™), the first in class HIV integrase inhibitor approved, and Grazoprevir[3], a pan-genotype HCV protease inhibitor approved in combination with Elbasvir (Zepatier™) to cure HCV patients in interferon free therapy. HIV and HCV differ significantly at the molecular level and with respect to their resultant pathogenesis. However, the development of effective therapies present similar challenges, rapid turnover and high viral load together with the propensity to select resistant variants and the need for chronic treatment months (HCV) or for even the entire life span (HIV). Failure and success will be presented in the strategies from hit identification to POC in animal model, candidate selection and clinical development including. Regarding HIV integrase, particularly relevant was the understanding of the hit mechanism of action and the required pharmacophore eventually leading to the switch from HCV polymerase to HIV integrase that combined with creative medicinal chemistry, led to the generation of a novel class of selective HIV integrase inhibitors allowing the selection and approval of Raltegravir. Instead, the profound analyses of the structural features of the different genotypes and in vitro selected mutants of the HCV protease, combining X-Ray and modelling studies, were the key elements for the discovery of Grazoprevir. Two drugs (Figure 1), two different Med Chem approaches and two-historical case of the antiviral development.

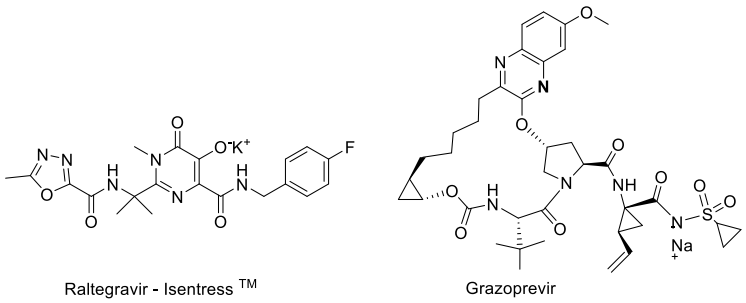

Figure 1: Raltegravir and Grazoprevir.

References:

[1] Summa, V.; et al. *Journal of Medicinal Chemistry* 2004, 47(22), 5336-9
[2] Summa V.; et al. *Journal of Medicinal Chemistry* 2008, 51(18), 5843-55,
[3] Summa, V.; et al. *Antimicrobial Agents and Chemotherapy* 2012, 56(8), 4161-4167

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FAR-PZ-01

Discovery of a polypharmacological drug candidate restoring the physiological Tau-microtubule interaction for the treatment of Alzheimer's disease

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Tauopathies encompass over twenty neurodegenerative diseases characterized by the aggregation of the Tau protein.[1] Physiologically, Tau is involved in the regulation of microtubules (MTs) dynamic stability.[2] However, when aberrantly phosphorylated or mutated, Tau can dissociate from MTs to assemble into aggregates responsible for neurodegeneration.[1,3] On these premises, the design of compounds restoring the physiological Tau-MTs interaction represents a promising strategy for tauopathies treatment. In search of compounds endowed with such an activity profile, we first performed extensive *in silico* analyses, identifying a series of 2-phenyloxazole (PHOX) compounds as potential candidates for the treatment of the Alzheimer's disease tauopathy. To assess the candidates' activity, we then performed extensive experimental analyses, and developed a novel *in vitro* cellular assay that enables to monitor pathological changes in human Tau. These analyses (Figure 1) allowed us to identify one candidate (PHOX15) able to restore Tau-MTs interaction and to reduce Tau aggregation.[4] Finally, *in silico* structure-based simulations allowed us to identify a series of cryptic pockets in Tau cryo-EM structures, one of which being potentially involved in the PHOX15 binding.[4]

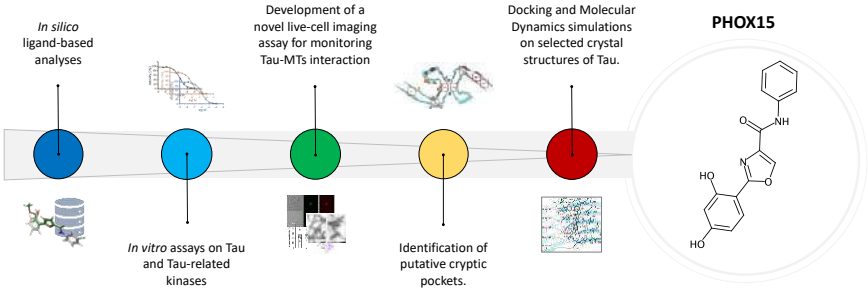

Figure 1: In silico and experimental workflow that led to the identification of the PHOX15 candidate.

References:

[1] K.A. Josephs, Mayo Clin. Proc., 2017, 92, 1291-1303.
[2] J. Avila, J.J. Lucas, M. Perez, F. Hernandez, Physiol. Rev., 2004, 84, 361-384.
[3] M.E. Orr, A.C. Sullivan, B. Frost, Trends Pharmacol. Sci., 2017, 38, 637-648.
[4] L. Pinzi, C. Conze, N. Bisi, G.D. Torre, A. Soliman, N. Monteiro-Abreu, N.I. Trushina, A. Krusenbaum, M.K. Dolouei, A. Hellwig, M.S. Christodoulou, D. Passarella, L. Bakota, G. Rastelli, R. Brandt, Nat. Commun. 2024, 15, 1679.

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FAR-PZ-02

Identification of new small molecule nsp13 inhibitors as pan-Coronavirus antiviral agents

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The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the causative agent behind the 2019 global pandemic (COVID-19). Despite the successful vaccination programs, little has been accomplished in the development of specific antivirals. The disparity in COVID-19 vaccine resistance, the emergence of SARS-CoV-2 variants of concern, and the potential to evade both vaccination and acquired immunity emphasize that the development of antiviral drugs to treat SARS-CoV-2 infections is of utmost importance. Among potential drug targets, the SARS-CoV-2 non-structural protein 13 (nsp13) is highly attractive thanks to its critical role in viral replication. Nsp13 utilizes the energy of nucleotide triphosphate hydrolysis to catalyze the unwinding of double-stranded DNA or RNA.[1] Moreover, nsp13 is the most conserved nsp among the coronavirus family.[2] This implies that small molecule nsp13 inhibitors may serve as pan-CoV antiviral agents and that previously found compounds targeting nsp13 in other CoVs species might be effective against COVID-19. Although the roles of nsp13 in the viral lifecycle, there is a paucity of information about small molecules endowed with nsp13-inhibitory activity. Basing on literature data and thanks to our longstanding expertise in the design and synthesis of DKA derivatives, we carried out a semi-random screening on our in-house library of DKA compounds, identifying a promising hit compound as micromolar nsp13 inhibitor.[3] We synthesized new DKA derivatives structurally related with the identified hit, obtaining dual SARS-CoV-2 nsp13 ATPase and unwinding inhibitors, also capable of inhibiting viral replication. Mode-of-action studies revealed ATP-non-competitive kinetics of inhibition, not affected by substrate-displacement effect, suggesting an allosteric binding. Docking studies suggested a possible binding mode within an allosteric pocket of nsp13. Moreover, the broad-spectrum antiviral activity was evaluated, highlighting their potential as pan-CoV inhibitors.

References:

[1] J. Chen, J. B. Malone, B. E. Llewellyn, M. Grasso, P.M.M. Shelton, et al., Cell 2020, 182, 1560 – 1573.
[2] M.A. White, W. Lin, X. Cheng, J. Phys. Chem. Lett. 2020, 11, 9144 – 9151.
[3] A. Corona, V.N. Madia, R. De Santis, C. Manelfi, R. Emmolo, D. Ialongo, et al., Antiviral Res. 2023, 217, 105697.

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FAR-PZ-03

Design, synthesis, and biological evaluation of bitopic ligands for novel strategies targeting cannabinoid receptors

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Endocannabinoids (ECs) are neuromodulatory signaling molecules implicated in a plethora of biological processes including cognition, analgesia, stress, anxiety, neuroprotection, and motor coordination. Arachidonoyl ethanolamide (anandamide or AEA) and 2-arachidonoyl glycerol (2-AG) are the most important ECs and function through the G-protein coupled cannabinoid receptors (CBRs, CB1R and CB2R). Since the discovery of CBRs, many efforts have been made to develop highly selective orthosteric compounds that would be suitable as potential therapeutic agents. In many cases, direct-acting agonists proved to cause serious adverse effects, such as psychotropic effects or immune dysfunction, which limited the clinical development of classical orthosteric CBR ligands. For this reason, interest in allosteric regulation as a new way of modulating receptor activity without the drawbacks associated with direct agonist activation is steadily increasing in the CBR field. By binding to topologically and often functionally distinct sites from their orthosteric counterparts, allosteric ligands typically allow high levels of selectivity. Notably, a new approach in medicinal chemistry has been reported in the literature based on the design of bitopic (or dualsteric) agents as single chemical entities capable of simultaneously interacting with both the orthosteric and allosteric binding sites. The idea behind the development of bitopic ligands is to combine the activation properties of orthosteric ligands with the higher selectivity profile of allosteric ligands. During my doctoral studies, I applied the concept of bitopic modulation to CBRs, resulting in the identification of the first two hetero-bivalent bitopic ligands for CB2R[1,2,3]. Following extensive biochemical and computational studies to confirm their bitopic nature, the therapeutic potential of these newly developed modulators was investigated. This exploration revealed potent anti-inflammatory activity in a human microglial cell inflammatory model for both ligands,[1,3] as well as antinociceptive activity in an experimental mouse model of neuropathic pain and pro-autophagic effects *in vitro* in an Alzheimer's Disease model for one of the ligands[1].
Afterward, expanding bitopic modulation to the other CBR subtype using potential CB1R dualsteric agents brought to light even more intriguing aspects of orthosteric/allosteric hybrid modulation.

References:

[1] F. Gado, R. Ferrisi, B. Polini, *et al.* Journal of Medicinal Chemistry, 2022, 65, 9918-9938.
[2] R. Ferrisi, F. Gado, B. Polini, *et al.* Frontiers in chemistry, 2022, 10, 984069.
[3] R. Ferrisi, B. Polini, C. Ricardi, *et al.* International Journal of Molecular Sciences, 2023, 24, 2135.

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FAR-PZ-04

Exploring innovative approaches to revolutionize leishmaniasis drug discovery: new chemical modalities and chemotypes

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Leishmaniasis causes considerable mortality and morbidity in many parts of the world. The most severe form of the disease, the visceral leishmaniasis, causes 20000–40000 deaths annually according to the WHO. None of the current front-line treatments are ideal for use due to cost, toxicity, resistance, and parenteral administration. As a result, there is an urgent need for new leishmaniasis treatment options. Trypanothione reductase (TR) represents one of the most robustly validated drug targets for *Leishmania* parasites. TR has been assessed for its suitability as a target in terms of level of genetic and chemical validation, assay feasibility, toxicity, resistance and druggability. However, the main area for caution for this target remains its druggability since the enzyme active site is large and featureless. For this reason, despite the efforts, TR is still considered a highly challenging target for conventional small-molecule-based inhibition approaches. A change in perspective is therefore needed. In this regard, drug discovery has experienced an incredible paradigm shift in the past two decades and includes now an innovative wave of chemical modalities to efficiently address difficult biological targets.

Based on this, the aim of my research was to develop novel approaches for the leishmaniasis drug discovery through four complementary projects that incorporate new chemical modalities (i.e., Targeted Protein Degradation, *TPD* for infectious diseases)[1] and novel chemotypes. Moreover, we harnessed a fragment-based drug discovery (FBDD) strategy to develop new TR inhibitors[2] in order to demonstrate the importance of employing diverse medicinal chemistry strategies and chemotypes as new tools in the drug discovery scenario for leishmaniasis.

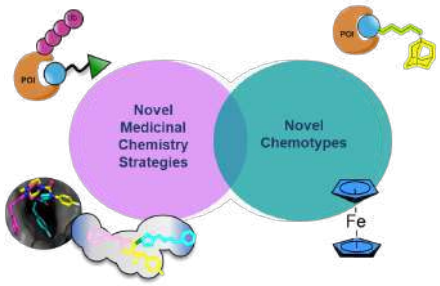

Figure 1: Schematic representation of the new chemical modalities for leishmaniasis

References:

[1] R. Espinoza-Chávez, A. Salerno, et al., *ACS Bio Med Chem Au*. **2022**, 15, 1, 32–45.
[2] C. Exertier,* A. Salerno,* et al., *J. Med. Chem.* **2024**, 67, 1, 402–419.

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Salvatore Di Maro, Università della Campania “Luigi Vanvitelli”

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FAR-KN-01

CXCR4 as potential predictive biomarkers for early-stage cancer detection, diagnosis and prognosis

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Targeted Positron Emission Tomography (PET) imaging, along with Liquid Biopsy for detecting circulating tumor cells (CTCs-LB), offers the potential to precisely identify tumour locations and track disease progression, respectively.[1] These techniques require the identification of pertinent cancer hallmarks, whose detection enable highly specific diagnostics and therapies. In this perspective, the C-X-C chemokine receptor type 4 (CXCR-4) is arising among the most promising targets due to its overexpression in more than 30 different cancer types.[2] We have recently described a family of small cyclic peptide acting as CXCR4 antagonists endowed with high receptor affinity, selectivity, and metabolic stability.[3] Herein, we report the use of the lead peptide R54 to develop radiolabelled probes and to decor self-assembling amphiphilic dendrimers (SAADs) for *in-vivo* PET imaging of CXCR4-overexpressing tumours. Additionally, we explore the use of its derivative, R54-L10, for functionalizing photonic biochips designed to detect CXCR4-overexpressing circulating tumour cells (CTCs). The resulting [^{68}Ga]NOTA-R54 was successfully employed for *in vivo* PET imaging studies using CHO-hCXCR4 and Daudi lymphoma cells, revealing high CXCR4-specific tumour uptake and high tumour/background ratios.[4] Currently, [^{68}Ga]NOTA-R54 is awaiting approval by the Italian Minister of Health for a microdose clinical phase 1 study involving 5 patients at the Istituto Nazionali Tumori di Napoli "G. Pascale." Promising results were also achieved with [^{68}Ga]NOTA-R54-decorated SAADs, which were characterized *in vivo* using mice carrying xenograft CHO-CXCR4. Finally, as a proof of concept, the R54-L10-functionalized biochips were preliminary assessed in the presence of CXCR4$^+$ and CXCR4$^-$ CHO cells (1 x 10^2 to 2.5 x 10^4 cells/ml), showing the capability to specifically detect the receptor at cell concentrations comparable to those of the CTCs.

References:

[1] S.P. Rowe, M.G. Pomper. *CA Cancer J Clin.* 2022, 72, 333-352.
[2] S. Chatterjee, B. Behnam Azad, S. Nimmagadda. *Adv. Cancer Res.* **2014**, *124*, 31-82.
[3] S. Di Maro, F.S. Di Leva, A.M. Trotta, D. Brancaccio, L. Portella, M. Aurilio, S. Tomassi, A. Messere, D. Sementa, S. Lastoria, A. Carotenuto, E. Novellino, S. Scala, L. Marinelli *J. Med. Chem*. **2017**, *60*, 9641-9652.
[4] A.M. Trotta, M. Aurilio, C. D'Alterio, C. Ieranò, D. Di Martino, A. Barbieri, A. Luciano, P. Gaballo, S. Santagata, L. Portella, S. Tomassi, L. Marinelli, D. Sementa, E. Novellino, S. Lastoria, S. Scala, M. Schottelius, S. Di Maro *J. Med. Chem.* **2021**, *64*, 3449–3461.

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FAR-KN-02

Gaining insights into SMYD3 binding and inhibition through a combination of biochemical and biophysical approaches

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Cancer is undeniably one of the most intricate diseases in the healthcare community. Epigenetic enzymes, responsible for the spatial-temporal regulation of gene expression, are key targets for oncotherapy. Among these, SET and MYND domain-containing protein 3 (SMYD3) is a lysine methyltransferase whose aberrant activity has been linked to several types of cancer, making it an exceedingly attractive target for oncotherapy. Although the development of SMYD3 inhibitors as anticancer drugs has faced attrition, recent findings have reignited interest in this target, showing that SMYD3 is involved in DNA repair mechanisms and its inhibition could impact cancer cell sensitivity to DNA-damaging drugs.[1] To support and expedite early-stage discovery campaigns on SMYD3, reliable and informative analytical platforms need to be established to prioritize the best promising inhibitors. Both chemical tools and drug-like compounds are required for progressing on SMYD3. In this scenario, and as part of a collaborative project involving multiple research groups, we developed various fit-to-purpose analytical methods, which have been used to ensure the required level of information was achieved. These include a mass spectrometry (MS)-based assay to overcome the use of radiolabelled activity assays, surface plasmon resonance (SPR) screenings, and top-down/bottom-up MS investigations to provide insights into the mechanism of action and site of interaction of new ligands. Results collected in these studies were combined with those achieved by others within an iterative medchem process to identify promising SMYD3 inhibitors. These efforts led to the groundbreaking discovery of the first allosteric ligand for SMYD3 and of a previously unknown allosteric site in the C-terminal domain.[2] Additionally, a screening campaign for targeted covalent inhibitors (TCIs) led to the identification of a potent 4-aminopyridine-based ligand bearing a 2-chloroethyl group as a reactive warhead. Further SPR and MS investigations provided a thorough definition of the kinetics and affinity parameters for the initial reversible complex, kinetic parameters for the subsequent covalent adduct formation, and the identification of the specifically targeted amino acid in SMYD3 structure[3].

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References:

[1] Sanese P, Fasano C, et al. iScience. 2020, 23, 101604.
[2] Talibov VO, Fabini E, et al. Chembiochem. 2021, 22, 1597-1608.
[3] Parenti MD, Naldi M, et al. Eur J Med Chem 2022, 243, 114683.

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FAR-KN-03

Inverse design for the generation of targeted libraries in drug discovery

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Inverse design has revolutionized how medicinal chemists approach drug discovery.[1] Pharmacological targets are now at the forefront of the discovery process to tailor the design of new compounds with desired physicochemical and pharmacological features but minimal side effects.[2] This new paradigm is very promising for exploring unknown regions of the chemical space in the search of new synthetically feasible bioactive molecules to prioritize for biological testing. We developed a user-friendly platform[3] based on artificial intelligence and multiobjective optimization methods to guide the human-like design of compounds reflecting the distributions of relevant druglike properties and the structural similarity of known compounds towards specific biological targets available from ChEMBL.[4] Several quality metrics were employed to evaluate the goodness of the new generated compounds. Results can be retrospectively evaluated by employing molecular docking simulations or, especially for large volume of data, by ligand-based screening carried out with PLATO,[5,6] a free web-platform designed for target fishing and bioactivity predictions.[7,8]

References:

[1] B. Sanchez-Lengeling, A. Aspuru-Guzik, A. Science 2018, 361, 360-365.
[2] F. Mastrolorito, M.V. Togo, N. Gambacorta, D. Trisciuzzi, V. Giannuzzi, F. Bonifazi, A. Liantonio, P. Imbrici, A. De Luca, C.D. Altomare, F. Ciriaco, N. Amoroso, O. Nicolotti, Chemical Research in Toxicology 2024, 37, 323-339.
[3] D. Alberga, N. Gambacorta, D. Trisciuzzi, F. Ciriaco, N. Amoroso, O. Nicolotti, Journal of Chemical Information and Modeling 2020, 60, 4582-4593.
[4] B. Zdrazil, E. Felix, F. Hunter, E.J. Manners, J. Blackshaw, S. Corbett, M. de Veij, H. Ioannidis, D.M. Lopez, J.F. Mosquera, M.P. Magarinos, N. Bosc, R. Arcila, T. Kizilören, A. Gaulton, A.P. Bento, M.F. Adasme, P. Monecke, G.A. Landrum, A.R. Leach, Nucleic Acids Research, 2024, 52, 1180-1192
[5] F. Ciriaco, N. Gambacorta, D. Trisciuzzi, O. Nicolotti, International Journal of Molecular Sciences, 2022, 23, 1-8.
[6] F. Ciriaco, N. Gambacorta, D. Alberga, O. Nicolotti, Journal of Chemical Information and Modeling, 2021, 61, 4868-4876.
[7] N. Gambacorta, F. Ciriaco, N. Amoroso, C.D. Altomare, J. Bajorath, O. Nicolotti, Journal of Chemical Information and Modeling 2023, 63,5916-5926.
[8] C. Mugnaini, A. Brizzi, M. Paolino, E. Scarselli, R. Castelli, M. de Candia, N. Gambacorta, O. Nicolotti, M. Kostrzewa, P. Kumar, A.M. Mahmoud, V. Borgonetti, M. Iannotta, A. Morace, N. Galeotti, S. Maione, C.D. Altomare, A. Ligresti, F. Corelli, ACS Chemical Neuroscience 2024, 15, 955-971.

FAR-KN-04

Integrated Phenotypic Strategies for Unlocking Challenging Biological Pathways

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The accurate prediction of the precise molecular interactions needed to modify a disease phenotype is still a challenging task in medicinal chemistry, and hinders the translation into safe and effective drug candidates. Although different target-based approaches have been successfully employed for rational development of different drugs, mounting evidences suggest that the reductionist lock-and-key target-based approach often results in molecules unable to exert their intended effects on complex biological systems (such as cells or animal models), despite evidences regarding target engagement and modulation. [1] Over the past decade, the re-evaluation of the role played by target-centric approaches in drug discovery has sparked a renewed interest in phenotypic approaches for the discovery of first-in-class candidates.

In this presentation, the phenotypic strategies recently undertaken by my research group to discover novel pharmacological tools capable of effectively modulating the CCL20/CCR6 and PCSK9 pathways will be discussed. [2, 3] These biological networks play a pivotal role in the pathogenesis of numerous chronic and infectious diseases. Although the druggability of these pathways was already proven by monoclonal antibodies, no small-molecule drugs have yet received approval for their modulation, presenting ample opportunities for the discovery of first-in-class drugs.

References:

[1] D.C. Swinney, Phenotypic drug discovery: history, evolution, future. B. Isherwood, A. Augustin (Eds.), The Royal Society of Chemistry, 2020, pp. 1–19, https://doi.org/10.1039/9781839160721-00001.
[2] M. G. Martina, C. Giorgio, M. Allodi, S. Palese, E. Barocelli, V. Ballabeni, M. Szpakowska, A. Chevigné, J. Piet Van Hamburg, N. Davelaar, E. Lubberts, S. Bertoni, M. Radi, Eur J Med Chem 243, 114703. https://doi.org/10.1016/j.ejmech.2022.114703.
[3] L. Giannessi, M.G. Lupo, I. Rossi, M.G. Martina, A. Vilella, M. Bodria, D. Giuliani, F. Zimetti, I. Zanotti, F. Potì, F. Bernini, N. Ferri, M. Radi, Eur. J. Med. Chem. 2024, 265, 116063, https://doi.org/10.1016/j.ejmech.2023.116063.

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FAR-OR-001

Acyclic purine and pyrimidine nucleotide analogs as ecto-5'-nucleotidase (CD73) inhibitors

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Ecto-5'-nucleotidase (CD73) is a potential target in cancer (immuno)therapy since its blockade prevents the formation of immunosuppressive and cancer-promoting adenosine from AMP.[1,2]

Here, we report on the development of a series of small molecules that mimic adenine nucleotides acting as non-cleavable competitive CD73 inhibitors. The ribose moiety of adenosine was replaced by an alkyl chain whose length was found to be crucial for potency.

The most potent CD73 inhibitor of the present series was the N^6-substituted acyclic ADP analog (N^6-benzyl,N^6-methyladenine-9-yl)hexyloxydiphosphonate which exhibited submicromolar potency at human CD73 displaying a Ki value of 563 nM towards the soluble enzyme, and of 481 nM towards the membrane-bound CD73 of triple-negative breast cancer cells. Investigation on the mechanism of inhibition confirmed a competitive inhibition mode of this compound. An X-ray co-crystal structure of the compound bound to the catalytic site of human CD73 has been obtained, providing information on the key interactions established between the inhibitor and the enzyme.

Acyclic nucleotide analogs may be advantageous compared to nucleotidic CD73 inhibitors due to their high chemical stability, and because less off-target effects are to be expected.

The structure-activity relationships discovered in this study, along with the obtained crystal structure provide valuable insights which will be useful for the future development of improved CD73 inhibitors as immunotherapeutic drugs.

References:

[1] O. Kepp, L. Bezu, T. Yamazaki, F. Di Virgilio, M.J. Smyth, G. Kroemer, L. Galluzzi, EMBO Journal 2021, 40, e108130.
[2] H. Zimmermann, Biochemical Pharmacology 2021, 187, 114322.

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FAR-OR-002

Unveiling Multimodal Solutions for Targeting IDO1 activities in Cancer Immunotherapy

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Background. Indoleamine 2,3-dioxygenase 1 (IDO1), an appealing target for cancer immunotherapy, is a moonlighting protein that, aside from its role as a tryptophan-metabolizing enzyme, functions as a complex signal-transducing molecule.[1] Following the disappointment with epacadostat, a holo-inhibitor, in a Phase III trial,[2] enthusiasm within academia and industry has declined, prompting scientists to reconsider the future direction for targeting IDO1. **Aims and results.** To address the constraints encountered with traditional catalytic inhibitors, we employed three distinct approaches for targeting IDO1. **i) Development of small molecules that modulate both enzymatic and signalling activities: VS-15** (A375, IC_{50} = 480 nM) and its analogue compound **1** represent the first apo-inhibitors that negatively modulates the SHP-mediated signalling activity of IDO1, with a great potential for decreasing IDO1 *de novo* synthesis and expression. Moreover, compound **1**, acts as a dual inhibitor of IDO1 and TDO and it has been encapsulated within silk fibroin nanoparticles[3] for preclinical studies due to its short *in vivo* half-life. **ii) Development of drug-like apo-IDO1 inhibitors: VS-13**[4] is a potent apo-IDO1 inhibitor (A375, IC_{50} = 16 nM) and it suffers from poor metabolic stability in mouse liver microsomes. Hence, a SAR/SPR exploration around **VS-13** relying on the use of different isosteres (deuterium, halogens, and ring equivalence) was carried out to increase its ADME profile. **iii) Synthesis of PROTACs**: a sustainable and environmentally friendly platform based on multi-component reactions[5] was exploited to synthetize a library of PROTACs characterized by linkers and linkage points of different nature and length. Cellular assays and Western Blot analysis are currently ongoing.

References:

[1] A. Adamo, C. Frusteri, M. T. Pallotta, T. Pirali, S. Sartoris, S. Ugel, 2021, 11, 613069.
[2] G. V. Long, R. Dummer, O. Hamid, T. F. Gajewski, C. Caglevic, S. Dalle, A. Arance, M. S. Carlino, J. J. Grob, T. M. Kim, L. Demidov, C. Robert, J. Larkin, J. R. Anderson, J. Maleski, M. Jones, S. J. Diede, T. C. Mitchell, 2018, 20, 1083–1097.
[3] E. Bari, F. Ferrera, T. Altosole, S. Perteghella, P. Mauri, R. Rossi, G. Passignani, L. Mastracci, M. Galati, G. I. Astone, M. Mastrogiacomo, P. Castagnola, D. Fenoglio, D. Di Silvestre, M. L. Torre, G. Filaci, 2023, 11, e005916.
[4] M. Serafini, E. Torre, S. Aprile, E. Del Grosso, A. Gesù, A. Griglio, G. Colombo, C. Travelli, S. Paiella, A. Adamo, E. Orecchini, A. Coletti, M.T. Pallotta, S. Ugel, A. Massarotti, T. Pirali, S. Fallarini, 2020, 63, 3047–3065.
[5] I. P. Bhela, A. Ranza, F. C. Balestrero, M. Serafini, S. Aprile, R. M. C. Di Martino, F. Condorelli, T. Pirali, 2022, 65, 15282-15299.

FAR-OR-003

New Pyrrole Derivatives as Ferroptosis Inducers

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Ferroptosis is an iron-dependent cell death which is different from apoptosis, necrosis, autophagy, and other forms of cell death [1]. We synthesized new aroyl diheterocyclic pyrroles (ARDHEPs) as tubulin polymerization inhibitors [2]. Among these compounds, the derivative (4-(furan-2-yl)-1-(pyrimidin-2-yl)-1*H*-pyrrol-3-yl)(3,4,5-trimethoxyphenyl)methanone (**1**) exhibited the hallmarks of ferroptosis (Figure 1). The new compound strongly inhibited U-87 MG, OVCAR-3, and MCF-7 cancer cells and induced an increase in cleaved PARP but was not toxic to normal human primary T lymphocytes at 0.1 μM concentration. Analysis of the levels of lactoperoxidase, malondialdehyde, lactic acid, total glutathione, and ATP suggested that the *in vivo* inhibition of cancer cell proliferation by the new compound occurred through the stimulation of oxidative stress injury and Fe^{2+} accumulation. Quantitative polymerase chain reaction analysis of mRNA expression in U-87 MG and SKOV-3 tumor tissues from new ARDHEP-treated mice showed the presence of *Ptgs2/Nfe2l2/Sat1/Akr1c1/Gpx4* genes correlated with ferroptosis in both groups. Immunofluorescence staining revealed significantly lower expressions of proteins Ki67, CD31, and ferroptosis-negative regulation proteins glutathione peroxidase 4 (GPX4) and FTH1. Finally, the new ARDHEP was found to be metabolically stable when incubated with human liver microsomes.

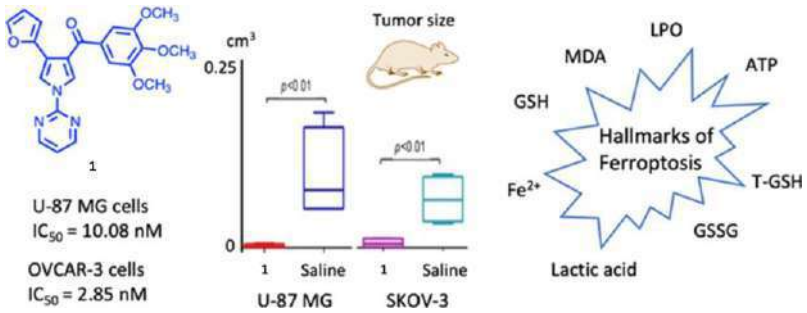

Figure 1: ARDHEP **1** as ferroptosis inducer.

References:
[1] Shi, T.-M. *et al.* Ferroptosis-Based Therapeutic Strategies toward Precision Medicine for Cancer. *J. Med. Chem.* **2024**, *67*, 2238−2263.
[2]. Puxeddu, M. *et al.* Induction of Ferroptosis in Glioblastoma and Ovarian Cancers by a New Pyrrole Tubulin Assembly Inhibitor. *J. Med. Chem.* **2022**, *65*, 15805−15818.

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FAR-OR-004

Overcoming of metabolic issues in 2-hydroxypyrazolo[1,5-a]pyridine scaffold-based inhibitors of human dihydroorotate dehydrogenase: the story of MEDS700

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Human dihydroorotate dehydrogenase (*h*DHODH), a crucial enzyme in the *de novo* pyrimidine biosynthesis, is a validated target for treating autoimmune diseases, solid tumors, and, more recently, acute myieloid leukemia (AML).[1] Through a *non*-classical bioisosteric approach supported by structure-based drug design, our research group recently discovered **MEDS613**, a molecule exhibiting 15-fold greater potency in cell-based assays compared to brequinar, a known *h*DHODH inhibitor. Unfortunately, **MEDS613** suffered from poor *in vitro* metabolic stability, thus limiting further preclinical studies.[1] This work unveils the identification process of **MEDS613**'s alkoxy chain metabolic soft spot, which finally led to the design of **MEDS700** (**Figure 1**), a metabolically stable analogue. **MEDS700**, whose *h*DHODH binding mode has been elucidated through x-ray crystallography, demonstrates comparable or even improved performance to **MEDS613**, in terms of enzymatic inhibition and pro-apoptotic and pro-differentiating induction on AML cell lines. **MEDS700** represents a promising candidate for further steps in the drug development process, thus, prior to future *in vivo* toxicity/efficacy studies, the pharmacokinetic profile of the new lead compound has been outlined and here fully discussed.

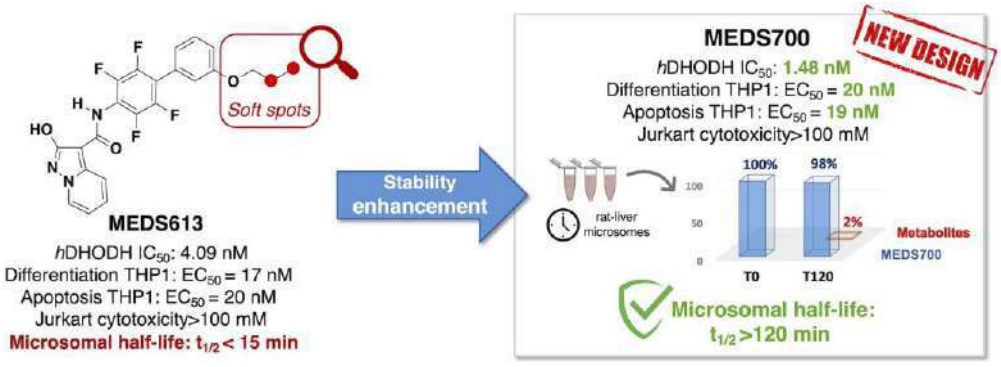

Figure 1: Optimization of **MEDS613** metabolic soft spots with the design of **MEDS700**.

References:

[1] Sainas, S. *et al.* J. Med. Chem. 2021, 64, 5404−5428

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FAR-OR-005

Design and Synthesis of Selective PPI Inhibitors Against the EphA2 Receptor Targeting Glioblastoma Multiforme (GBM)

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Compealing evidence show the cardinal role of the Eph-ephrin system in tumour initiation and sustenance. EphA2 has been found often overexpressed and deregulated in Glioblastoma Multiforme (GBM).[1] Agents able to prevent EphA2-ephrin-A1 association are available and include bile acid conjugates, such as **UniPR1447** (N-(3β-hydroxy-5-cholen-24-oyl)-L-β-homotryptophan, IC_{50}= 5.4μM). However, the compound lacks selectivity towards Eph receptors (Fig.1)[2]. A combined experimental and computational approach was exploited to selectively identify inhibitors of EphA2, targeting a peripheral pocket of the ligand binding domain (Fig.1), over the EphB2 receptor. **UniPR1449** (N-(3β-hydroxy-5-cholen-24-oyl)-1-benzensulfonyl-L-β-homotryptophan, Fig.1) was firstly identified as selective inhibitor of the EphA receptors (Fig.1), while inactive on EphBs.[2] A further rational exploration guided by the combined application of an experimental design on physicochemical descriptors and docking simulations led to the discovery of **UniPR1454** (N-(3β-hydroxy-5-cholen-24-oyl)-(4-(trifluoromethyl)phenylsulfonyl)-L-β-homotryptophan, Fig.1), acting as potent and competitive EphA2 ligand (IC_{50}= 2.6μM) able to inhibit ephrin-A1 dependent signals in intact cancer cells and to block the growth of GBM cell lines at low micromolar concentrations.

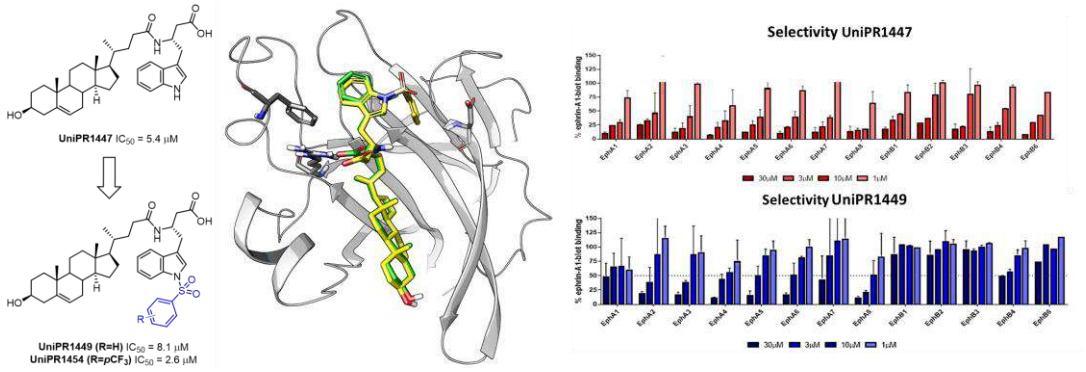

Figure 1. (left) Chemical structure of **UniPR1447** and selective inhibitors. (center) Docking poses of **UniPR1447** (green) and **UniPR1449** (yellow) within the LBD of EphA2. (Right) Selectivity profile of **UniPR1447** and **UniPR1449** against Eph receptors.

References:

[1] J. Wykosky *et al.* EphA2 as a novel molecular marker and target in glioblastoma multiforme. Mol. Cancer Res. 2005, 3, 541–551.

[2] L. Guidetti *et al.* Molecular Determinants of EphA2 and EphB2 Antagonism Enable the Design of Ligands with Improved Selectivity. J. Chem. Inf. Model. 2023, 63, 6900-6911.

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FAR-OR-006

Novel 5-arylamino pyrazoles able to interfere with angiogenesis and Ca^{2+} homeostasis

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In the last years, several pyrazole derivatives have been reported as antiangiogenetic agents.[1,2] In particular, 5-phenylamino pyrazole **I** (Scheme 1) proved to inhibit Akt phosphorylation in human foreskin fibroblasts (HFF) and human umbilical vein endothelial cells (HUVEC) and to interfere with HFF migration in wound healing assays, being more active than our reference compound **GeGe-3** (Scheme 1).[2] In functional proteomics investigations on HUVEC, **GeGe-3** proved to affect intracellular Ca^{2+} levels in a dose dependent fashion through the interaction with calreticulin (CALR).[3] Docking simulations helped to elucidate the molecular basis of pyrazole **I**/CALR interaction.[2] To further extend the SARs of derivatives **I**, novel 5-arylamino pyrazoles **II** and **III** were designed and synthesized. The new molecules share with **I** and **GeGe-3** the *N*1- hydroxyalkyl or hydroxy phenyl chains and the free amino group at position five of the ring. Differently from their parents' compounds, the novel derivatives presented variously substituted aryl-amino moieties at position three.

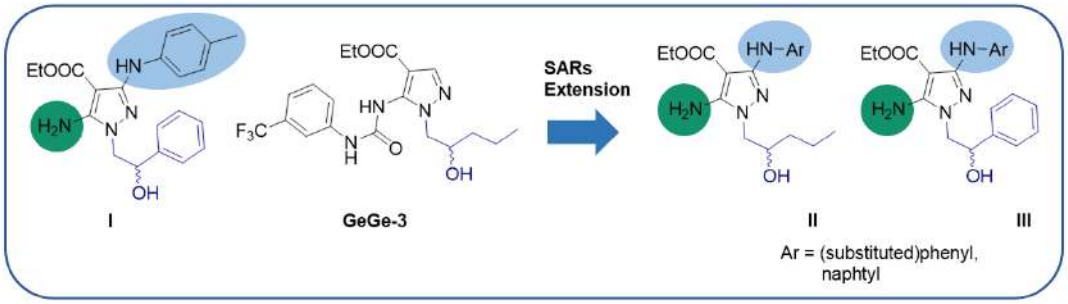

Figure 1: Structures of previously reported pyrazoles **I** and **GeGe-3** and new derivatives **II** and **III**.

All the isolated compounds were preliminary screened by MTT assays to prove the absence of cytotoxicity against normal human cells. Additionally, the effects on angiogenesis and calcium mobilization were evaluate *in vitro* on HUVEC. Selected derivatives showed improved antiangiogenic activities compared to **GeGe-3** and **I**.

References:

[1] E. Meta, C. Brullo, A. Sidibè, B.A. Imhof, O. Bruno, Eur. J. Med. Chem. 2017, 133, 24-35.
[2] E. Moretta, R. Belvedere, A. Petrella, A. Spallarossa, F. Rapetti, O. Bruno, C. Brullo, M.C. Monti, Bioorg. Chem. 2021, 115, 105168.
[3] M. Lusardi, B. Wehrle-Haller, A. Sidibè, M. Ponassi, E. Iervasi, C. Rosano, C. Brullo, A. Spallarossa, Eur. J. Med. Chem. 2023, 260, 115727.

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FAR-OR-007

Unveiling the potential anticancer activity of newly developed Cu(I) phosphino complexes

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Platinum(II) complexes are nowadays the unique metal-based drugs clinically approved for the treatment of a large number of solid tumors. However, platinum drugs cause severe toxic effects on normal tissues and induce the appearance of resistance phenomena.[1] These drawbacks have stimulated an extensive search for the development of alternative metal-based drugs with improved pharmacological properties and able to target different tumor-specific molecular determinants. Among a variety of tumor predictive and prognostic biomarkers, protein disulphide isomerase (PDI) recently emerged as a potential family of enzymes to inhibit to disrupt cell proteostasis, thus triggering a non-apoptotic cell death pathway, called paraptosis, that could represent a getaway to overcome cancer-related apoptosis resistance phenomena.[2] Among different classes of PDI inhibitors, copper complexes showed encouraging perspectives. Copper-based complexes have been originally investigated as potential anticancer agents on the assumption that endogenous metals may be less toxic than non-essential metals for normal cells. Actually, copper (Cu) is an essential cofactor in the redox chemistry of proteins performing key biological functions involved in cellular growth and development.[1,2] However, current knowledge shows that Cu homeostasis is dysregulated in cancer cells, which are prone to enrich their intracellular Cu content to fuel tumor progression. On the contrary, normal cells strictly regulate intracellular Cu concentration by homeostatic mechanisms. Due to this altered Cu metabolism and trafficking, cancer cells react differently than normal ones to Cu overload and this unique homeostatic feature can be therefore exploited for selectively targeting cancer cells.[3] In this work, we present a series of newly developed homoleptic copper(I) phosphino complexes tested on a wide panel of human cancer cell lines for their anticancer potential both in bidimensional and spheroid models. Mechanistic studies were also performed to assess the ability of these complexes to hamper PDI activity end to better elucidate the cell signaling and cell death induction pathways. As a step forward towards preclinical evaluation, their anticancer activity was validate in *in vivo* murine models. In light the promising result obtained, the newly developed copper(I) phosphino complexes were radiolabeled using ^{64}Cu in order to investigate their theragnostic potential. To this aim, preliminary PET/CT imaging and biodistribution studies in human xenografts mice models have been performed.

References:

[1] D. Denoyer, S. Masaldan, S. La Fontaine, M.A. Cater, Metallomics, 2015, 7, 1459–1476.

[2] M. Carcelli, M. Tegoni, J. Bartoli, C. Marzano, G. Pelosi, M. Salvalaio, D. Rogolino, V. Gandin, Eur. J. Med. Chem, 2020, 194, 112266

[3] M. De Franco, M. Porchia, F. Tisato, C. Marzano, V. Gandin, EIBC, 2021, 1-21.

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FAR-OR-008

Novel Dual HDAC1,2/LSD1 Inhibitors as Epi-pharmacological Approach to Combat Cancer

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Nowadays a simultaneous inhibition of two or more targets involved in cancer can improve therapeutic efficacy over a single-target inhibitor [1]. In collaboration with the Cole's and Mattevi's team, we previously developed Corin, an hybrid molecule that targets the CoREST complex resulting in the inhibition of LSD1 and HDAC1 at sub-micromolar doses [2]. The aim of our present research is to develop, synthesize and validate anticancer activity of new GSK2879552-based hybrids, which could specifically inhibit the specific isoforms HDAC1 and/or HDAC2, in addition to LSD1. Particularly, the carboxylic acid of GSK-2879552, an LSD1 inhibitor undergoing clinical trials (NCT02929498, NCT02034123, NCT02177812), was modified by incorporating the *ortho*-aminoanilide portion of Entinostat, an inhibitor of HDAC 1-3. The resulting compound **1a** was primarily obtained. Later, the amino group in the *para* position of the *o*-aminoanilide portion was replaced with different substituents including a fluorine atom (**1b**) to study hydrogen bonding effects, a thiophene (**1c**) known to confer selectivity to HDAC1/2 [3], and various aromatic monocyclic groups (**1d-m**) isomers/bioisosters of the 2-thienyl group. Our preliminary results proved that the novel hybrid compounds **1c**, **1h** and **1m** displayed nanomolar inhibition against HDAC1 and HDAC2 and sub-micromolar inhibition against LSD1. These three most promising hybrid compounds were tested in typologically different cancer cell lines (SKMEL28, U937, HL60, A549, HCT-116 and MCF7) and the dual inhibitor **1c** displayed a higher cell vitality reduction than the reference inhibitor Corin, with the A549, HCT-116 and MCF7 cell lines being the most responsive ones. During the next months we will perform further in-depth biochemical and biological assays by evaluating the HDAC- and LSD1-target-engagements, cell death mechanism, targets-related genes modulation, migration-invasiveness impairment in one of the most sensitive cell lines aforementioned.

References:

[1] Stazi, G.; Fioravanti, R.; Mai, A.; Mattevi, A.; Valente, S. Curr Opin Chem Biol 2019, 50, 89-100.
[2] Kalin, J. H.; Wu, M.; Gomez, A. V.; Song, Y.; Das, J.; Hayward, D.; Adejola, N.; Wu, M.; Panova, I.; Chung, H. J.; et al. Nat Commun 2018, 9 (1), 53.
[3] Methot, J. L.; Chakravarty, P. K.; Chenard, M.; Close, J.; Cruz, J. C.; Dahlberg, W. K.; Fleming, J.; Hamblett, C. L.; Hamill, J. E.; Harrington, P.; et al. Bioorg Med Chem Lett 2008, 18 (3), 973-978.

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FAR-OR-009

A journey through targeting BRCA2-RAD51 protein-protein interaction to establish synthetic lethality as paradigm for anticancer drug discovery

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Nowadays, synthetic lethality (SL) is a known effective paradigm in anticancer therapy.[1] However, SL has been mostly limited to the combination of pre-existing mutations with drugs against their synthetic lethal partners.[1] In this context, we envisioned SL as paradigm to design synergistic combinations of drugs, targeting pairs of synthetic lethal targets. We selected the synthetic lethal pair PARP/BRCA2, taking advantage of the approved PARPis. We picked BRCA2-RAD51 protein-protein interaction (PPI) as target for our medicinal chemistry campaign, reasoning that its inhibition would mimic BRCAness and trigger SL with PARPi.[2] To design small molecule PPI inhibitors, we explored three distinct approaches. First, we used BRC4-RAD51 crystal structure to perform virtual screening against two distinct PPI hot spots, zone I and II. Pyrazoline hit **1** from zone II led to **2** (Fig. 1), which induced SL with PARPi and gave us the first proof-of-concept of a "fully-small-molecule induced SL".[2] In parallel, we used protein-templated dynamic combinatorial chemistry (ptDCC) on RAD51 and identified ten *N*-acylhydrazones, as micromolar PPI inhibitors. In particular, **3** was found to bind at BRC4 binding site by ^{19}F-NMR (Fig. 1).[3] Finally, we used a ^{19}F-NMR fragment screening and identified **4** and subsequently developed the pyrazole pyrimidinone **5**, which induced SL in several pancreatic cancer models (Fig. 1).[4] Despite issues related to PPI inhibition by small molecules, this work shows the variety of effective approaches that can be used to reach that goal, opening to future development of PPI inhibitors. Moreover, it consolidates SL as paradigm for anticancer drug combinations, promoting future medicinal chemistry efforts against synthetic lethal targets, especially if involved in the DNA damage response.

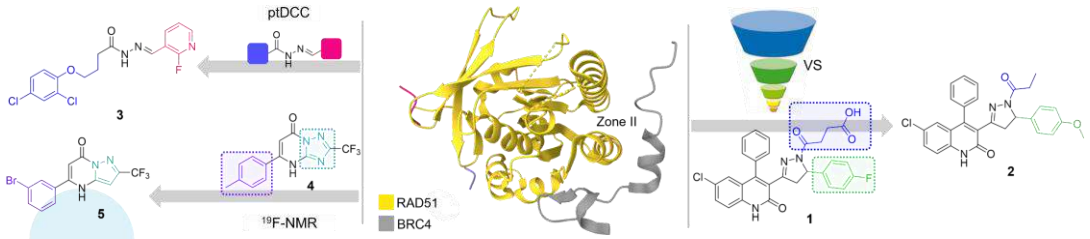

Figure 1: Approaches employed for the development of BRCA2-RAD51 PPI inhibitors (PDB: 1N0W).

References:

[1] SH. Myers, A. M. Ortega et al. J Med Chem 2020, 63, 14151– 14183.
[2] G. Bagnolini, D. Milano, et al. J Med Chem 2020, 63 (5), 2588– 2619.
[3] G. Bagnolini, B. Balboni, et al. ACS Med Chem Lett 2022, 13(8),1262– 1269.
[4] SH Myers, L. Poppi, et al. Eur J Med Chem 2024, 265, 116114.

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FAR-OR-010

Reshaping therapeutic options for triple negative breast cancer: selective histone deacetylase 6 inhibitors on the stage with merit

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Triple negative breast cancer (TNBC) accounts for about 20% of all breast cancer (BC) subtypes, lacking the expression of progesterone, estrogen and HER2 receptors, thus rendering ineffective hormone therapy. For this reason, TNBC represents the most aggressive BC subtype, due to its invasiveness and challenging therapy, with about one year life expectancy. TNBC cells show uncontrolled matrix remodeling and the consequent epithelial-mesenchymal transition (EMT), related to uncontrolled cell invasiveness, proliferation, and differentiation. Recent studies pointed out the role of epigenetic players in TNBC insurgence and progression, whit particular emphasis on the effectiveness of targeting histone deacetylases (HDACs) against TNBC tumorogenesis[1,2]. We recently discovered a novel class of spirocyclic compounds acting as potent and selective HDAC6 inhibitors[3-5]. The behavior of all synthetized compounds was assessed in MDA-MB-231 TNBC cell line, showing efficacy against TNBC. In particular, compound 1 ($IC_{50\ HDAC6}$ = 7.7 nM, $IC_{50\ HDAC1}$ = 2188 nM; Selectivity index $_{HDAC6/HDAC1}$= 275) stood out as the most promising compound for its highly efficient anti-proliferative effect in MTT assay, related to the activation of apoptotic process. Cytofluorometric assay also confirmed no effects on necrosis pathways, further validated by western blot analysis, with the detection of cleaved caspase-3, a reliable marker for apoptotic process. Also, increased levels of both Beclin-1 (BECN1) and Bcl-2 interacting protein 3 (BNIP1) were observed after 24 hours of treatment with compound 1, thus also suggesting the involvement of autophagy process in cell death induction. The in vivo validation of the best performing compound 1 is currently ongoing in order to confirm the promising results obtained in the in vitro assays. Taken together, our results underscore the key role of epigenetic modifications driven by HDAC6 enzyme in TNBC tumorogenesis and cancer progression, providing a solid groundwork to reshape canonical chemotherapeutic approaches.

References:

[1] A.Plotkin, C.H.Volmar, C. Wahlestedt, N. Ayad, D. El-Ashry, Breast Cancer Res Treat , 2014, 147, 249–263.
[2] Y.D Kim, S.M. Park, H.C. Ha, A.R. Lee, H. Won, H. Cha, S. Cho, J.M. Cho, H, *J.* Cancer, 2020, 11 (14), 4059-4072.
[3] C.M. Dowling, K.E.R. Hollinshead, A. Di Grande, J. Pritchard, H. Zhang, E.T. Dillon, K. Haley, E. Papadopoulos, A.K. Mehta, R. Bleach, A.U. Lindner, B. Mooney, H. Düssmann, D. O'Connor, J.H.M. Prehn, K. Wynne, M. Hemann, J.E. Bradner, A.C. Kimmelman, J.L. Guerriero, G. Cagney, K.K. Wong, A.G. Letai, T.N. Chonghaile, Science Advances, 2021, 7, 3.
[4] D. Ruzic, B. Ellinger, N. Djokovic, J.F. Santibanez, S. Gul, M. Beljkas, A. Djuric, A. Ganesan, A. Pavic, T. Srdic-Rajic, M. Petkovic, K. Nikolic, Pharmaceutics, 2020, 14, 2600.
[5] T. Oba, M. Ono, H. Matoba, T. Uehara, Y. Hasegawa, K.I. Ito, Breast Cancer Researc and Treatment, 2021, 186(1), 37-51.

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FAR-OR-011

Identification of small molecules affecting the interaction between human hemoglobin and *Staphylococcus aureus* IsdB hemophore

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Human hemoglobin (Hb) is the preferred iron source of Staphylococcus aureus. This pathogenic bacterium exploits a sophisticated protein machinery called Iron-regulated surface determinant (Isd) system to bind Hb, extract and internalize heme, and finally degrade it to complete iron acquisition. IsdB, the surface exposed Hb receptor, is a proven virulence factor of S. aureus and the inhibition of its interaction with Hb can be pursued as a strategy to develop new classes of antimicrobials.

To identify small molecules able to disrupt IsdB:Hb protein-protein interactions (PPIs), we carried out a structure-based virtual screening campaign and developed an ad-hoc immunoassay to screen the retrieved set of commercially available compounds. Saturation-transfer difference (STD) NMR was applied to verify specific interactions of a sub-set of molecules, chosen based on their efficacy in reducing the amount of Hb bound to IsdB. Among molecules for which direct binding was verified, the best hit was submitted to ITC analysis to measure the binding affinity to Hb, which was found to be in the low micromolar range.

The results demonstrate the viability of the proposed in silico/in vitro experimental pipeline to discover and test IsdB:Hb PPI inhibitors. The identified lead compound will be the starting point for future SAR and molecule optimization campaigns.

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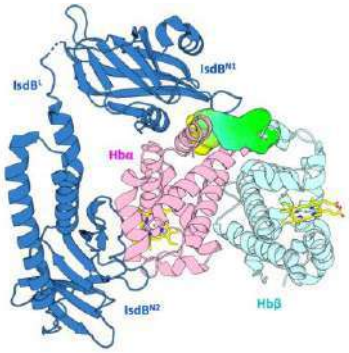

Figure 1: Model of IsdB:Hb complex.

References:

[1] E.P. Skaar, M. Humayun, T. Bae, K.L. DeBord, O. Schneewind. Science 2004, 305, 1626 – 1628.

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FAR-OR-012

Exploiting new medicinal chemistry trends to fight the antimicrobial resistance big challenge

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Antimicrobial resistance (AMR) is a serious global problem listed by the World Health Organization (WHO) among the top 10 health threats. The fact that anti-infective R&D pipeline is risky, time-consuming, and expensive undertaking, is hampering the discovery of new chemical entities that ultimately reach patients.[1] With the aim to overcome the current innovation gap, we are developing two different projects that address this problem by exploiting two innovative concepts.

First, the Energy-Coupling Factor (ECF) transporters are a hitherto underexplored target involved in the simultaneous uptake of several micronutrients in bacteria. Their central role in the metabolism of bacteria and absence in humans make the ECF transporters a novel invaluable antibacterial target. A Structure-Based-Virtual Screening performed on *Lactobacillus delbrueckii* ECF-FolT2 led to the identification of the first ECF small-molecule inhibitor.[2] Then, (1) we performed extensive structure-activity relationship to improve potency; (2) we run unbiased coarse-grained molecular dynamics simulations to profile the binding mode and, (3) we demonstrated that the expression of the genes encoding ECF are essential for bacterial growth in *Streptococcus pneumoniae*.[3]

Second, we leveraged the proteolysis targeting chimeras (PROTAC) strategy to develop a new class of small molecule antivirals that induce proteasomal degradation of viral proteins. We applied the innovative PROTAC approach to target the NS2B-NS3 protease which is essential for the replication of West-Nile, Dengue and Zika virus that belong to the Flavivirus family. PROTACs are heterobifunctional degraders with the ability to activate the ubiquitination and, subsequent proteasomal degradation, *via* a molecule that simultaneous bind to the protein of interest and an E3 ligase.[4] We successfully manage to set out the multi-step synthetic pathway to get access to final PROTAC molecules, to establish the conditions for co-crystallization and, to assess the cellular degradation.

References:

[1] Antimicrobial Resistance Collaborators, Lancet 2022, 399, 629–55.
[2] E. Diamanti, P. C. T. Souza, I. Setyawati, S. Bousis, L. Monjas, L. Swier, A. Shams, A. Tsarenko, W. K. Stanek, M. Jäger, S. J. Marrink, D. J. Slotboom, A. K. H. Hirsch, Communications Biology, 2023, 1-8.
[3] E. Diamanti, A.J.H. Cremers, L. Yue, I. Exapicheidou, P. Gibson, R. Becker, I. Setyawati, A. Shams, J. Haupenthal, D.J. Slotboom, M. M. Hamed, J.-W. Veening, A.K.H. Hirsch., Journal of Medicinal Chemistry, submitted 2024.
[4] A. Pasieka, E. Diamanti, E. Uliassi, M. L. Bolognesi, ChemMedChem, 2023, 18, e202300422.

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FAR-OR-013

AlkylGuanidino Ureas as Promising Weapons to Fight Antibacterial Resistance

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Antimicrobial resistance is seriously threatening the Public Health system and affecting the efficacy of the current antibacterial drugs armamentarium, highlighting the need for new treatment options. We recently reported AlkylGuanidino Ureas (AGUs) as promising membrane-active broad-spectrum antibacterial agents (minimal inhibitory concentrations (MICs) ranging from 0.12 to 16 µg/mL), with a bactericidal behavior.[1-3] Herein, a new series of AGUs were designed and synthesized through a straightforward orthogonal protecting groups strategy and tested on a panel of representative bacterial strains, allowing the establishment of robust structure-activity relationships (SARs). The membrane-based mechanism of action was then investigated through molecular dynamics (MD) on simulated membranes via a previously validated *in silico* protocol.[3] In the end, the whole library of compounds (more than 70) was tested in combination with subinhibitory concentrations of the last-resort antibiotic colistin, assessing synergistic or additive effects also on colistin-resistant isolates. Moreover, all the AGUs were analyzed via cheminformatics and machine learning to gain a deeper understanding of the key features required for bioactivity.

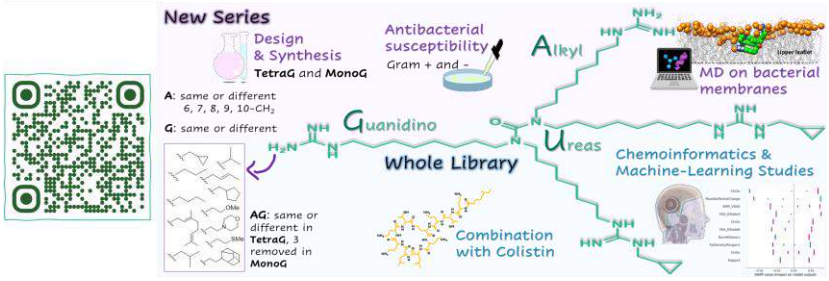

Figure 1: Overview of the work.

References:

[1] C. Zamperini, G. Maccari, D. Deodato, C. Pasero, I. D'Agostino, F. Orofino, F. De Luca, E. Dreassi, J. D. Docquier, M. Botta, Sci. Rep. 2017, 7, 8251.
[2] C. Pasero, I. D'Agostino, F. De Luca, C. Zamperini, D. Deodato, G. I. Truglio, F. Sannio, R. Del Prete, T. Ferraro, D. Visaggio, A. Mancini, M. B. Guglielmi, P. Visca, J. D. Docquier, M. Botta, J. Med. Chem. 2018, 61, 9162–9176.
[3] I. D'Agostino, C. Ardino, G. Poli, F. Sannio, M. Lucidi, F. Poggialini, D. Visaggio, E. Rango, S. Filippi, E. Petricci, P. Visca, L. Botta, J.D. Docquier, E. Dreassi, Eur. J. Med. Chem. 2022, 231, 114158.

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FAR-OR-014

Discovery of α9α10 nicotinic acetylcholine receptor ligands: a SAR study on MG624

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Noncanonical α9α10 nicotinic receptors expressed in the cells of immune system can be targeted to reduce pain related to inflammation.[1] The 2-triethylammonium ethyl ether of 4-stilbenol (MG624) is an unselective antagonist of the α7-nAChR and α9α10-nAChR expressed in *X. laevis* oocytes.[2] Aiming to increase the functional selectivity toward α9α10- over the α7-nAChR subtype, the synthesis of more than sixty MG624 analogues and their pharmacological characterization was previously performed. The SAR study allowed to define that selective inhibition of ACh-evoked currents at α9α10-nAChR could be achieved by modifying different moieties of the lead compound MG624 (*i.e.*, ammonium head, linker, and stilbene, **Figure 1**).[2] Compound **1** was identified as the most interesting of the series, being a potent and selective antagonist of α9α10-nAChR (5.74 μM IC_{50}), and completely devoid of activity at the α7-nAChR subtype at 100 μM.[2]

To deeply investigate the activity of **1**, new electrophysiological experiments using *X. laevis* oocytes expressing *human* α9α10-nAChRs showed both agonist (385 nM EC_{50}) and antagonist activity (60.2 nM IC_{50}). Due to the interesting activity at the α9α10-nAChRs and selectivity *versus* α7-nAChR possessed by compound **1**, a new series of analogues modified at the ammonium head, and at the linker were designed, synthesized, and pharmacologically characterized to investigate the impact on α9α10- *versus* α7-nAChR activities. Furthermore, compound **1** and some analogues are currently being investigated as potential immunoregulatory agents *in vitro*. Preliminary results showed **1** as an effective modulator of the ATP-mediated release of the pro-inflammatory cytokine interleukin-1β by LPS-primed *human* monocytic THP-1 cells.

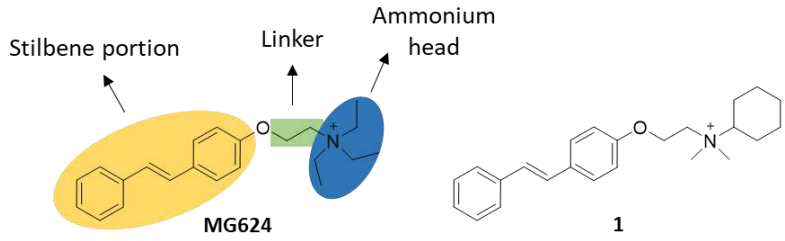

Figure 1: Representation of SAR study on MG624 and structure of compound **1**

References:

[1] Richter, K.; Grau, V. Pharmacological Research 2023, 191, 106727
[2] Bavo, F.; Pallavicini, M.; Giraudo, A.; Gotti, C.; Bolchi, C. *et al.* J. Med. Chem. 2022, 65, 14, 10079–10097

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FAR-OR-015

HDAC enzymes to treat retinitis pigmentosa: identification of a potent inhibitor preferentially targeting HDAC6 with *in vitro* and *in vivo* efficacy

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Retinitis Pigmentosa (RP) is a genetic disorder characterized by gradual rod-cone degeneration and vision loss, without effective pharmacological treatments. Experimental approaches aim at delaying disease progression plus supporting the survival of cones, which are crucial for human vision[1].

Histone deacetylases (HDACs) mediate the activation of epigenetic and non-epigenetic pathways[2] that modulate cone degeneration in *cpfl1* and *rd1* mice, in which HDAC inhibitors promote cone survival and vision rescue. A new family of tetrahydro-γ-carboline-based HDAC inhibitors (**5a-p**), was developed and characterized by high inhibition potency, selectivity, and balanced physicochemical properties for *in vivo* studies. The compound **5d** (IC_{50} HDAC6 = 6.32 nM, Fig. 1) showed specific inhibitory activity on HDAC6 on ARPE-19 cells and was able to limit cell death of 661W retinal cells stressed with hydrogen peroxide (H_2O_2), by inhibiting HDAC6. **5d** also promoted a significant rescue of vision in the *atp6v0e1*$^{-/-}$ zebrafish model of photoreceptor dysfunction. When used in the *rd10* mouse model of RP, **5d** supported morphological and functional preservation of cone cells and maintenance of the retinal pigment epithelium array. **5d** is a new pharmacological tool useful to treat Retinitis Pigmentosa.

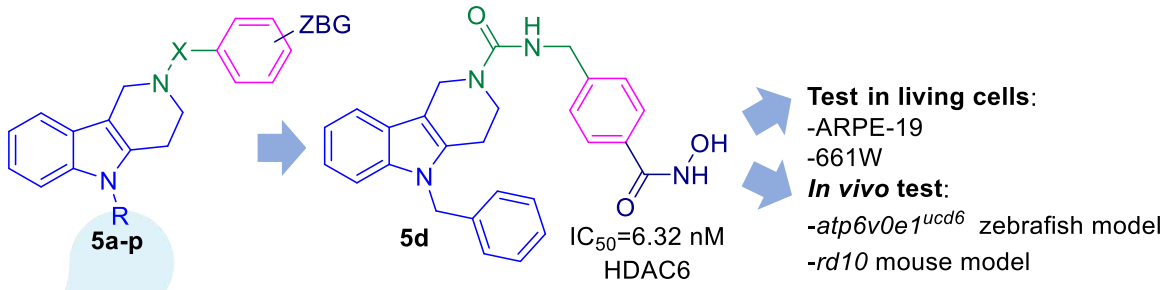

Figure 1: New HDAC6 inhibitors **5a-p** and the most potent compound **5d.**

References:

[1] G. Carullo, *et al.*, ACS Chemical Neuroscience 2020, 11, 2173 – 2191.
[2] G. Campiani, *et al.*, J. Med. Chem. 2021, 64, 9960 – 9988.

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FAR-OR-016

In silico assisted design of pyrrole-based derivatives as CB2 agonists: a comprehensive analysis of CB2R role in memory and cognition

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Cannabinoid receptors, CB1 and CB2, are highly expressed in the central nervous system (CNS), where they mediate the biochemical activities of endogenous cannabinoids.[1] Their role ranges from physiological processes such as appetite regulation[2] and neuroprotection,[3] to pathological processes such as cancer,[4] pain, and neuroinflammation.[5] Furthermore, CB2 receptor is upregulated under neuroinflammatory, oxidative and ischemic conditions and several agonists are reported to exert neuroprotective activity in models of neurodegenerative conditions.[6] In the present work, we tested a series of molecules from an in-house library, upon filtration by virtual screening protocol, as CB2 agonists. The compounds were initially tested by chemical-physical assays for their ability to bind both CB1 and CB2 receptors. In this way a hit compound was identified, with outmost selectivity over CB2 isoform. This compound was then subjected to a hit-to-lead rational development, designing a new library of analogues. The new compounds were screened for their ability to activate CB2 receptors using functional assays. Compound **70** was selected as the most potent derivative, also showing suitable pharmacokinetic properties, and was then further characterized for its in vivo impact on short-term memory, using a scopolamine-induced amnesia protocol. Moreover, compound **70** was challenged for its capability in modulating neuromodulators levels, using MALDI-imaging technique. Collectively, compound **70** displayed high in vivo effectiveness, suggesting pyrrole scaffold as starting point for further development of new small molecules for the treatment of neuroinflammatory diseases.

References:

[1] Zou, S.; Kumar, U. Int. J. Mol. Sci. **2018**, 19, 833.
[2] Kirkham, T.C. Behav Pharmacol. **2005**, 16, 297-313.
[3] Maguire, G.; et al. Neuronal Signal **2022**; 6, NS20210038.
[4] Salamat, J.M.; et al. ACS Omega **2022**, 7, 9995–10000.
[5] Vuic, B.; et al. Biomedicines **2022**, 10, 3000.
[6] Yu, H.; et al. Cells. **2021**, 10, 3548.

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FAR-OR-017

Targeting the Sigma-1 Receptor and the TSPO protein with bivalent ligands: exploring a new way against neurodegeneration.

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Neurodegeneration is a multifaceted condition underpinning several diseases that constitute major therapeutic challenges nowadays. In this context, multi-target directed ligands (MTDLs) are considered a promising approach to achieve enhanced therapeutic effects. They can also validate new, unexplored protein-protein crosstalk and interactions.[1] Herein we report on the development of bivalent ligands that target Sigma-1 Receptor (S1R) and the 18kDa Translocator Protein (TSPO). S1R is a ligand-operated molecular chaperone highly expressed in the central nervous system (CNS) and involved in neuroprotection.[2] TSPO is a transmembrane protein that takes part to different pathways affecting cells survival. It is clinically used for neuroinflammation imaging, but its therapeutic potential is still poorly explored.[3] Considering these premises and the convergence of S1R and TSPO pathways on the modulation of mitochondrial function, targeting both receptors could enhance therapeutic effects. Accordingly, to verify that this could be an effective strategy to manage neurological disorders, we designed and synthetized dual S1R-TSPO ligands, based on our in-house developed S1R agonist, RC-33, and the clinically validated TSPO ligand PK-11195. Their interaction with the targets and pharmacodynamic profile were assessed through binding and functional assays. Their stability is currently under evaluation as well. The results obtained demonstrated the usefulness of such compounds as pharmacological tools, and provide a starting point for the development of drug-like compounds.

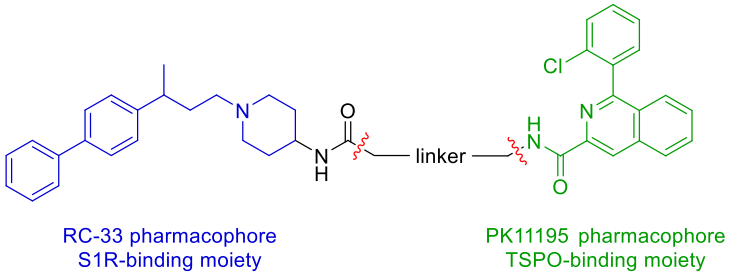

Figure 1: general structure of bivalent S1R-TSPO ligands.

References:

[1] A. D. Gitler, P. Dhillon, J. Shorter, Disease Models & Mechanisms 2017, 10, 499 – 502.
[2] D. A. Ryskamp, S. Korban, V. Zhemkov, N. Kraskovskaya, I. Bezprozvanny, Front. Neurosci. 2019, 13, 1 – 20.
[3] T. R. Guilarte, Pharmacol. Ther. 2019, 194, 44–58.

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FAR-OR-018

Discovery of novel derivatives as high selective sigma-1 receptor ligands

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Literature studies and clinical trials report that sigma-1 receptor (S1R) ligands exhibit significant antiallodynic effects in neuropathic pain animal's models and demonstrate fewer side effects compared to conventional therapy.[1] Therefore, the aim of the present study was the development of new potent and selective S1R antagonist for the treatment of neuropathic pain. For this purpose, several piperazine and *N*-methylpiperidin-4-amine derivatives have been designed and synthesized. Radioligand binding assays allowed to assess affinity towards S1R and sigma-2 receptor (S2R).[2] Among the tested compounds, AC1 emerged as particularly noteworthy. It displayed high binding affinity to S1R and selectivity over S2R (K_iS1R = 0.54 nM; K_iS2R > 10,000 nM) and a moderate inhibition of K^+hERG channel (IC_{50} = 1.6 μM).

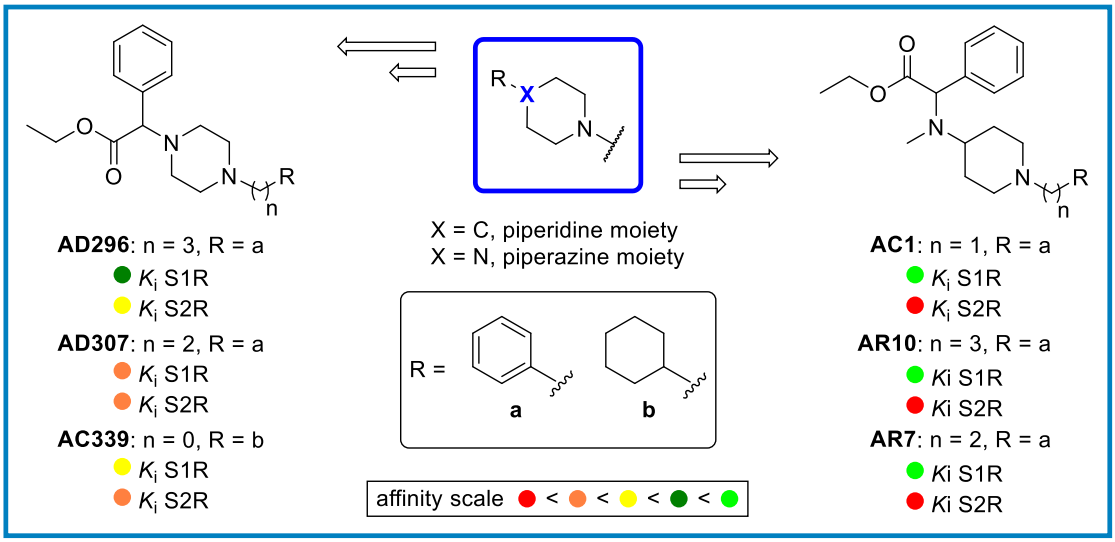

Figure 1. Structure and affinities of novel piperazine and piperidine derivatives.

Molecular modeling studies, functional profile, toxicity tests and the *in vivo* analgesic effects of the best developed molecules will be further evaluated.

References:

[1] E. Balzani, A. Fanelli, V. Malafoglia, M. Tenti, S. Ilari, A. Corraro, C. Muscoli, W. Raffaeli, Biomedicines 2021, 9(9), 1239.

[2] M. Dichiara, F. A. Ambrosio, S. M. Lee, M. C. Ruiz-Cantero, J. Lombino, A. Coricello, G. Costa, D. Shah, G. Costanzo, L. Pasquinucci. K. No Son, G. Cosentino, R. González-Cano, A. Marrazzo, V. K. Aakalu, E. J Cobos, S. Alcaro, E. Amata, Journal of Medicinal Chemistry 2023, 66(16), 11447-11463.

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Multitarget Neuroprotective Potential of Novel BChE-Selective Inhibitors 6-Alkyl-Bridged 4-Arylalkylpiperazin-1-yl Azepino[4,3-*b*]indol-1(2*H*)-ones

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Given the proposed function of butyrylcholinesterase (BChE) in controlling acetylcholine levels and its role in the advanced stages of Alzheimer's disease (AD)[1], the use of selective inhibitors (BChEIs) is being considered as alternative to acetylcholinesterase inhibitors (AChEIs).

In this study, we identified a series of N*6*-substituted 3,4,5,6-tetrahydroazepino[4,3-*b*]indol-1(2*H*)-one (THAI). These compounds demonstrated their efficacy as nanomolar potent inhibitors of BChE, with additional neuroprotective effects against NMDA-induced excitotoxicity. The potency of enzyme inhibition and the selectivity between BChE and acetylcholinesterase (AChE) were modulated by the incorporation of alkyl chains bearing differently decorated piperazine fragments.[2]

Molecular docking simulations provided a critical evaluation of the observed differences in the BChE inhibition potency (Fig. 1). The binding kinetics of these compounds, studied through surface plasmon resonance (SPR), revealed differences in their residence times on BChE. The most promising compounds exhibited in vitro efficacy against other mechanisms known to instigate neurodegeneration underlying AD and other central nervous system disorders. These mechanisms include the inhibition of self-induced aggregation of the neurotoxic amyloid-β (Aβ) peptide and the counteraction of glutamate excitotoxicity due to over-excitation of NMDA receptors.

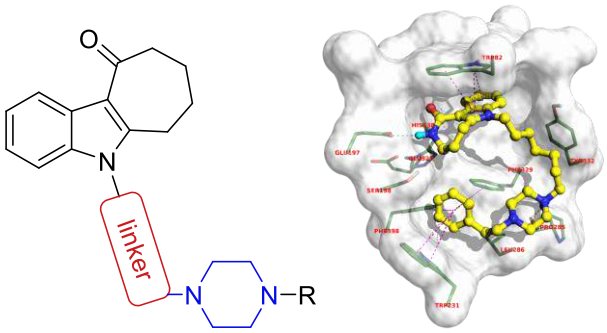

Figure 1. Schematic representation of N*6*-alkylpiperazine-substituted THAI (left) and docking pose of one compound of the series into the BChE binding site (right).

References:

[1] N.H. Greig, T. Utsuki, Q. Yu, X. Zhu, H.W. Holloway, T. Perry, B. Lee, D.K. Ingram, D.K. Lahiri, Curr. Med. Res. Opin., 2001, 17, 159–165.

[2] F. Samarelli, R. Purgatorio, G. Lopopolo, C. Deruvo, M. Catto, M. Andresini, A. Carrieri, O. Nicolotti, A. De Palma, D.V. Miniero, M. de Candia, C.D. Altomare, Eur. J. Med. Chem., 2024, accepted (10.1016/j.ejmech.2024.116353).

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FAR-OR-020

Novel Nicotinamide Phosphoribosyltransferase (NAPRT) Modulators as Potential Neuroprotective or Antitumor Agents

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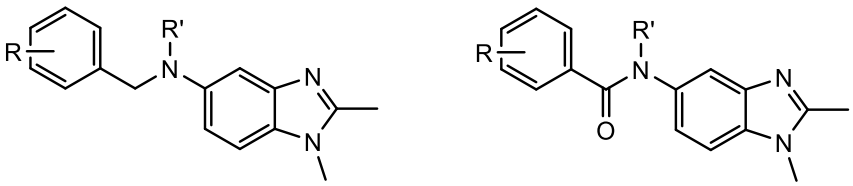
The co-enzyme nicotinamide adenine dinucleotide (NAD) plays a pivotal role in the metabolism of human cells. Since it is continuously used up by cellular processes and replenished by its biosynthetic pathways, its concentration is vital to maintain the cellular homeostasis[1]. Indeed, it has been shown that a lack of NAD can lead to neurodegenerative disorders, while an excessive production of the co-enzyme can support tumor growth. The enzymes nicotinamide phosphoribosyltransferase (NAMPT) and nicotinate phosphoribosyltransferase (NAPRT), which regulate NAD biosynthesis from nicotinamide and nicotinic acid, respectively, are considered promising targets to modulate intracellular NAD levels[2]. While several NAMPT inhibitors and activators have been identified over the years, the search for NAPRT modulators is still in its infancy[3]. By screening more than 200 lead-like molecules available in our labs and characterized by different chemical scaffolds, we have identified the properly substituted 1,2-dimethylbenzimidazole nucleus as a novel chemotype for the preparation of ligands able to modulate NAPRT activity (Figure 1).



R = $CH_2NHCOCH_3$, CH_2NH_2, $NHCOCH_3$, NH_2
R' = H, CH_3

Figure 1: 1,2-benzimidazole scaffold with a substituted amine (left) or amide (right) on 5 position.

This study identified new NAPRT inhibitors and activators, which might represent useful pharmacological tools to explore the therapeutic potential of NAPRT modulation.

References:

[1] S. Lautrup, D. A. Sinclair, Cell Press 2019, 30, 630 – 655.
[2] A. S. Alexandris, J. Ryu, Neurobiology of Disease 2022, 171, 1 – 15.
[3] F. Piacente, I. Caffa, Cancer Research 2017, 77, 3857-3869.

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FAR-OR-021

Development of Synthetic Chemical Methods for Advanced Molecular Functionalization in Medicinal Chemistry

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The present lecture will be focused on the development of synthetic strategies to achieve *late-stage functionalization* of complex structures, such as drugs and natural compounds, by exploiting convergent multicomponent reactions and light-triggered mechanistic pathways.[1-3] Due to mild reaction conditions, both multicomponent and photocatalytic methods are considered as a valuable tool to achieve exquisite chemo-selectivities. Such synthetic methods, by enabling the introduction of either specific functional groups or structural moieties directly on *hit*/*lead* compounds, have been receiving increasing attention both from academia and pharmaceutical companies. Representative applications will span from the synthesis of deuterium-labelled compounds to the identification of promising lead compounds targeting brain cancers.[4-6]

References:

[1] R. Cannalire, S. Pelliccia, L. Sancineto, E. Novellino, G. C. Tron, M. Giustiniano. *Chem. Soc. Rev.* **2021**, *50*, 766-897.
[2] V. Nenajdenko, *Isocyanide Chemistry: Applications in Synthesis and Materials Science*; Wiley-VCH, Weinheim, Germany, **2012**.
[3] C. Stephenson, T. Yoon, D. W. C. MacMillan, *Visible Light Photocatalysis in Organic Chemistry*, Wiley-VCH, Germany, **2018**.
[4] C. Russo, F. Brunelli, G. C. Tron, M. Giustiniano, *Chem. Eur. J.* **2023**, *29*, e202203150.
[5] C. Russo, J. Amato, G. C. Tron, M. Giustiniano, *J. Org. Chem.* **2021**, *86*, 18117.
[6] C. Russo, G. Graziani, R. Cannalire, G. C. Tron, M. Giustiniano, *Green Chem.* **2022**, *24*, 3993.
[7] C. Russo, G. Donati, F. Giustiniano, J. Amato, L. Marinelli, R. J. Whitby, M. Giustiniano, *Chem. Eur. J.* **2023**, e202301852.

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FAR-OR-022

Chemoenzymatic approach towards the synthesis of the antitumor and antileishmanial marine metabolite (+)-Harzialactone A via the stereoselective, biocatalyzed reduction of a prochiral ketone

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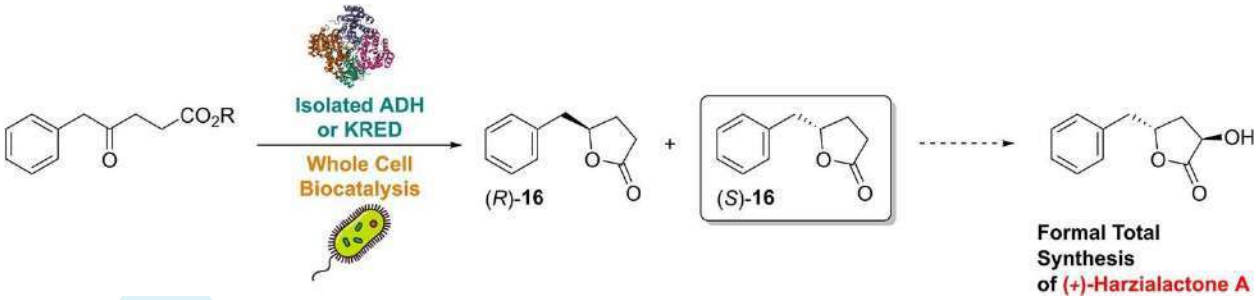
In the quest for novel drug candidates, marine ecosystems have emerged as a valuable source of biologically active compounds. Among the diverse array of marine products and metabolites, (+)-Harzialactone A has garnered substantial attention due to its remarkable antitumor and antileishmanial properties[1,2]. In this work, a chemoenzymatic strategy was applied for the synthesis of (+)-Harzialactone A. The core of this synthetic pathway revolves around the precise, stereoselective reduction of the prochiral ketone of 4-oxo-5-phenylpentanoic acid and its corresponding esters. Our investigation encompassed an extensive exploration of various promiscuous oxidoreductases, including wild-type and engineered variants, together with a diverse set of microorganism strains. In addition, to optimize the bioreduction process, different co-solvent and co-substrate were investigated as well. Tailoring synthesis parameters allowed the identification of ADH442 and the conjunction of *T. molischiana* together with a choline hydrochloride and glucose NADES (non-aqueous deep eutectic solvent) as the most promising entries. These biocatalysts enable the synthesis of the (*S*)-enantiomer of (+)-Harzialactone A achieving enantiomeric excess (*ee*) of the biotransformation product ranging from 97% to over 99%, coupled with robust conversion rates ranging from 88% to 80%.
In essence, this successful endeavour introduces an innovative chemoenzymatic approach that holds great promise for the efficient production of the valuable marine natural product (+)-Harzialactone A[3].



References

[1] G. H. Braun, H. P. Ramos, A. C. B. Candido, R. C. N. Pedroso, K. A. Siqueira, M. A. Soares, G. M. Dias, L. G. Malgalhães, S. R. Ambrósio, A. H. Januário, R. C. L. R. Pietro, Nat. Prod. Res., 2019, 35, 1644-1647.
[2] V.U. Pawar, S. Ghosh, B.A. Chopade, V.S. Shinde, Bioorg. Med. Chem. Lett., 2010, 20, 7243–7245.
[3] A. Artasensi, I. Bassanini, E. E. Ferrandi, L. Feni, G. Vistoli, L. Fumagalli, R. Gandolfi, Bioorg. Chem., 2023, 138, 106675.

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FAR-OR-023

Chemo-enzymatic flow synthesis of nature-inspired phenolic carbonates and carbamates as antimicrobial and antiradical agents

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Food-derived phenolic compounds are well known for their antioxidant and antimicrobial effects[1]. Because of their hydrophilic nature and their intrinsic stability and bioavailability issues, their use as active ingredients is limited. Lipophilization of phenolic derivatives is a valid strategy to obtain amphiphilic compounds that can be used as multifunctional additives in the pharmaceutical, nutraceutical, and cosmetic fields[2]. In particular, the synthesis of carbonates and carbamates is an attractive strategy to increase the lipophilicity of phenolic derivatives. However, their classic synthesis requires the employment of toxic acylating agents, unsafe solvents and experimental conditions.

In this context, we developed a reproducible, green, and scalable chemo-enzymatic flow process for the obtainment of a series of lipophilic carbonate and carbamate derivatives (Scheme 1) of natural tyrosol (Ty) and hydroxytyrosol (HTy)[3,4]. Immobilized CaLB was used in a packed bed reactor for the selective carbonation of the primary alcohol of Ty and HTy in a non-conventional green solvent as *tert*-amyl alcohol. Then, two selected carbonates were reacted in flow with the appropriate amine to obtain the desired carbamates. A telescoped two-step process was set up allowing to reduce the manual handling, time, and costs of the process.

All compounds were tested as antimicrobials and radical scavengers and they showed similar or even better activity compared to the parent compound, with a significant increase in their lipophilicity.

Scheme 1: Schematic representation of the chemo-enzymatic continuous synthesis.

References:

[1] N. Kumar, N. Goel, Biotechnology Reports, 2019, 24, e00370.
[2] S.I. Arzola-Rodriguez, L.N. Muñoz-Castellanos, C. Lopez-Camarillo, E. Salas, Biomolecules, 2022, 12, 1897.
[3] S. Vicinanza, F. Annunziata, D. Pecora, A. Pinto, L. Tamborini, RSC Advances,2023, 13, 22901.
[4] S. Vicinanza et al., Sustainable Chemistry and Pharmacy, 2024, 39, 101542.

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FAR-OR-024

Targeting the TPP1-Telomerase Complex: Ligand Discovery, Experimental Validation, and Therapeutic Implications in Cancer

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The lifespan of a cell is intricately linked to the shortening of its telomeric DNA through the telomere maintenance mechanism.[1] Many cancer cells take advantage of this mechanism by employing the telomerase enzyme, assisted by RNA and the Shelterin protein TPP1, to elongate telomeric DNA strands.[2] This enables evasion of cellular senescence, granting the attainment of immortality.[3,4] Inhibiting the formation of the telomerase-TPP1 complex emerges as an attractive, yet unexplored, strategy to induce senescence in cancer cells. A targeted virtual screening in the "Oligonucleotide/Oligosaccharide-Binding" (OB) domain of TPP1, which is the binding interface in the TPP1-hTEN (the TPP1 binding domain of telomerase) complex, led to the identification of the first two ligands of TPP1, namely LRG4 and LRG17. To experimentally validate these results, we performed ligand-based NMR experiments, specifically Saturation Transfer Difference (STD)[5] and WaterLOGSY (WL)[6] techniques, that confirmed the binding of the ligands to the TPP1 OB domain. This binding was further confirmed using a macromolecule-based approach, particularly through NH-HSQC[7] spectra acquisition. These experiments offer insights into the ligands' specific binding region, contingent upon protein assignment. To this end, we acquired and are currently analyzing 3D NMR spectra using artificial intelligence.[8] The pharmacological activity of the ligands was also tested through anti-proliferative, pro-senescence, and telomeric DNA shortening experiments. Therefore, by intertwining computational predictions with experimental methodologies, we can affirm the inhibitory potential of LRG4 and LRG17 in disrupting telomere maintenance mechanisms. This integrated approach underscores the significance of TPP1 as a therapeutic target for various cancers, providing a promising foundation for future drug design campaigns focused on developing effective anticancer agents.

References:

[1] V. A. Zakian, Science 1995, 270, 1601–1607.
[2] K. A. Lewis, D. S. Wuttke, Structure 2012, 20, 28–39.
[3] G.-Z. Li, M. S. Eller, R. Firoozabadi, B. A. Gilchrest, Proc. Natl Acad. Sci. USA 2003, 100, 527–531.
[4] W. C. Hahn et al., Nat. Med. 1999, 5, 1164–1170.
[5] M. Mayer, B. Meyer, Angew. Chem. Int. Ed. 1999, 38, 1784–1788.
[6] C. Dalvit, G. Fogliatto, A. Stewart, M. Veronesi, B. Stockman, J. Biomol. NMR 2001, 21, 349−359.
[7] G. Bodenhausen, D. J. Ruben, Chem. Phys. Lett. 1980, 69, 185–189.
[8] P. Klukowski, R. Riek, P. Güntert, Nat Commun 2022, 13, 6151.

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FAR-OR-025

A Valuable Computational Approach to Identify Structural Requirements for Sigma-1 Receptor Ligands

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The Sigma 1 Receptor (S1R) has emerged as a therapeutic target in drug discovery for CNS diseases. While a variety of ligands with diverse chemical structures are able to interact with S1R, literature underscores crucial pharmacophore features, embracing two hydrophobic regions and a central basic core.[1] The exploitation of crystallographic structures of human S1R co-crystalized with various ligands have provided valuable insights for developing pharmacophore models.[2,3] However, relying solely on rigid crystal structures shows limitations, as they represent only one conformation and lack thorough insight into ligand-residue interactions. To achieve a comprehensive study on S1R-ligand complexes, molecular dynamics simulations were employed here to generate an extensive ensemble of conformations for each complex. Subsequently, each ensemble was explored to characterize the most energetically favorable interactions between ligands and residues using the Grid-Based Pharmacophore Model method.[4] The resulting data were exploited to build a shared pharmacophore model, thus identifying new potential ligands. Corroborated the predictiveness of our S1R pharmacophore, a set of candidate ligands was designed based on query features and the synthesized compounds were evaluated through *in vitro* sigma receptor binding assays. These candidates revealed good K_i affinity values (ranging from 4.8 to 25.4 nM), thus supporting the robustness of our computational approach. The proposed pharmacophore model holds promise as a valuable tool for designing and discovering new effective S1R ligands.

References:

[1] A.N. Fallica, V. Pittalà, M.N. Modica, L. Salerno, G. Romeo, A. Marrazzo, M.A. Helal, S. Intagliata, Journal of Medicinal Chemistry 2021, 64, 7926-7962.
[2] H.R. Schmidt, S. Zheng, E. Gurpinar, A. Koehl, A. Manglik, A.C. Kruse, Nature 2016, 532, 527-530.
[3] H.R. Schmidt, R.M. Betz, R.O. Dror, A.C. Kruse, Nature Structural and Molecular Biology 2018**,** 25, 981-987.
[4] F. Ortuso, T. Langer, S. Alcaro, Bioinformatics 2006, 22, 1449-1455.

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Investigating the protective effects of grape seed proanthocyanidins: an integrated approach revealing the paraormetic mechanism via metabolic, in silico and proteomic analyses

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Proanthocyanidins (PACs) are plants secondary metabolites whose health benefits on inflammatory-based diseases are supported by several studies. A large portion of orally ingested PACs reach the colon where they are catabolized by colonic microflora into phenyl-γ-valerolactones, which showed anti-inflammatory activity. The aim of this study was to evaluate (i) the catabolic conversion of a standardized oligo-polymeric PACs grape seed extract (GSE, Ecovitis®), both in vitro and in a human intervention study, and (ii) the biological activity and molecular mechanism of the main metabolite, namely 5-(3′,4′-dihydroxyphenyl)-γ-valerolactone (VL), by an integrated metabolic, in silico and proteomic approach. An in vitro human fermentation model allowed to identify VL as the main PACs colonic microbiota catabolite. VL was identified as sulfate and glucuronide phase II metabolites by LC-ESI-MS/MS in the urine of volunteers treated with PACs. VL was synthesized and its effect evaluated by two phenotypic cell models: HEK293 with the cell reporter for Nrf2 activation and R3/1 with cell reporter for NF-κB activation. A dose-dependent activity was observed in both experiments. The molecular mechanism of Nrf2 activation by VL was then elucidated in silico studies which clarified the molecular engagement of VL with the thiol group of KEAP-1. The ability of VL to modulate the NF-κB levels was confirmed on human colon Caco-2 cells. Quantitative proteomics studies were then carried out on Caco-2 cells, in physiological and inflammatory conditions. When a pro-inflammatory stimulus was used (TNFα), VL reverted the expression levels of certain integrin signalling pathway genes. Moreover, the activation of the Nrf2 cascade was indirectly observed through the modulation of the downstream gene products, including COX2, upregulated in the inflammatory state and downregulated in the presence of VL. In conclusion, we demonstrated how VL can enhance body's resilience through Nrf2 activation, which works as an hormetic mediator protecting biological systems and conserving resources through its controlled reaction, as reported for phytochemicals that act by such a mechanism that can be called "parahormesis".[1]

References:

[1] H.J.Forman, K.J.A.Davies, F.Ursini, Free Radic Biol Med, 2014, 66, 24-35.

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Integrating MS proteomics in the Medicinal Chemistry pipeline as powerful tool to overcome drug resistance issues in colorectal cancer

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Recent technological developments in high resolution mass spectrometry now allow the deep characterization of complex *in vitro* and *in vivo* biological systems. By processing thousands of proteins and quantifying their fluctuations in expression, the combination of MS proteomics with bioinformatics allows the investigation of the subcellular mechanisms triggered by a drug administration or a combination of medicines[1]. Also, the brand-new invention of peptide labelling kits, like the TMT-tagging system (Thermo Fisher), makes it possible to analyse multiple samples in a single MS run, detecting even smaller differences in protein concentrations. By exploiting this powerful tool, the Drug Discovery Network has recently examined the mechanism of action of their novel thymidylate synthase inhibitors (namely dimer destabilizers, or Ddis), that induce cancer cell death by targeting the enzyme at the interface of the two monomers. Unlike 5-FU and antifolates, this innovative medicinal chemistry strategy delays/halts drug resistance onset[2]. Herein, by MS proteomics, we demonstrate that the co-administration of a low-dose of Ddis with 5-FU, with respect to 5-FU only, significantly reduces the drug sentitization in HCT-116 cells. Overall, we have identified a total of 5900 proteins, 19 of which differentially expressed proteins (DEPs), *i.e.* whose expression is significantly different from control cells. These proteins were investigated with dedicated bioinformatic tools, which suggested a strong overexpression of the RNA catabolic process (Nonsense Mediated Decay pathway), mitochondrial ATP-related metabolism, and pro-apoptotic p53 path for the drug combination (PI3K and mTORR), whereas 5-FU-only effect is less significant (no DEP was identified). Interestingly, despite both treatments have evidenced TS downregulation, only in drug combination the SHMT enzyme significantly decreases, which may suggest a folate imbalance. Overall, this study contributes to the demonstration MS proteomics is a powerful tool to speed up the drug discovery pipeline, providing insightful information about molecular mechanisms of drugs.

References:

[1] D'Arca D, et al. Serum Mass Spectrometry Proteomics and Protein Set Identification in Response to FOLFOX-4 in Drug-Resistant Ovarian Carcinoma. *Cancers.* **2023** Jan 8;15(2):412. doi: 10.3390/cancers15020412.
[2] Costantino L et al. Destabilizers of the thymidylate synthase homodimer accelerate its proteasomal degradation and inhibit cancer growth. *Elife*. **2022** Dec 7;11:e73862. doi: 10.7554/eLife.73862.

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Development of advanced experimental and in silico methods for the characterization of biopolymers in complex matrices

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The main aim of the study was to determine the molecular weight (MW) of the fragments generated from poly(L-lactide) (PLLA) after treatment with UV radiation in the presence/absence of different nano bio-materials. MWs were determined through gel permeation chromatography (GPC) analysis, using a PLgel 5 µm Mixed-C column (from Agilent Technologies), and a number of polystyrene standards with molecular weight distribution in the 2,500-100,000 Da range. A calibration curve was built up plotting the logarithm of the molecular weight (log MM) vs the retention volume [V (mL)].

Chloroform was used as eluent at 1.0 mL/min flow rate, while the column temperature set at 40 °C. For most of the investigated composites, a progressive reduction of the MW turned out with the exposition time to UV-radiation. Instead, a counter-intuitive behavior was observed for the systems including softwood Kraft lignin (SKL) and titanium dioxide (TiO2): in these cases, an increase of the MW turned out.

In order to deeper investigate the synergic stabilizing effect on the photodegradation of the PLLA observed by adding SKL and titanium dioxide to the nanocomposites, four in silico molecular dynamic simulations (MDs) have been performed. The four simulated systems were composed by: (1) 404 tetramers of PLLA; two binary systems composed by (2) 402 tetramers of PLLA and 1 SKL molecule, (3) 402 tetramers of PLLA and 7 titanium dioxide molecules; one ternary system composed by (4) 402 tetramers of PLLA, 1 SKL and 7 titanium dioxide molecules. After a simulation lasting 500ns, we measured the total number of atomic contacts explored by each heavy atom of the system. Interestingly, the box plot generated for the obtained data well correlates with the degradation effect experimentally measured at 60 and 180 minutes. In particular, when SKL and the titanium dioxide are added together to the system they display a synergic effect, leading to a massive increment of the MW measured, as analogously reported in a recent publication.[1] To the best of our knowledge, this is the first approach able to rationalize at a molecular level the synergic effect of SKL and titanium dioxide on the PLLA degradation. This work has been supported by the European Union – Next Generation EU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 – VITALITY - CUP J97G22000170005, and Università degli Studi di Perugia and MUR for support within the project Vitality.

References:

[1] E. Lizundia, I. Armentano, F. Luzi, F. Bertoglio, E. Restivo, L. Visai, L. Torre, D. Puglia, 2020, 8, 5263-5274.

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Exploring the interactions of small molecules with RNA in drug discovery and development

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After a long limbo, RNA has gained its credibility as a druggable target, fully earning its deserved role in the next generation of pharmaceutical R&D.

The emergence of new viruses highlighted the dearth of first-line antivirals for the urgent care of patients as well as the urgent need for the development of new RNA-targeting therapeutics to fight old and new diseases associated with RNA viruses. Conserved structured RNA regions of viruses genome such as HIV-1 and SARS-CoV-2 play critical functional roles in the viral replication cycle representing potential drug targets. We will illustrate mass spectrometry (MS)-based strategies for the identification and functional investigation of drug-like molecules capable of binding to essential regulatory structures of the viral RNA. Examples will be provided in which our biophysical-analytical approach enabled the determination of stoichiometries and binding modes, as well as the evaluation of the binding affinities for selected RNA targets and the inhibitory properties of specific complexes involving such targets and cognate viral proteins[1-3].

Additionally, human non-coding RNAs (ncRNAs), such as human microRNA-21 (miR-21), are involved in the regulation of a variety of cellular functions and their dysregulation is often observed in human diseases, including solid tumors[4]. In this context, we show how native MS plays a leading role in early drug discovery by enabling the screening of new potential ligands for the RNA target and by providing valuable information on their interactions, thus guiding the synthesis of more effective and selective RNA binders.

References:

[1] Sosic, A.; Olivato, G.; Carraro, C.; Göttlich, R.; Fabris, D.; Gatto, B. Bis-3-Chloropiperidines Targeting TAR RNA as A Novel Strategy to Impair the HIV-1 Nucleocapsid Protein. Molecules 2021, 26, 1874.

[2] Sosic, A.; Gottlich, R.; Fabris, D.; Gatto, B. B-CePs as cross-linking probes for the investigation of RNA higher-order structure. Nucleic Acids Res. 2021, 49, 6660–6672.

[3] Sosic, A.; Olivato, G.; Carraro, C.; Göttlich, R.; Fabris, D.; Gatto, B. In Vitro Evaluation of Bis-3-Chloropiperidines as RNA Modulators Targeting TAR and TAR-Protein Interaction. Int. J. Mol. Sci.2022,23,582.

[4] Krichevsky, A. M., Gabriely, G. miR-21: a small multi-faceted RNA. J Cell Mol Med. 2009 13, 39-53.

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FAR-OR-030

Advanced analytical approaches for the evaluation of small molecules as G-quadruplex stabilizers

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In guanine-rich sequences, DNA and RNA can fold into non-canonical arrangements that are called G-quadruplexes (GQs).[1] The structure of GQ is based on guanine quartets organized through non-canonical Hoogsten base pairing and stabilized by monovalent cations at the center, which are stacked on the top of each other.[2] They are mainly present in telomeres and in promoter regions of oncogenes, and their stabilization with small molecules represents an attractive therapeutical approach.[3] Our group developed a protocol based on a combination of advanced analytical techniques for evaluating the ability of small molecules to interact with GQs in vitro, from a structural and quantitative point of view. In this context, Nuclear Overhauser Effect (NOE)-based NMR experiments, such as Saturation-Transfer Difference (STD), are an ideal option to characterize the ligand-target interaction from a structural perspective. NOE causes the transfer of nuclear spin polarization from one population of spin-active nuclei to another. Thus, it is possible to gain insights on the ligand-target interaction in conditions that closely resemble the physiological environment. STD relies on the nuclear spin polarization transfer between the target and the ligand, as bound and unbound fractions of ligands behave differently. This technique can be applied to nucleic acids including GQs.[4] Moreover, in addition to a previously established approach for ligands screening, based on electrospray mass spectrometry (ESI-MS), the nano-ESI setup recently implemented in our laboratory can provide more accurate quantitative insights regarding the binding of small molecules to GQs in native conditions. Through this work, we present a combined approach, highlighting that the use of different advanced techniques is pivotal to fully characterize the interaction of small molecules with GQs.

References:

[1] J., Spiegel, S., Adhikari, S., Balasubramanian, Trends in Chemistry 2020, 2 (2), 123–136.
[2] S., Burge, G. N., Parkinson, P., Hazel, A. K., Todd, S., Neidle, Nucleic Acids Res 2006, 34 (19), 5402–5415.
[3] N., Kosiol, S., Juranek, P., Brossart, A., Heine, K., Paeschke, Mol Cancer 2021, 20 (1), 40.
[4] L., Martino, A., Virno, B., Pagano, A., Virgilio, S., Di Micco, A., Galeone, C., Giancola, G., Bifulco, L., Mayol, A., Randazzo, J. Am. Chem. Soc. 2007, 129 (51), 16048-1605

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Q-raKtion: A Novel Data Curation Tool to Aid Drug/Agrochemical Discovery

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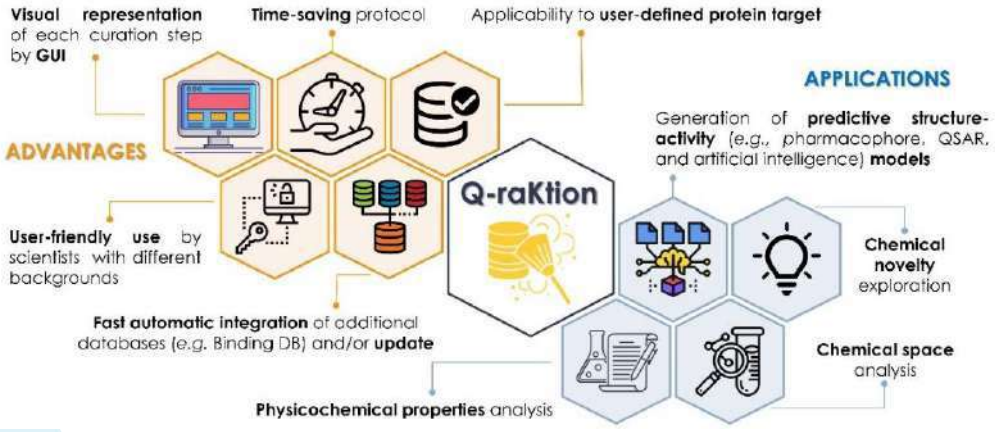
Predictive models can be developed using a wealth of ready-to-use data that has recently become more readily available to the scientific community and stored as activity datapoints in chemogenomic repositories. However, the lack of uniformity and consistency of data from various sources, which necessitates a process of integration and harmonization, strongly offsets the advantages provided by the availability of such a vast amount of accessible information.[1,2] In this context we developed Q-raKtion,[3] a systematic, semi-automated, flexible, and customizable KNIME workflow that effectively aggregates information on biological activities of compounds retrieved by two of the most comprehensive and widely used repositories, namely PubChem and ChEMBL. The main advantages of the developed tool consist of i) the availability of a general pipeline that integrates different data curation and integration tasks, ii) the use of a graphical interface that allows the visual representation of each curation step, and iii) the high propensity of the protocol to be easily interpretable and reproducible.

As a practically case studies, we reported the application of the Q-raKtion pipeline to build well-annotated, high-quality compound datasets and their use in drug/agrochemical discovery projects.



References:

[1] T. Kalliokoski, C. Kramer, and A. Vulpetti, *Mol. Inform.*, **2013**, 32(11-12), pp.898-905.

[2] D. Fourches, E. Muratov, and A. Tropsha, *J Chem Inf Model*, **2016**, 56(7), pp.1243-1252.

[3] D. Palazzotti, M. Fiorelli, S. Sabatini, S. Massari, ML. Barreca, and A. Astolfi. *J Chem Inf Model*, **2022**, 62(24), pp.6309-6315.

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FAR-PO-001

Rational optimization of the *N*-adamantyl-anthranil amide structural core for the developtment of new selective ligands for the Cannabinoid subtype 2 Receptor (CB2R)

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CB2R is a Gi-protein-coupled receptor (GPCR) which, together with CB1R, the endocannabinoids and the enzymes responsible for their synthesis and degradation, forms the endocannabinoid system (ECS). The expression of CB2R at the level of immune tissues, its over-expression, and up-regulation at the level of microglia cells in the CNS in pathological states, have led to questions about its role in inflammatory and neurodegenerative diseases. In 2023, we synthesized, evaluated, and published *N*-adamantyl-anthranil amide derivatives as CB2R selective ligands (Fig. 1B)[1]. We based our design on the proposed binding mode of the most potent CB2R antagonist AM10257, called "three-arm pose" (Fig. 1A). The best results in terms of affinity were observed in compounds presenting the phenyl ring or hydrogen on arm 1 and an alkyl chain with 5-carbon atoms as arm 2. The carboxy-adamantyl amide group as arm 3 was found to be critical for interaction with CB2R. We rationally explored a series of substitutions on the *N*-adamantyl-anthranil amide structural core as to assess any variations in affinity for CB2R. We also tested these synthetized compounds to evaluate their CB2R affinity and selectivity towards CB1R, obtaining interesting results. Compounds exhibiting the best pharmacodynamic profile in terms of CB2R affinity were also evaluated for the functional behavior and molecular docking simulations provided sound rationale.

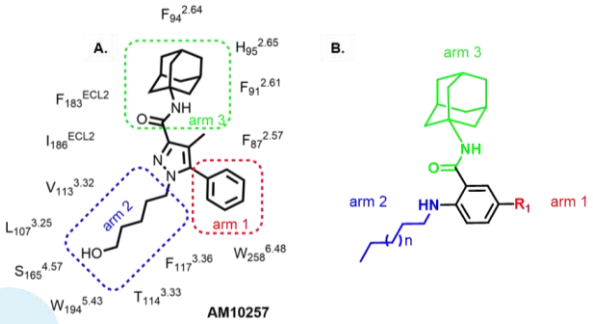

Figure 1: AM10257, CB2R antagonist (A), General structure of our N-adamantyl-anthranil amide derivatives (B).

References:

[1] Graziano G, Delre P, Carofiglio F, et al., European Journal of Medicinal Chemistry, 248, (**2023**) 115109.

FAR-PO-002

Development of new selective ligands for the cannabinoid receptor subtype 2 (CB2R)

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Cannabinoid 2 receptor (CB2R) is a G-protein coupled receptor and, together with Cannabinoid 1 receptor (CB1R), is part of the Endocannabinoid system (ECS). CB2R resulted overexpressed in cells of the immune system and play a key role in disorders based on an inflammatory state, such as neurodegenerative diseases, neuropathic pain and cancer. We designed, synthesized, and biologically evaluated a series of new N-adamantyl-anthranil amide derivatives as CB2R selective ligands (Figure 1A).[1] Molecular docking simulations provided a sound rationale by highlighting the relevance of the arm 1 substitution to prompt CB2R action (Figure 1B). Moreover, the modulation of the pro- and anti-inflammatory cytokines production was also investigated to study the ability of the best compounds to modulate the inflammatory cascade (Figure 1C).

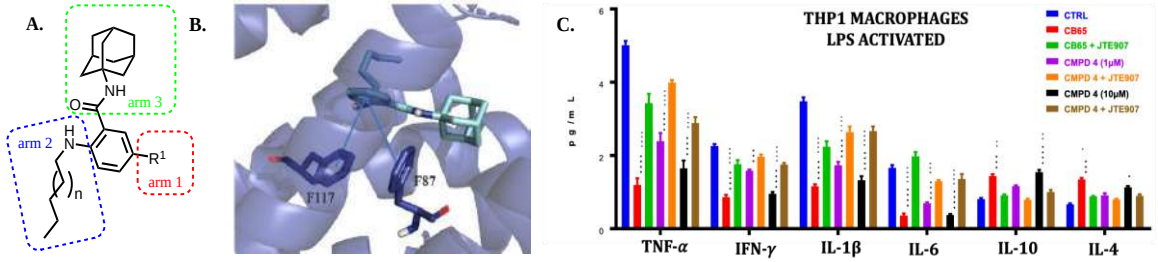

Figure 1. General structure of our *N*-adamantyl-anthranil amide derivatives (A), top-scored docking poses returned by docking simulations (B) and modulation of the best compound on cytokine production (C)

Their promising anti-inflammatory effect prompted their investigation in different models: on gastric cancer onset and in vivo on a murine model of Alzheimer disease. Our latest studies were principally directed to the improvement of their pharmacokinetic properties.

Acknowledgement: The authors gratefully thank MIUR PRIN 2022 PNRR P2022TRR3Y financed by European Union "NextGenerationEU"

References:

[1] Graziano, G.; Delre, P.; Carofiglio, F.; Brea, J.; Ligresti, A.; Kostrzewa, M.; Riganti, C.; Gioè-Gallo, C.; Majellaro, M.; Nicolotti, O.; Colabufo, N. A.; Abate, C.; Loza, M. I.; Sotelo, E.; Mangiatordi, G. F.; Contino, M.; Stefanachi, A.; Leonetti, F. *Eur. J. Med. Chem.* **2023**, *248*, 115109.

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FAR-PO-003

A family of nitrogen-containing heterocycles as sirtuin inhibitors: synthesis and *in vitro* biological evaluation

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Sirtuins (SIRTs) are a family of NAD^+-dependent deacetylases including seven members, named from SIRT-1 to SIRT-7 and characterized by diverse subcellular localizations and distinct enzymatic activities.[1] The SIRT family is involved in translation, metabolism, and genome stability.[2,3] Hence, their dysregulation is closely associated with several diseases such as cancer, diabetes, and neurological illnesses. The availability of different X-ray crystallographic structures of SIRT-2−ligand complexes made it possible to build up a structure-based investigation in the hunt for SIRT-2 inhibitors (SIRTIs).[4] A series of *in-house* pyrazolo[3,4-*d*]pyrimidine derivatives as a class of SIRT-2 inhibitors were evaluated *in silico* and *in vitro*, leading to the identification of two effective compounds, **1** and **2** (**Figure 1**). Then, further modeling studies drove the synthesis of a library of analogue compounds. The identified derivatives have been tested *in vitro*, and an accurate structure-activity relationship study was carried out. Interestingly, few compounds showed a low micromolar/nanomolar activity towards SIRT-2. The synthesis and the biological results will be discussed.

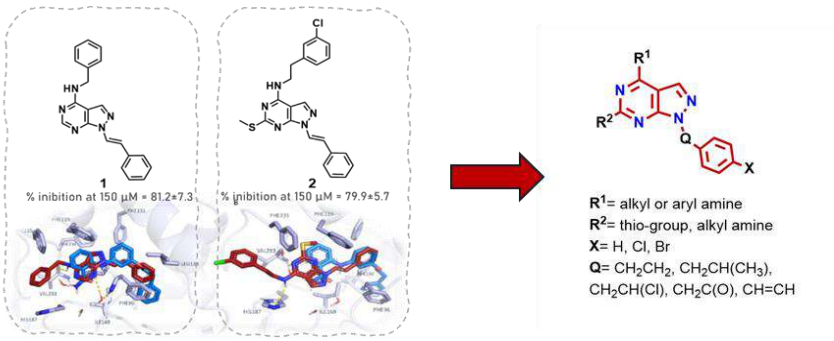

Figure 1: Structure, inhibitory activity towards SIRT-2, and docking pose of the first series of pyrazolo-pyrimidines **1**,**2** and general structure of newly synthesized inhibitors.

References:

[1] M.C. Haigis, L.P. Guarente, Genes Dev, 2006, 20, 2913–2921.
[2] J.A. Leite, B. Ghirotto, V.P. Targhetta, J. Lima, N.O.S. Câmara, Br J Pharmacol, 2022, 179, 1496–1511.
[3] E. Zhao, J. Hou, X. Ke, M.N. Abbas, S. Kausar, L. Zhang, H. Cui, Cancers, 2019, 11, 1949-1971.
[4] E. Abbotto, N. Scarano, F. Piacente, E. Millo, E. Cichero, S. Bruzzone, Molecules, 2022, 27, 5641-5694.

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FAR-PO-004

Glyphosate Renewal in the EU: A MAATrica-Based Assessment of the Scientific Literature

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The widespread use of herbicides, including glyphosate, has raised concerns about potential health risks. Glyphosate, a primary herbicidal agent used globally, has been linked to various human health issues, prompting scrutiny from regulatory bodies. Despite its approval for use until 2033 in the European Union, questions persist regarding its safety [1]. This study utilizes the MAATrica assessment metric [2] to analyse the scientific validity and coherence of publicly available literature and studies utilized by the Glyphosate Renewal Group [3] and European Commission [4] to support glyphosate renewal efforts.
By analyzing accessible studies, we aim to provide insights into the reliability of scientific evidence surrounding glyphosate, contributing to informed decision-making in public health policy.

References:

[1] B. Casassus, *Nature*, 2023. EU allows use of controversial weedkiller glyphosate for 10 more years.
[2] G. Panzarella, A. Gallo, J. Bajorath, P. Veltri, M. Hofmann-Apitius, F. Ortuso, S. Coecke, and S. Alcaro. Submitted, 2024: "MAATrica: a Measure for Assessing Consistency and Methods in Medicinal and Nutraceutical Chemistry Papers"
[3] Glyphosate Renewal Group, https://www.glyphosate.eu/transparency/scientific-dossier/public-literature/ (last access: March 8, 2024)
[4] European Commission, https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/ (last access: March 8, 2024)

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FAR-PO-005

Harnessing Nature's arsenal: virtual screening for IL-20 receptor inhibitors among natural compounds

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Current clinical trials investigate the role of interleukin (IL) blockade as innovative cancer treatment approaches, thus targeting IL20 receptor (IL20R) which is elevated in breast cancer, might modulate TME (Tumor Microenvironment) and could be an efficient direct anticancer treatment as well. The aim of the project is to identify ligands that can simultaneously interact on both subunits (α and β) of the receptor and on IL-20. The considered ternary complex is IL20/IL201/IL20R2, deposited with the accession code 4DOH[1]. The structure was energetically optimised using the Protein Preparation Wizard[2] tool. Subsequently, the complex was subjected to 300 ns Molecular Dynamics through Desmond[2], with the aim of studying the adaptation process of the complex over time. The resulting trajectory was clustered according to the RMSD and of the resulting clusters, the most representative was chosen according to the probability estimated by the Boltzmann Population for subsequent studies. Subsequently, the selected cluster was used as an input structure for protein mapping and identification of binding pockets via SiteMap[2]. Of the eight sites identified, three were taken into account: two constituted the binding site at the interface between the α subunit and IL-20 and one constituted the binding site at the interface between the β subunit and IL-20, in accordance with what has been described in the literature. Three grids were constructed considering the same coordinates for the left side of the protein (complexA, IL-20Rα, IL-20A), and three others on the right side (complexB, IL-20Rβ, IL-20B) again using the same coordinates for all three. Virtual screening was conducted using the database downloaded from Zinc[3] and containing 307814 ligands of natural origin, which were prepared with the LigPrep[2] tool. For each of the 6 grids generated, molecular docking calculations were performed using the Glide[2] Standard Protocol (SP) algorithm to obtain the theoretical binding affinities for each ligand expressed in terms of energy values (Kcal/mol); 10 poses per ligand were generated. At the moment, analysis of the results are still in progress. This work is supported by a PRIN project[4].

References:

[1] N. J. Logsdon, A. Deshpande, B. D. Harris, K. R. Rajashankar, M.R. Walter, *Proceedings of the National Academy of Sciences*, **2012**, *109*, 12704-12709.
[2] Schrödinger Suite, LCC, New York, NY, (2018).
[3] ZINC (docking.org)
[4] PRIN project "Development of molecules for reshaping tumor microenvironment in aggressive breast cancer: analysis of the effects of novel inhibitors of interleukin 20 receptor" code 2022YHL52A.

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FAR-PO-006

Targeting hypoxia in cancer therapy

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Hypoxia, defined as a condition of lower-than-normal oxygen levels, is a key feature of most solid tumours, associated with therapy resistance and poor patient prognosis.[1] Alongside, the chemically reducing environment found in hypoxia allows it to be targeted with pro-drugs. Hypoxia-activated prodrugs based on indolequinone and nitroaryl groups have been exploited by our group to specifically target the oxygen-deficient fraction of tumour cells,[2] reducing the systemic exposure. By using this approach, we have developed two series of hypoxia-activated PROTACs (HAP-TACs) targeting BRD4 which degrading activity is triggered when oxygen levels are reduced below 2%. Our HAP-TACs are stable in normoxic conditions (21% O_2) and undergo enzyme-mediated bioreduction in cells to release the active PROTACs in hypoxia (2-0.1% O_2). The conditional degradation of BRD4 is reflected by a selective antiproliferative activity in colorectal cancer cells exposed to hypoxia, whereas proliferation of normoxic cells is not affected. As the bioreductive groups used to develop our HAP-TACs are attached to the cereblon and VHL E3 ligase ligands (Figure 1), this strategy is applicable to any PROTAC that recruits these E3 ligases, with the potential of increasing the therapeutic index of already reported PROTACs against a wide range of target proteins. Complementary work to develop hypoxia-triggered biorthogonal reactions to form anticancer agents inside tumour cells will also be presented.

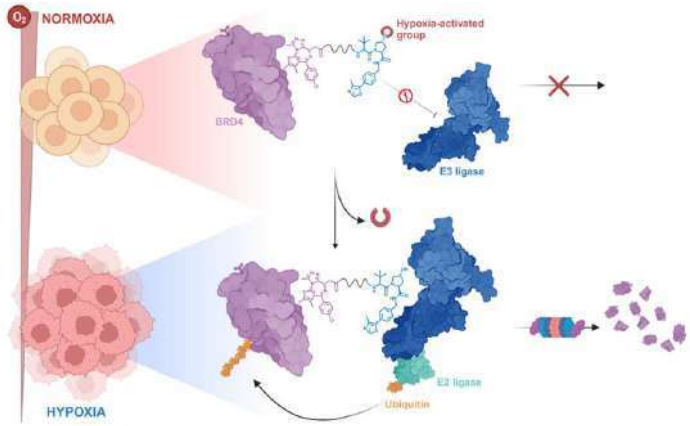

Figure 1: The concept of hypoxia-activated PROTACs.

References:

[1] Z. Chen, *et al.* Signal Transduct Target Ther. 2023, 8, 70.
[2] L. Skwarska, *et al.* Cell Chem. Biol. 2021, 28, 1258 - 1270.

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FAR-PO-007

Innovation in Virtual Screening: PyRMD2Dock's AI-Infused Approach

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This abstract introduces a new computational approach, PyRMD2Dock, designed to enhance the efficiency of virtual screening campaigns for drug discovery by combining our Ligand-Based AI- enforced Virtual Screening tool PyRMD with the widely used docking software AutoDock-GPU (AD4- GPU).

Recent research has highlighted the importance of using ultralarge molecular databases (i.e., containing millions or even billions of compounds) for SBVS campaigns.[1] The screening of vast compound libraries, exemplified by the Enamine REAL database with approximately 7 billion compounds,[2] increases the chances of identifying novel and potent drug candidates not simply achievable with smaller databases.[3] However, screening millions or billions of compounds presents challenges, necessitating substantial computational resources and specialized software.[4]

Through the implementation of PyRMD2Dock, we demonstrated the rapid screening of massive chemical databases to identify compounds with the highest predicted binding affinity to a target protein. Benchmarking and screening experiments highlighted the predictive accuracy and speed of PyRMD2Dock, emphasizing its potential to expedite the discovery of novel drug candidates.

Overall, this research underscores the value of integrating AI-powered LBVS tools with docking software for effective and high-throughput virtual screening of ultralarge molecular databases in drug discovery. The open-source tools, PyRMD[5] and the PyRMD2Dock[6] protocol, are freely accessible on our GitHub page (https://github.com/cosconatilab/PyRMD).

References:

[1] J. Lyu, S. Wang, T. E. Balius, I. Singh, A. Levit, Y. S. Moroz, M. J. O'Meara, T. Che, E. Algaa, K. Tolmachova, A. A. Tolmachev, B. K. Shoichet, B. L. Roth, and J. J. Irwin, Nature 2019, 566, 224 – 229.
[2] REAL Database - Enamine. https://enamine.net/compound-collections/real-compounds/real-database.
[3] B. Wu, E. Y. T. Chien, C. D. Mol, G. Fenalti, W. Liu, V. Katritch, R. Abagyan, A. Brooun, P. Wells, F. C. Bi, D. J. Hamel, P. Kuhn, T. M. Handel, V. Cherezov, and R. C. Stevens, Science 2010, 330, 1066 – 1071.
[4] B. J. Bender, S. Gahbauer, A. Luttens, J. Lyu, C. M. Webb, R. M. Stein, E. A. Fink, T. E. Balius, J. Carlsson, J. J. Irwin, and B. K. Shoichet, Nature Protocols 2021, 16, 4799 – 4832.
[5] G. Amendola, and S. Cosconati, Journal of Chemical Information and Modeling 2021, 61, 3835 – 3845
[6] M. Roggia, B. Natale, G. Amendola, S. Di Maro, and S. Cosconati, Journal of Chemical Information and Modeling 2023, ASAP

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FAR-PO-008

AI-driven Discovery of TERRA G4 Ligands for ALT Anticancer Therapy

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While most cancer types rely on telomerase reactivation for telomere maintenance and sustained proliferation, a subset (~15%) of cancers employs telomerase-independent mechanisms, referred to as Alternative-Lengthening of Telomeres (ALT). Several evidence demonstrates that ALT-elongated telomeres exhibit a permissive chromatin state that leads telomeres to be hyper-transcribed into long non-coding RNA transcripts, called telomeric repeat-containing RNA (TERRA)[1]. TERRA is implicated in numerous functions, including the interaction with telomeric proteins, modulation of telomeric chromatin, and transcription[2].

TERRA contains long tracts of telomeric r(UUAGGG) repeats, and as such it can form G-quadruplex (G4) structures. G4-interacting small molecules have shown potent inhibition of TERRA interaction with proteins, resulting in loss of TERRA at telomeres. This event is related to induction of telomeric DNA damage, decreased telomere length, and increased telomere aberrations[3]. These results suggest that targeting TERRA G4 could spearhead novel therapeutic strategies for the selective killing of ALT cancer cells.

The present contribution showcases the application of the newly developed AI-powered Virtual Screening method, PyRMD2Dock[4], to screen an ultra-large chemical database for the lead discovery of new chemotypes able to bind the TERRA G4 fold. Biophysical and biological evaluation is here reported to demonstrate the predictiveness of the employed method in the identification of potential ALT-selective antiproliferative TERRA G4 binders.

References:

[1] C. M. Azzalin, P. Reichenbach, L. Khoriauli, E. Giulotto, and J. Lingner, Science 2007, 318, 798 - 801.
[2] K. Rippe, and L. Brian, Nature structural & molecular biology 2015, 22, 853 - 8.
[3] Y. Mei, Z. Deng, O. Vladimirova, N. Gulve, F. B. Johnson, W. C. Drosopoulos, C. L. Schildkraut, and Paul M. Lieberman, Scientific reports 2021, 11, 3509.
[4] M. Roggia, B. Natale, G. Amendola, S. Di Maro, and S. Cosconati, Journal of chemical information and modeling 2023, ASAP

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FAR-PO-009

Multistep Flow Synthesis of HYDAMTIQ and Its Derivatives as PARP-1/2 Inhibitors

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HYDAMTIQ is a potent dual PARP-1/2 inhibitor that has been advanced in pre-clinical settings for the treatment of brain ischemia, asthma and cancer.[1–3] The original medicinal chemistry route to HYDAMTIQ suffers from some limitations such as the moderate overall yield, the low scalability and the use of hazardous chemicals.[4] To bridge the gap between the initial compound discovery and development, as well as to support further medicinal chemistry investigations, in this communication we report the development of a flow chemistry approach to streamline the preparation of HYDAMTIQ and novel analogues (Figure 1).[5,6] The optimized flow process resulted in a greater sustainability and simplification for both scale-up operations and lead optimization programs, enabling the development of novel PARP-1/2 inhibitors with improved properties and therapeutic potential.

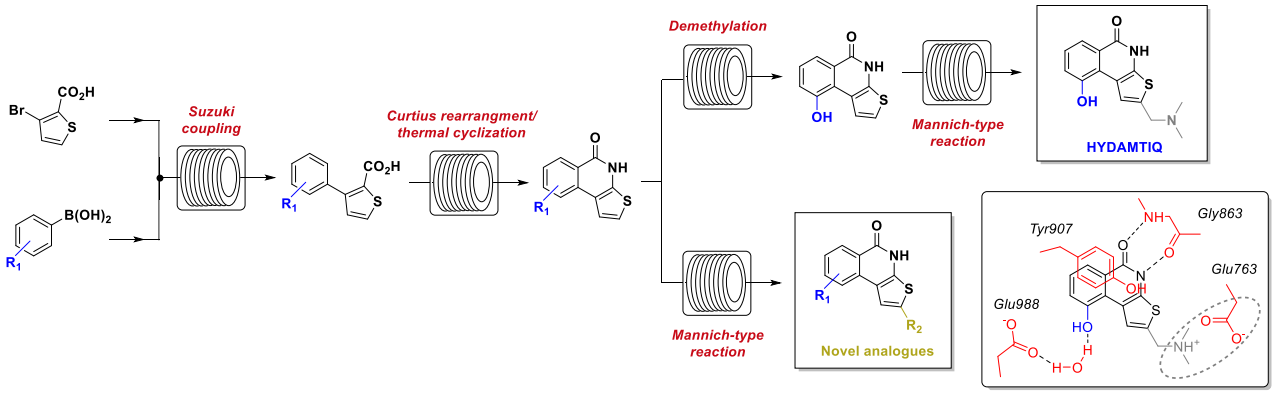

Figure 1: Multistep flow synthesis of HYDAMTIQ and its analogues.

References:

[1] F. Moroni, A. Cozzi, A. Chiarugi, L. Formentini, E. Camaioni, *et al.*, Br. J. Pharmacol. 2012, 165, 1487–1500.
[2] L. Lucarini, A. Pini, E. Gerace, R. Pellicciari, E. Masini, F. Moroni, J. Cell. Mol. Med. 2014, 18, 468–479.
[3] L. Lucarini, M. Durante, C. Lanzi, A. Pini, G. Boccalini, L. Calosi, F. Moroni, J. Cell. Mol. Med. 2017, 21, 324–335.
[4] R. Pellicciari, E. Camaioni, A. M. Gilbert, A. Macchiarulo, *et al.*, Med Chem Commun. 2011, 2, 559–565.
[5] P. Filipponi, C. Ostacolo, E. Novellino, R. Pellicciari, A. Gioiello, Org. Process Res. Dev. 2014, 18, 11, 1345–1353.
[6] P. Filipponi, B. Cerra, A. Piccinno, E. Camaioni, A. Gioiello, Org. Process Res. Dev. 2023, in press, DOI: 10.1021/acs.oprd.3c00295

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FAR-PO-010

Synthetic Optimization, Biological Activity and Early PK/PD Characterization of Dafachronic Acids, the Endogenous Ligands of DAF-12 Receptor

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Dafachronic acids (DAs) are steroidal hormones derived from the catabolism of cholesterol. They exhibit a unique structure featuring a C3-keto group, a double bond at the C4- or C7-position, a C25-methyl group, and a C26-carboxylic tail (Figure 1). Several evidences have shown that these signalling molecules play a pivotal role in regulating the life cycle of both free living and parasitic nematodes through the modulation of the nuclear receptor DAF-12.[1,2] Remarkably, in preclinical models of hyperinfection the activation of DAF-12 by DAs was able to suppress infection and to reduce lethality.[3] The readily availability of DAs is therefore crucial not only to better define their therapeutic potential but also to enable medicinal chemistry investigations towards more effective modulators. In this communication, we report a novel, straightforward synthesis of DAs starting from the readily available and low-cost Ergosterol (Figure 1). The new synthetic route is superior to previously reported methods as it furnishes DAs in good yield and high purity, also at large scale. The synthesized ligands have been tested in terms of human receptor selectivity, physicochemical and metabolic profile unveiling some hidden properties shared by the molecular shape of DAs that can be exploited in the design of novel and highly potent DAF-12 modulators for the treatment of parasitic disorders, such as Strongyloidiasis.[4]

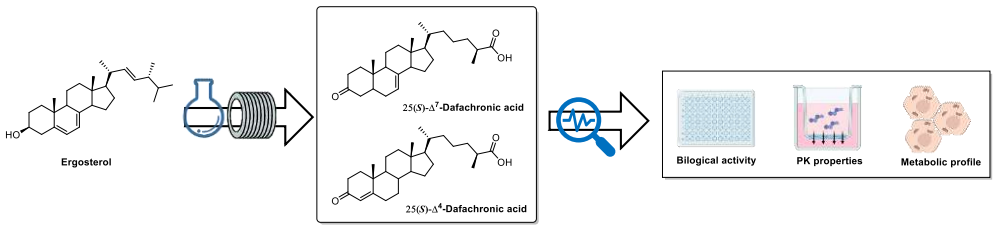

Figure 1: Overview of the synthesis, structure and profiling of endogenous DA-12 ligands dafachronic acids.

References:

[1] D.L. Motola, C.L. Cummins, V. Rottiers, K.K. Sharma, T. Li, Y. Li, K. Suino-Powell, H.E. Xu, R.J. Auchus, A. Antebi, D.J. Mangelsdorf, Cell 2006, 124, 1209–1223.
[2] Z. Wang, X.E. Zhou, D.L. Motola, X. Gao, K. Suino-Powell, A. Conneely, C. Ogata, K.K. Sharma, R.J. Auchus, J.B. Lok, J.M. Hawdon, Proc Natl Acad Sci USA 2009, 106, 9138–9143.
[3] J.B. Patton, S. Bonne-Année, J. Deckman, J.A. Hess, A. Torigian, T.J. Nolan, Z. Wang, S.A. Kliewer, A.C. Durham, J.J. Lee, M.L. Eberhard, D.J. Mangelsdorf, PNAS 2018, 115, 204-209.
[4] Ending the neglect to attain the Sustainable Development Goals: A road map for neglected tropical diseases 2021–2030, https://www.who.int/publications/i/item/9789240010352 (last access: 15/02/2024)

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FAR-PO-011

Identification of novel potential elastase inhibitors with anti-aging activity using computational alanine scanning and pharmacophore modelling

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Skin aging is characterized by wrinkles, fine lines, loss of elasticity, and non-uniform pigmentation due to a combination of exogenous factors, including U.V., chemicals, pollutants, and endogenous factors, such as cellular metabolism, genetic mutations, and hormonal factors.[1] A main hallmark of skin aging is the loss of structure in the extracellular matrix, which contains numerous proteins, including collagen and elastin, that play an important role in maintaining skin elasticity. Extracellular matrix degradation is mainly due to the increased activity of certain proteolytic enzymes, such as elastase, which is responsible for the breakdown of elastin.[2] Inhibition of this enzyme can lead to increased skin elasticity, preventing the formation of wrinkles and sagging.[3]

In this regard, we present a study aimed at identifying potential small molecules capable of inhibiting elastase enzyme by computational approaches. Several hotspot residues on elastase were identified using a combination of pharmacophore modelling, computational alanine scanning and molecular dynamics.

Then, an accurate pharmacophore was created, consisting of a hydrogen bond donor, two acceptors, and two hydrophobic features. This pharmacophore was used screen in silico different libraries, including naturals and synthetics compounds. Molecular docking studies were carried out to investigate the binding mode of the selected hits. Finally, binding free energy was calculated and a series of molecular dynamic simulations were performed to gain information about the stability of protein-ligand complexes.

References:

[1] I. Kalyana Sundaram, D.D. Sarangi, V. Sundararajan, S. George, S. Sheik Mohideen, BMC Complement Altern Med. 2018, 18, 33.
[2] F. Pintus, S. Floris, A. Fais, B. Era, C. Porcedda, C.I.G. Tuberoso, C. Caddeo., Plants (Basel) 2022, 11, 1849.
[3] F. Pintus, S. Floris, A. Fais, B. Era, A. Kumar, G. Gatto, E. Uriarte, M.J. Matos, Molecules 2022, 27, 6914.

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FAR-PO-012

Functionalizing Photonic Biochips With CXCR4 Antagonist: Towards A New Potential Easy-Accessible Detection Strategy Of CXCR4-Overexpressing Circulating Tumor Cells

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Point-of-Care (PoC) tests based on biomarkers represent useful tools for diagnosing and monitoring tumor diseases. In this context, we aimed at implementing PoC Test devices for the development of diagnostic strategies for the early detection of circulating tumor cells (CTC). Specifically, the CXCR4 chemokine receptor, overexpressed in more than 30 different types of solid and hematological tumors1, was considered as "hallmark" to be detected by applying photonic biochips previously functionalized with CXCR4-ligands. Specifically, peptide L10 (Ac-Arg-Ala-[Dap-Arg-2Nal-His-Glu]-COOH), recently characterized as potent and selective CXCR4 antagonist, was modified to identify a suitable position within the sequence for introducing a residue of L-Cys, which could be employed to anchor the peptide on an Au-functionalized solid surface. The described peptides were endowed with the following general structure: Ac-Cys-X-Arg-Ala-[Dap-Arg-2Nal-His-Glu]-COOH, where X represents an amphiphilic linker that was modulated in composition and length. This strategy led to the identification of two promising selective and potent CXCR4 antagonists, which were employed to functionalize photonic biochips (CXCR4-PB)2. As a proof of concept, the CXCR4-functionalized biochips obtained were initially evaluated in the presence different concentration (1 x 102 to 2.5 x 104 cells/ml) of both CXCR4-positive (CXCR4+) and CXCR4-negative (CXCR4-) CHO cells, showing the capability to specifically detect the receptor at concentrations comparable to those of the CTC in cancer patients. Encouraged by these promising results, ongoing investigations involve various solid tumor-derived cancer cells expressing different levels of CXCR4 (e.g., CEM, HCT116, HT29 and ASPC-1). The primary objective is to establish the lowest limit of detection for our Point-of-Care tests before advancing to their application in more complex biological matrices such as blood.

References:

[1] S. Scala, Cancer Res. 2015, 21, 4278-85
[2] N. Cennamo, A. Piccirillo,D. Bencivenga, F. Arcadio, M. Annunziata ,F. Della Ragione , L. Guida , L. Zeni , A. Borriello, Talanta 2023, 256,124284

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FAR-PO-013

Expanding the chemical space to discover new *Mycobacterium avium* Efflux Pump Inhibitors

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Antimicrobial resistance (AMR) is one of the most complex threats to human health. In the field of nontuberculous mycobacteria (NTM), especially *Mycobacterium avium* complex (MAC), high intrinsic multidrug resistance (MDR) is observed due to decreased permeability of the mycobacterial cell wall and drug efflux mediated by efflux pumps (EPs). Treatment of such infections is a clinical challenge due to the long duration, cost, and high likelihood of failure. *M. avium* EPs can extrude macrolides, leading to the emergence of macrolide-resistant phenotypes. Therefore, the development of efflux pump inhibitors (EPIs) represents a strategy to restore the efficacy of already approved antibiotics that are substrates of EPs, such as clarithromycin (CLA).[1]

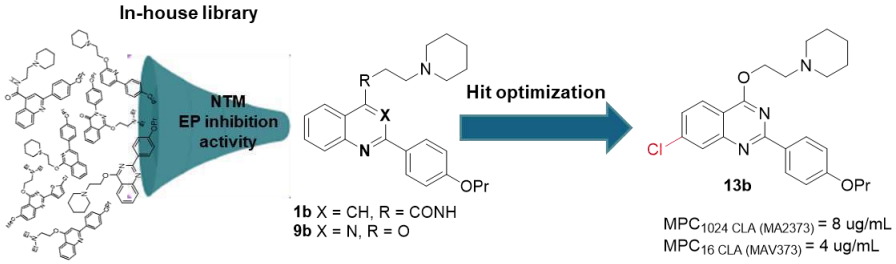

Figure 1: Schematic representation of the present work

Due to the lack of in-depth knowledge of the structure of NTM EPs, only a few molecules characterized by a narrow chemical diversity have been reported as NTM EPIs.[2] In this study, with the aim of expanding the chemical space of NTM EPIs, a selection of compounds from an in-house library was screened to evaluate their NTM EPI activity against *M. smegmatis* mc^{2}155 and the clinical isolates *M. avium* 2373. Compounds **1b** and **9b** emerged as promising hits capable of synergizing with CLA at low concentrations and exhibiting a good safety profile. Analogues were designed with the aim of obtaining more information on the structure-activity relationship and improving potency as NTM EPIs, as was the case for compound **13b** (Figure 1). The synthetic procedures together with the biological data will be presented in this study.

References:

[1] L. Rodrigues *et al.*, *BMC Microbiol*. 2009, 34, 529 – 533.
[2] *a)* L. Rindi, *Int. J. Mol. Sci.* 2020, 21, 1 – 13. *b)* R. Cannalire *et al.*, *Eur. J. Med. Chem.* 2017, 140, 321 – 330. c) T. Felicetti *et al.*, *ACS Infect. Dis.* 2019, 5, 982 – 1000.

FAR-PO-015

Effects of Redox Alterations on Ligand Binding Properties of IDO1 Inhibitors.

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The heme-containing indoleamine 2,3-dioxygenase 1 (IDO1) catalyses the O2-dependent oxidation of L-tryptophan (Trp) to the immunosuppressive metabolite L-kynurenine (Kyn). This reaction is the rate-limiting step in the kynurenine pathway, which leads to the formation of NAD^+ and regulates the immune response in host-pathogen interactions.[1] Dendritic cells (DCs) exploit IDO1 activity to create an immuno-tolerogenic microenvironment and to maintain tolerance to self-antigens. These functions occur in tissues and organs that may feature variations in metabolic factors such as nutrients and growth factors, as well as chemical factors such as pH and redox conditions. Early studies highlighted altering redox conditions, independent of oxygen levels, controls the expression and catalytic activity of IDO1 in DCs.[2] At the protein level, this may occur through redox conditions that regulate the oxidative turnover of the heme cofactor and/or disulfide bridge formation of cysteine residues in IDO1.

Several types of inhibitors have been developed to modulate IDO1 catalytic activity, with different binding modes that may engage or not the heme group through a coordination bond to the iron atom.[3]

In this study, we have tested the hypothesis that redox conditions may affect the binding properties of inhibitors to the enzyme. At this aim, we have investigated the effect of reducing agents on the interaction between IDO1 and its inhibitors in clinical trials, using MicroScale Thermophoresis (MST) and nano Differential Scanning Fluorimetry (nanoDSF) techniques. Our results show that redox conditions have different effects on the dissociation constant (K_d) of distinct types of inhibitors to the enzyme and suggest how redox imbalances in the tumour microenvironment may contribute to drug resistance mechanisms against specific classes of IDO1 inhibitors, making them ineffective for clinical benefits.

References:

[1] A. Mammoli, A Riccio, E. Bianconi, A. Coletti, E. Camaioni, A. Macchiarulo, ChemMedChem, 2021, 16, 2732-2743
[2] M. L. Mattox, J. A. D'Angelo, B. L. Dickinson, Scand J Immunol, 2014, 79, 325-332.
[3] G. Jiafeng, A. Liu, Arch. Biochem Biophys, 2014, 544, 18-26

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FAR-PO-016

Structural simplification of imipridones to speed up the knowledge on the nature of the interactions with the human ClpP, a mitochondrial protease strictly linked to DIPG

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The human ClpP (*h*ClpP), a mitochondrial matrix caseinolytic protease, is responsible for the mitochondria proteostasis by degradation of misfolded and damaged proteins under the physiological regulation of the AAA+ ATPase chaperone ClpX. By consuming ATP, ClpX recognizes, unfolds, and translocates the tagged proteins into the *h*ClpP tetradecamer proteolytic cylindrical chamber to be degraded. High *h*ClpP expression levels were found in multiple tumor tissues in which may play an oncogenic role. Given that *h*ClpP inhibition by small molecule inhibitors has shown therapeutic effects in several tumour types, the chemo-activation of mitochondrial *h*ClpP can also exhibits promising anticancer properties[1]. The most successful ClpP activators belong to the class of imipridones and ONC201, also named dordaviprone, is the first-in-class of the series (Figure 1). Currently ONC201 is worldwide evaluated in a Phase 3 study in H3K27-altered glioma, including Diffuse Intrinsic Pontine Glioma (DIPG)[2]. Through *a rational drug design approach*, the tetrahydropyridopyrimidinone (THPPD) was identified as a new scaffold for *h*ClpP potent activators development (e.g. TR57). Structure optimization led to a novel series of piperazine derivatives as putative *h*ClpP activators. A structure-activity relationship study aimed at deeply knowing the nature of the interactions with the *h*ClpP to identify a better *h*ClpP activator will be presented.

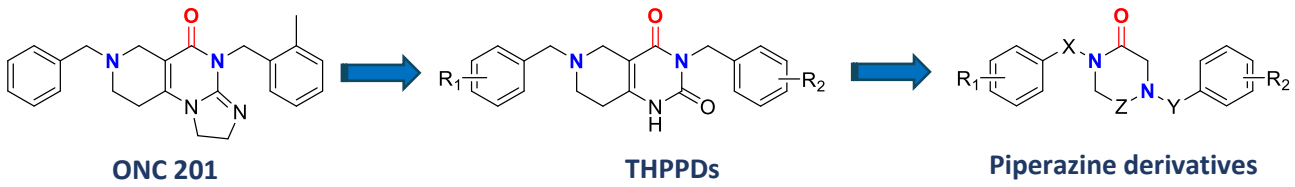

Figure 1: From ONC201 to novel piperazine derivatives as *h*ClpP activators.

References:

[1] M. Miciaccia, F. Rizzo, M.G. Perrone, A. Scilimati, et al. Harmaline to Human Mitochondrial Caseinolytic Serine Protease Activation for Pediatric Diffuse Intrinsic Pontine Glioma Treatment. *Pharmaceuticals (Basel).* 2024, *17*(1):135.
[2] M.G. Perrone, A. Ruggiero, A. Centonze, A. Carrieri, S. Ferorelli, A. Scilimati. Curr. Med. Chem. 2021, 28(17), 3287-3317.

FAR-PO-017

Low molecular weight cationic lipopeptides as innovative strategy for fighting antimicrobial resistance.

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Antibiotic Resistance is a global clinical issue caused by the widespread and incorrect use of antibiotics.[1] In this perspective, antimicrobial peptides (AMPs) are an emerging class of chemotypes that could represent new agents against resistant bacterial infections with a broad spectrum of activity. Unfortunately, AMPs have several pharmacokinetics limitations. To address these issues, several chemical modifications have been investigated. Among them, the reduction of the AMPs size and the conjugation of lipid moieties are emerging as promising strategies to improve antimicrobial activity and metabolic stability, minimizing the host cells toxicity[2]. Herein, a library of short lipopeptides was de novo designed and synthesized. These are endowed with a common peptide core consisting of Arg-Pro-Arg, wherein the Arg residues interact with the negatively charged bacterial counterpart, while the Pro, a well-known structuring amino acid, reduces the freedom degree of a spacer or a cationic amino acid bearing the fatty acid. The so-obtained lipopeptidomimetics were preliminary tested in vitro and a structure-guided design was employed to improve their activity and reduce their toxicity. Among all the synthesized tested lipo-peptidomimetics we identified some promising results, which displayed MIC values in the low-μM range against gram (-) and gram (+) bacteria and low-to-moderate toxicity versus host cells, favourable stability in human serum and a considerable ability to inhibit and destroy a biofilm of Staphylococcus aureus. Finally, this candidate is now under investigation for its potential capability to serve as the potential adjuvant in combination with conventional antibiotics.

References:

[1] M Erdem Büyükkiraz., & Z. Kesmen, J Appl Microbiol. 2022 Mar;132(3):1573-1596
[2] ZY Ong , N Wiradharma , YY Yang Adv Drug Deliv Rev. 2014 Nov 30;78:28-45.

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FAR-PO-018

Isocyanide: A Paradigm Shift in Medicinal Chemistry

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The **isocyanide** stands out as an intriguing entity, owing to its **chameleonic reactivity** that has made it a widely utilized reactant in organic synthesis, especially in multicomponent reactions (MCRs). Despite its pivotal role in the biological activity of natural compounds, isocyanides have historically been overlooked by medicinal chemists due to misconceptions about their toxicity, reactivity, and metabolic instability. Additionally, the structural complexity and limited availability of natural isocyanides have contributed to this neglect. However, our recent investigations have revealed that, under specific molecular contexts, the isocyanide group can **resist human metabolism** and show promise as a pharmacophoric group in medicinal chemistry.[1] Notably, its unique attributes, such as its ability to act as a hydrogen bond acceptor with a high dipole moment, to serve as a π hole acceptor, and to function as a metal coordinating agent, coupled with its chemical inertness to major nucleophiles present in the organism at room temperature, render it an **aggressive pharmacophore**.

Therefore, our aim is to systematically utilize the isocyanide as a pharmacophoric group, integrating it into chemically straightforward and expeditiously synthesized structures, with the goal of deploy them in medicinal chemistry screening campaigns, particularly within the domains of **antimicrobial and oncological research**.

As a demonstration of the potential of the isocyanide group in drug discovery, we have developed a **one-pot synthetic strategy** to generate molecules containing an isocyanide warhead group using either a Ugi or Passerini MCR. Many of these isocyanides demonstrated **potent antibacterial activity** against the **multidrug-resistant strain *Staphylococcus aureus* MU50**, which is resistant to vancomycin, the antibiotic of last resort. These compounds do not exhibit **any cytotoxicity on human cell lines** at concentrations up to 100 times their MICs values and **preliminary *in vivo* studies** on a *C. elegans* model have confirmed their efficacy and safety.

In the oncological field, we are employing isocyanides to hit various targets important for tumors. For instance, by harnessing their significant ability to coordinate heme iron, we have developed isocyanides capable of **inhibiting cytochrome CYP4A11**, implicated in different types of **cancer**. Some of these compounds, besides demonstrating potent inhibitory capacity (IC_{50} = 57 nM), have also shown excellent selectivity towards other cytochrome isoforms.

Therefore, the use of the neglected isocyanide as a pharmacophoric group could potentially determine a **paradigm shift in the treatment of multidrug-resistant infections** and it can provide **new treatment opportunities for oncological pathologies.**

References:

[1] A. Massarotti, F. Brunelli, S. Aprile, M. Giustiniano, G. C. Tron, Chem. Rev. 2021, 121 (17), 10742–10788.

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FAR-PO-019

NR2F2 and NR2F6 as targets for drug repurposing: an insight by means of computational analysis

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Within the framework of the PNRR project "HEAL ITALIA", we focussed our interest on a small group of orphan nuclear receptors (ORFs), a small family of ligand-dependent transcriptional factors (15 members) controlling the expression of various target genes. In this context, we performed structural analyses aimed at identifying small organic molecules capable of interacting with the selected sub-group of ORFs. The ultimate goal of the study is to identify compounds available in public drug databases, which may be ready to be tested against target ORFs in view of rapid translational medicinal chemistry applications "from the bench to the bed".

Like all ORFS, NR2Fs constitute a sub-group of three receptors lacking endogenous ligands, i.e. NR2F1 (COUP-TFI, EAR-3), NR2F2 (COUP-TFII, ARP-1) and NR2F6 (COUP-TFIII, EAR-2). Structurally, the two most important regions of NR2Fs are the DBD (DNA binding domain) and the LBD (ligand binding domain), which act independently from each other. The overall structures of DBDs and LBDs are very similar in the three NR2F family members. In contrast, the structures of the N-terminal and the C-terminal regions of ORFs are variable. Indeed, the C-terminal region is missing in some ORFs and the knowledge on its functional significance is limited. Because of their central role in cell growth, NR2Fs are promising candidates as novel therapeutic targets in the treatment of cancer[1]. In the present study, we conducted a computational analysis on the X-ray crystal structures of the human NR2F2 ligand binding domain (PDB ID: 3CJW) and the human NR2F6 ligand binding domain (PDB ID: 8C5L). The initial aim of these analyses was to identify potential hotspot binding sites and to predict their druggability. Subsequently, we used the identified binding sites to perform a virtual screening protocol, involving pharmacophore models and docking studies, on large libraries such as Drugbank, FDA and commercial libraries for drug repurposing.

We identified a number of drug hits as possible ligands/inhibitors of the target ORFs. Currently, we are in the process of verifying the ability of these compounds to interact with and modulate the activity of NR2Fs with the use of suitable biological tests.

References and Notes:

The research leading to these results has received funding from the European Union - NextGenerationEU through the Italian Ministry of University and Research under PNRR - M4C2-I1.3 Project PE_00000019 "HEAL ITALIA"

[1] T. Sajinovic, G. Baier, Front. Biosci. (Landmark Ed) 2023, 28, 13.

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FAR-PO-020

Novel Opportunities to Fight Pancreatic and Prostate Cancer Exploiting 1,2,4-Oxadiazole-Bearing Compounds

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Pancreatic ductal adenocarcinoma (PDAC) is one of the most lethal malignancies, with an average 5-year survival rate of 11%, mainly due to the lack of early diagnosis and limited response to treatments. Prostate cancer is the second most frequent cause of cancer death in men, with around 1.2 million of new cases diagnosed each year. Chemoresistance is a key impediment for treating both diseases, and drugs with innovative mechanisms of action could allow to overcome resistance to therapies. The 1,2,4-oxadiazole ring is considered a privileged scaffold in drug discovery, and it constitutes the pharmacophore moiety of several anticancer agents. Starting from an in-house library of 1,2,4-oxadiazole derivatives, we evaluated the antiproliferative activity towards two different human prostate cancer cell lines, DU-145 and LNCaP. In addition, we investigated the ability of the two most active compounds (**11** and **16**) to inhibit cell migration using wound healing assays in DU-145. Compounds **11** and **16** were also tested in two different pancreatic cancer cell lines (PANC-1 and MIA PaCa-2) and they showed low micromolar IC_{50}s. Early ADME-Tox investigation were performed to exclude drug-drug interaction, cardiotoxicity and cytotoxicity. In addition to the 1,2,4-oxadiazole ring, compounds **11** and **16** contain a 3-Br-4,5-dihydroisoxazole (BDHI)[1] nucleus, which is known to behave as a moderately reactive warhead. Thus, these compounds are expected to act as covalent inhibitors. Target(s) identification via mass spectrometry under denaturing conditions is currently ongoing, using PDAC cell lysates exposed to compound **16** under conditions mirroring those inducing antiproliferative effects. Overall, we identified novel agents for the treatment of pancreatic and prostate cancers, and their novel mode of action is currently being elucidated.

References:

[1] A. Galbiati, S. Bova, R. Pacchiana, C. Borsari, M. Persico, A. Zana, S. Bruno, M. Donadelli, C. Fattorusso, P. Conti. Discovery of a spirocyclic 3-bromo-4,5-dihydroisoxazole covalent inhibitor of hGAPDH with antiproliferative activity against pancreatic cancer cells. *Eur J Med Chem* 2023, 254, 115286.

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FAR-PO-021

Pre-ADMET studies of 5-(3',4'-dihydroxyphenyl)-γ-valerolactone, the bioactive intestinal catabolite of proanthocyanidins.

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The interest for 5-(3',4'-dihydroxyphenyl)-γ-valerolactone (VL) has increased as it is one of the major metabolites derived from the catabolism of flavonoids by gut microbiota and is a well-known compound with health-promoting effects. However, the pre-ADMET properties have not yet been clarified due to the lack of a commercially available standard. Therefore, the purpose of this study is to understand and demonstrate the mechanism of absorption, efflux, metabolic stability, cytotoxicity, and druglike properties of synthetized VL, to fully comprehend the correlation between PACs and VL biological activities[1].

To evaluate the absorption, Caco2 and Wt-MDCK monolayer models were chosen and a UPLC-QqQ platform was used to quantify VL and to calculate its apparent permeability and efflux ratio. VL is rapidly metabolized into its phase II metabolite, 5-(hydroxyphenyl)-γ-valerolactone sulfate (VLS), which was confirmed by LC-HRMS. Although VLS showed in both models an apparent permeability acceptable for the oral route of administration the efflux ratio values found are discrepant in the two models: in Caco2 it is >2 but lower in Wt-MDCK, indicating that VLS is a substrate of an efflux transporter more expressed in Caco2 cell line (BCRP)[2]. Phase II and I metabolism of VL was evaluated with human liver S9 and microsome fraction (HLM). VL was found to be rapidly degraded in the S9 fraction (t ½ 8.72 minutes) but degraded at a slower rate in HLM (t ½ 23.08 minutes). Most importantly, in the S9 fraction, VL forms two different phase II metabolites over time, both glucuronic adducts, on the two possible sites of the molecule; moreover, the sum of glucuronic conjugates accounts for 49% of the metabolized VL. VL has been tested for its modulation of major CYPs, demonstrating its metabolic safety.

In conclusion, VL is widely absorbed as sulfate conjugate in the intestine and reaches systemic circulation. The sulfation pathway is reversible, and reversal is presumed to be mediated by arylsulfatase[3], hence the active form VL can circulate and reach the liver, where VL can be further metabolized into its glucuronide adducts. Finally, it neither induces nor blocks major CYPs and gene receptors that can alter its expression, nor efflux systems, causing no herb-drug interaction.

References:

[1] P. Mena, Nat. Prod. Rep. 2019, 36 (5), 714–752.
[2] D. Volpe, Future Medicinal Chemistry 2011, 3 (16), 2063–2077.
[3] M.W.H. Coughtrie, Chemico-Biological Interactions 1998, 109 (1–3), 3–27.

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FAR-PO-022

Planning and development of new potential diimidazopyrimidine molecular tools for the binding on G-quadruplex structures

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Among innovative targets for cancer research, non-canonical structures of nucleic acids like G-quadruplex (G4), have represented an interesting focus in Medicinal Chemistry with the design of new G4-ligands able stabilize them, leading to the blocking of the catalytic activity of key and eventually to cell death.[1] A first diimidazopyrimidine core[2] was studied as a starting point for the development of new ligands, and the use of SAR together with techniques like FRET and CD spectroscopy, were helpful to optimize the design, the activity and selectivity of the analogues affording to FG (**Figure 1**),[3] a well-studied hit compound. Previous modification paved the way to a para-functionalization of the ring, making the synthesis of new potential molecular tools possible, where the FG scaffold could be enriched by other useful moieties for a later functionalization. Throughout the synthetic process we did not focus on the formation of the desired products only: mass and NMR analyses were used to characterize the byproducts formed throughout the synthesis, with the main aim of improving the yields of the reactions, optimizing the product formation. Moreover, our work will proceed with the synthesis of these candidates and with new one as well.

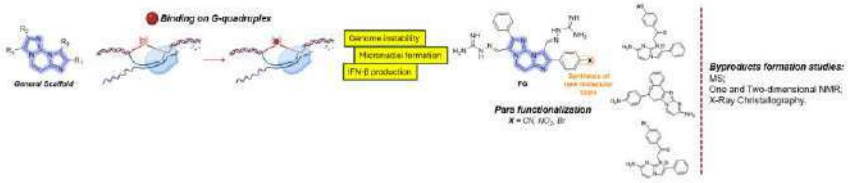

Figure 1

References:
[1] De Magis, A.; Manzo, S. G.; Russo, M.; Marinello, J.; Morigi, R.; Sordet, O.; Capranico, G. *Proc Natl Acad Sci U S A* **2019**, *116* (3), 816–825.
[2] Sparapani, S.; Bellini, S.; Gunaratnam, M.; Haider, S. M.; Andreani, A.; Rambaldi, M.; Locatelli, A.; Morigi, R.; Granaiola, M.; Varoli, L.; Burnelli, S.; Leoni, A.; Neidle, S. *Chemical Communications* **2010**, *46* (31), 5680–5682.
[3] Amato, J.; Morigi, R.; Pagano, B.; Pagano, A.; Ohnmacht, S.; De Magis, A.; Tiang, Y. P.; Capranico, G.; Locatelli, A.; Graziadio, A.; Leoni, A.; Rambaldi, M.; Novellino, E.; Neidle, S.; Randazzo, A. *J Med Chem* **2016**, *59* (12), 5706–5720.

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FAR-PO-023

Second generation pyridobenzothiazolone analogues as potent anti-flavivirus agents: beyond NS5 polymerase inhibition

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The mosquito-borne viruses belonging to the Flavivirus genus, such as Dengue (DENV), Zika (ZIKV), and West Nile (WNV) viruses, are responsible for a high number of infections in humans. These infections can range from mild flu-like symptoms to severe conditions like hemorrhagic fevers, hepatitis, and neuropathies.[1] Unfortunately, there are currently no effective and specific treatments available for flavivirus diseases and new anti-flavivirus drugs are urgently needed.[1]

For years, we have been researching pyridobenzothiazolone (PBTZ) analogues as anti-flavivirus agents targeting the NS5 RNA polymerase.[2] Recently, we also developed a sustainable three-component reaction for synthesizing the PBTZ scaffold, which allowed us to efficiently create a wide range of PBTZ analogues[3]. Building on our previous findings, this study reports the design, synthesis, and biological evaluation of a new series of PBTZ analogues. Although these new compounds lost their ability to inhibit the NS5 polymerase, they still showed potent anti-flavivirus activity. This lack of viral RNA polymerase inhibition is likely due to the absence of the carboxylic function at the C-4 portion of the molecule. Despite this, the new compounds still exhibited valuable anti-flavivirus activity in cell-based assays, with EC_{50} values against DENV-2 in the low µM range, albeit with sub-optimal selectivity indexes (SIs). Further medicinal chemistry efforts were undertaken to replace the liable ester functionality present at the C-4 position and explore the chemical space around the PBTZ core. These efforts led to the identification of a new set of C-2 modified PBTZ amide analogues with nanomolar EC_{50} values and SIs greater than 1000. Additional studies have provided insights into the new mechanism of action of this series of PBTZ derivatives that lack the carboxylic function. These studies indicated that the derivatives acted during the viral entry phase, highlighting the difference between them and PBTZ analogues from the first series. Additionally, investigations have shown that these compounds have a broad-spectrum antiviral activity against various RNA viruses. Furthermore, PBTZ derivatives demonstrated potent anti-DENV activity in an antibody-dependent enhancement (ADE) infection model. In summary, our findings highlight the potential of PBTZ derivatives as a promising class of anti-flavivirus agents, warranting further investigation and development.

References:

[1] X. Yang, M.B.M. Quam, T. Zhang, S. Sang, *J. Travel Med.* **2021**, *28*, taab146.
[2] T. Felicetti, G. Manfroni, V. Cecchetti, R. Cannalire, *ChemMedChem*, **2020**, *15*, 2391-2419.
[3] T. Felicetti, M.B. Burali, C.P. Gwee, K.W.K. Chan, S. Alonso, S. Massari, S. Sabatini, O. Tabarrini, M.L. Barreca, V. Cecchetti, S.G. Vasudevan, G. Manfroni, *Eur. J. Med. Chem.* **2021**, *210*, 112992.

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FAR-PO-024

Expanding the Toolbox for the Synthesis of Protein Degraders: Spotlight on BRD4-Targeting Hydrophobic-Tags

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To address the challenge posed by undruggable proteins, researchers have developed various approaches based on the use of small molecules to induce targeted protein degradation, including the growing success of Proteolysis Targeting Chimeras (PROTACs)[1]. Another promising technology is the Hydrophobic tag (HyTag)-based protein degradation, wherein ligands containing highly hydrophobic groups bind to the protein of interest (POI), mimicking a damaged or misfolded protein state. This represents the stimulus that eventually triggers the degradation of the POI through the Ubiquitin Proteasome System or the Lysosomal Autophagy Pathway[2]. In detail, HyTags consist of a ligand for the target protein, a linker, and a hydrophobic moiety such as adamantane, fluorene, and norbornene[3-5]. Compared to PROTACs, HyTags are not subject to the so-called "hook effect" and, due to their simpler chemical structure, they are endowed with a lower molecular weight and improved drug-like properties. Despite these advantages, synthesizing new HyTags is still a considerable challenge. The linker needs to be asymmetrically diversified, which leads to a long multistep synthesis. In our recent work, we conceived a multicomponent platform based on Ugi and Passerini reactions to synthesize PROTAC degraders in a single step[6]. To further study the scope of this methodology, we applied the platform to the *one-pot* synthesis of novel BRD4-targeting HyTags. In a short period, we successfully synthesized a library of HyTag-based degraders, among which a compound stands out for its effective degradation of BRD4 in MDA-B-231 cells. This finding further corroborates the potential of Hy-tags as a new approach for targeted protein degradation and points out our multicomponent platform as an efficient and versatile tool for the synthesis of new protein degraders, regardless of the technology to which they belong.

References:

[1] M. Békés, DR. Langley, CM. Crews. Nat Rev Drug Discov, 2022, 21:181-200.
[2] S. Xie, J. Li, F. Zhan, H. Yao, J. Xu, S. Xu, J Med Chem, 2023, 24;66:10917-10933.
[3] Q. He, X. Zhao, D. Wu, S. Jia, Z. Cheng, F. Huang, Y. Chen, T. Lu, S. Lu. Eur J Med Chem, 2023, 260:115741.
[4] S. Xie, F. Zhan, J. Zhu, Y. Sun, H. Zhu, J. Liu, J. Chen, Z. Zhu, DH. Yang, ZS. Chen, H. Yao, J. Xu, S. Xu. Angew Chem Int Ed Engl, 2023, 62:e202217246.
[5] A. Go, JW. Jang, W. Lee, JD. Ha, HJ. Kim, HJ. Nam. Eur J Med Chem. 2020, 204:112635.
[6] IP. Bhela, A. Ranza, FC. Balestrero, M. Serafini, S. Aprile, RMC. Di Martino, F. Condorelli, T. Pirali. J Med Chem. 2022, 65:15282–99.

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FAR-PO-025

Pyrazine-based CK1δ inhibitors as potent neuroprotective agents

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Casein Kinase 1δ is a serine/threonine kinase involved in several biological processes, including mitotic checkpoint signaling, DNA repair, circadian rhythm, Wnt signaling, endocytosis and neurodegenerative disease progression.[1] Thus, the importance in finding new inhibitors towards this enzyme. The base of the project comes from an in-house screening of some pyrazine-derivatives that showed interesting activity towards CK1δ, in particular compound **1** that displayed an IC_{50} of 1.86 μM and represented the starting point for the structure optimization. In this work we explored the chemical space around pyrazine scaffold by introducing different substituents, considering aromatic groups, alkyl chains and both linear and cyclic amines (**Figure 1**). The obtained results allow to define a structure activity relationship and, supported by both docking studies and X-ray structure analysis of molecules-target co-crystals, a strong structural optimization has been carried out, leading to active compounds in the nanomolar range. Most promising compounds have been preliminary assayed for their neuroprotective effect on a neuronal cell model, giving encouraging results.

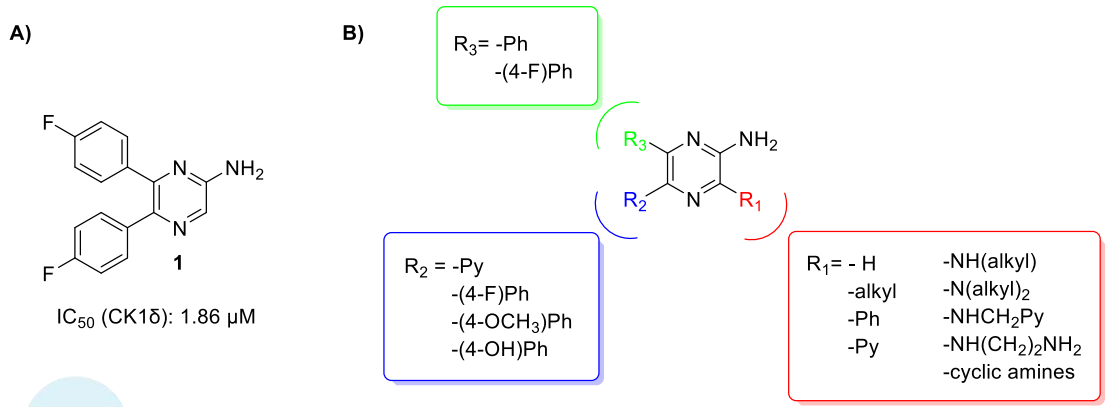

Figure 1: Panel A: Structure of compound **1**, starting point of this work, and its inhibitory activity towards the enzyme. Panel B: schematic representation of the investigation on the pyrazine scaffold.

References:

[1] P. Xu, C. Ianes, F. Gärtner, C. Liu, T. Burster, V. Bakulev, N. Rachidi, U. Knippschild, J. Bischof, Gene 2019. https://doi.org/10.1016/j.gene.2019.144005.

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FAR-PO-026

Synthesis of CK1δ covalent inhibitors: fascinating molecules to investigate the therapeutic role of the enzyme

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Casein Kinase (CK) 1δ is a protein that belongs to the class of serine-threonine kinases. A dysregulation in the activity of CK1δ can bring to hyperphosphorylation of substrates potentially related to the development and progress of pathological conditions including cancer and neurodegenerative diseases.[1] Among pharmacological tools useful to investigate the potential therapeutic role of CK1δ inhibition, covalent inhibitors, which could have some advantages respect to reversible inhibitors, are still missing. To bridge the gap, a series of covalent CK1δ inhibitors were designed, starting from the already known inhibitor reported in **Figure 1a**,[2] with the aim to target the catalytic Lys38 residue (**Figure 1b**).

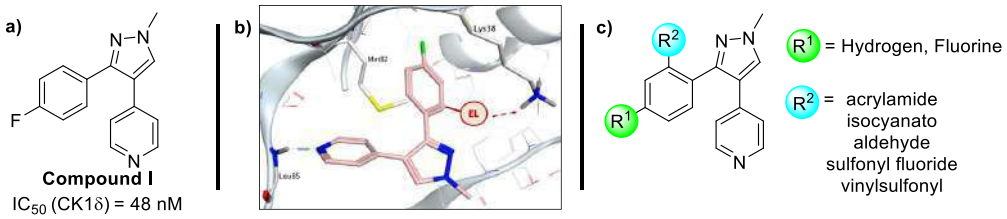

Figure 1: (**a**) Known reversible inhibitor used for the synthesis of CK1δ covalent inhibitors; (**b**) Representation of the hypothetical covalent bond formation in CK1δ; (**c**) Designed CK1δ covalent inhibitors.

Different electrophiles, chosen among the most common used to covalently bond a lysine residue, were introduced at the 2 position of the phenyl ring of compound I (**Figure 1c**).[3] Obtained results allow to point out a strict steric control at the 2 position, with most of the common electrophiles giving clashes in the CK1δ binding cleft. This has been confirmed both from enzyme activity assays and from computational studies. On the most promising compounds further characterization have been performed to prove the covalent nature of the binding between the molecule and the target enzyme.

References:

[1] D. Catarzi, F. Varano, E. Vigiani, C. Lambertucci, A. Spinaci, R. Volpini, V. Colotta, Current Medicinal Chemistry 2022, 29, 4698-4737.
[2] S. Mente, E. Arnold, T. Butler, S. Chakrapani, R. Chandrasekaran, K. Cherry, K. DiRico, A. Doran, K. Fisher, P. Galatsis, M. Green, M. Hayward, J. Humphrey, J. Knafels, J. Li, S. Liu, M. Marconi, S. McDonald, J. Ohren, V. Paradis, B. Sneed, K. Walton, T. Wager, Journal of Medicinal Chemistry 2013, 56, 6819-6828.
[3] Z. Zhao, P.E. Bourne, Pharmaceuticals 2022, 15, 1322.

FAR-PO-027

Extraction, analytical profile and biological activity of white grape by-product: an example of circular economy

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The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials as long as possible aiming to extend the life cycle of products. In this case our goal is the valorization, from the perspective of circular economy, of distillation subproducts, to produce nutraceuticals for the consumer care. This project is conducted in collaboration with Bonollo Distillery which gave us raw material, more specifically white grape skin (WGS) as by product of grappa process. Firstly, WGS was pulverized in liquid nitrogen and the resulting matrix was extracted setting up different methods either with water and with a hydro-alcoholic solution [1]. The hydro-alcoholic extract (HAE) was further treated with a resin (Sepabeads SP207) in order to enrich its polyphenol content. The polyphenolic profile have been characterized for both the extracts with hyphenated techniques. A qualitative analysis with LC-HRMS identified 51 compounds in HAE and a total of 39 compounds in the aqueous extract (AE). A subsequent quantitative analysis and the determination of the total polyphenol content by HPLC-PDA confirmed a richer profile in HAE compared to AE. Also spectroscopic analysis have been performed to furtherly characterized the two extracts. Moreover, HAE and AE have been tested on two different cell lines with gene reporter for the transcriptional factors Nrf2 e NfkB in order to evaluate their anti-oxidant and anti-inflammatory activity, respectively. Interestingly results showed that AE, despite its less abundant polyphenolic composition, present a stronger anti-inflammatory effect (from 1 μg/ml) in respect to HAE, totally independent from the NRF2 pathway since AE resulted unable to modulate the NRF2 activity. The scale up was made from the AE since it presents an easier and greener method of extraction with a strong anti-inflammatory activity. This industrial extract is called VITUVA® and was subjected again to all the analysis and tests of the parent extract AE in order to evaluate if AE properties have been mantained after the scale up process. Further studies will focus on the polyphenolic composition of HAE and AE in order to identify the compounds responsible of AE activity.

Concluding, we demonstrated that WGS may be effectively considered as a valuable source of polyphenols to be use as nutraceuticals to prevent / treat various inflammatory conditions highlighting the importance of the circular economy and the valorization of natural by products.

References:

[1] G. Baron, G. Ferrario, C. Marinello, M. Carini, P. Morazzoni, G. Aldini. Molecule 2021, 26 (18), 5454.

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FAR-PO-028

Dual Inhibitors of Brain Carbonic Anhydrases and Monoamine Oxidase-B Efficiently Protect against Amyloid-β-Induced Neuronal Toxicity, Oxidative Stress, and Mitochondrial Dysfunction

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We report here the first dual inhibitors of brain carbonic anhydrases (CAs) and monoamine oxidase-B (MAO-B) for the management of Alzheimer's disease.[1] Classical CA inhibitors (CAIs) such as methazolamide prevent amyloid-β-peptide (Aβ)-induced overproduction of reactive oxygen species (ROS) and mitochondrial dysfunction.[2] MAO-B is also implicated in ROS production, cholinergic system disruption, and amyloid plaque formation.[3] In this work, we combined a reversible MAO-B inhibitor of the coumarin and chromone type with benzenesulfonamide fragments as highly effective CAIs. A hit-to-lead optimization led to a significant set of derivatives showing potent low nanomolar inhibition of the target brain CAs (KIs in the range of 0.1-90.0 nM) and MAO-B (IC50 in the range of 6.7-32.6 nM). Computational studies were conducted to elucidate the structure–activity relationship and predict ADMET properties. The most effective multitarget compounds totally prevented Aβ-related toxicity, reverted ROS formation, and restored the mitochondrial functionality in an SH-SY5Y cell model surpassing the efficacy of single-target drugs.

References:

[1] D.M.N. Sikazwe, 2012, 1, 1000 – 1101.
[2] E. Canepa, R. Parodi-Rullan, R. Vazquez-Torres, B. Gamallo-Lana, R. Guzman-Hernandez, N.L. Lemon, F. Angiulli, L. Debure, M.A. Ilies, L. Østergaard, T. Wisniewski, E. Gutiérrez-Jiménez, A.C. Mar, S. Fossati, 2023, 9, 5048 – 5073.
[3] Z. Cai, 2014, 9, 1533 – 1541.

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FAR-PO-030

Synthesis and biological evaluation of Hsp90/HDAC6 dual inhibitors bearing a 2-amino-pyrrolopyrimidine and purine scaffold as potential anticancer drugs to treat prostate cancer

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Prostate cancer (PC) is the second common tumor diagnosed in men. Although current treatments are effective at the early stage of the disease, they lack efficacy in advanced stage and metastatic castrate-resistant prostate cancer (CRPC). HDAC6 and Hsp90 play a significant role in cellular processes and are involved in tumor genesis, metastasis and drug resistance.[1-2] Therefore, the possibility to simultaneous inhibit HDAC6 and Hsp90 would represent a promising strategy to treat CRPC. Recently, we identified potent pyrrolo-pyrimidine/purine HDAC inhibitors with excellent antiproliferative activity and anti-migration properties on PC.[3-4]

The 2-amino-pyrrolopyrimidine scaffold is also present in potent Hsp90 inhibitors. Thus, in the search of Hsp90/HDAC6 dual inhibitors we designed two series of 2-amino-pyrrolopyrimidine and purine derivatives carrying an hydroxamate or 3-hydroxyisoxazole as Zinc Binding Group required to coordinate the catalytic zinc ion present in the small hydrophobic pocket of HDAC6, and a benzyl linker of variable length with different decorations (**Figure 1**).

Two efficient synthetic routes were identified, allowing the obtainment of the desired products. The compounds were tested *in vitro* to assess their ability to inhibit recombinant HDAC6 and Hsp90. The results of the *in silico* design, chemical synthesis, and biological evaluation of the two series of compounds will be presented.

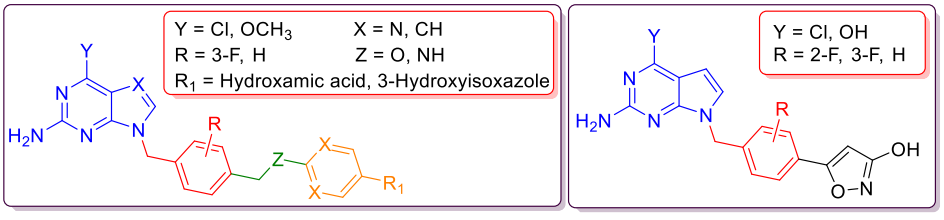

Figure 1: General structures of the dual HDAC6/Hsp90 inhibitors.

References:

[1] J. Trepel, M. Mollapour, G. Giaccone, L. Neckers, Nature Reviews Cancer, 2010, 10 (8), 537 - 549.
[2] A. Hoter, M. El-Sabban, H. Y. Naim, International Journal of Molecular Sciences, 2018, 19 (9), 2560, 1 - 33.
[3] P. Linciano, L. Pinzi, S. Belluti, U. Chianese, R. Benedetti, D. Moi, L. Altucci, S. Franchini, C. Imbriano, C. Sorbi, G. Rastelli, Journal of Enzyme Inhibition and Medicinal Chemistry, 2021, 36:1, 2080 - 2086.

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FAR-PO-031

Identification of drug repurposing candidates against prostate cancer through integration of chemoinformatics and machine learning approaches

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Prostate cancer (PC) is often associated with poor outcomes in advanced stages, primarily due to the emergence of drug resistance which limits current therapies efficacy, emphasizing the need for novel treatments.[1] Drug repurposing (DR) is a viable strategy to leveraging existing drugs with known safety profiles for new applications and bypassing traditional issues of drug development (*i.e.*, timelines, costs and failures).[2] Notably, integrating synergic techniques like chemoinformatics and machine learning (ML) offers advantages in DR processes.[3] To identify potential DR candidates, we performed in depth similarity screenings on DrugBank, identifying 138 ligands significantly similar to compounds with potent antiproliferative activity of PC cell lines. Interestingly, some of the identified ligands resulted to be previously tested against PC cells with favourable outcomes, but had never been considered for therapeutic repositioning.[4] More importantly, 90 ligands have not been evaluated against PC cells, thus representing new repurposing possibilities. These candidates have been tested on *in-house* developed ML classifiers to predict their antiproliferative activity of PC-3 cell lines.[5] The performed analyses allowed the selection of 11 drug candidates, that were tested *in vitro* on PC cells with different aggressiveness. Remarkably, several of the selected candidates showed marked antiproliferative activity, and represent valuable candidates for further experimental testing.

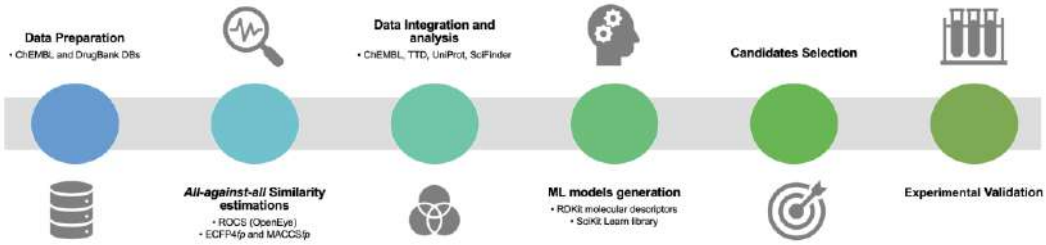

Figure 1: Workflow of the PC drug repurposing process.

References:

[1] P.A. Watson, V.K. Arora, C.L. Sawyers, Nature Reviews Cancer, 2015, 15, 701–711.
[2] B. Turanli, M. Grøtli, J. Boren, J. Nielsen, M. Uhlen, K.Y. Arga, A. Mardinoglu, Front. Physiol., 2018, 9, 500–520.
[3] E. March-Vila, L. Pinzi, N. Sturm, A. Tinivella, O. Engkvist, H. Chen, G. Rastelli, Front. Pharmacol., 2017, 8, 1–7.
[4] L. Bernal, L. Pinzi, G. Rastelli, Int. J. Mol. Sci., 2023, 24, 3135–3158.
[5] D. Bonanni, L. Pinzi, G. Rastelli, J. Cheminform., 2022, 14, 77–93

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FAR-PO-033

Deciphering HSP90 Interaction Dynamics: An AI-Guided Approach Towards Targeted Prostate Cancer Therapies

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The quest for effective and targeted prostate cancer therapies continues to pose significant challenges in the oncological research community. The chaperone protein Heat Shock Protein 90 (HSP90) has been identified as a critical facilitator of cancer cell survival and proliferation, making it a promising therapeutic target in prostate cancer.[1] This study introduces a novel methodology for identifying potent HSP90 inhibitors, utilizing precision in thermodynamic and kinetic calculations to elucidate the complex binding/unbinding dynamics of protein-ligand interactions. This study exploits AI's potential to drive enhanced dynamic sampling techniques,[2] using multidimensional collective variables through artificial neural networks optimized with supplementary AI systems.[3,4] This innovative method enables a thorough investigation of protein-ligand complex dynamics, accentuating critical elements like solvation dynamics, and the conformational changes of ligands, amino acids, and protein segments. Significantly, the research has achieved accurate predictions of experimentally evaluated residence times and binding free energies, alongside exploring binding conformations and providing insights into the mechanisms and modes of binding. The primary goal is to achieve a better understanding of the key molecular events occurring upon ligand binding/unbinding processes in HSP90, as a way to design inhibitors characterized by higher residence times, potency, and specificity.[5]

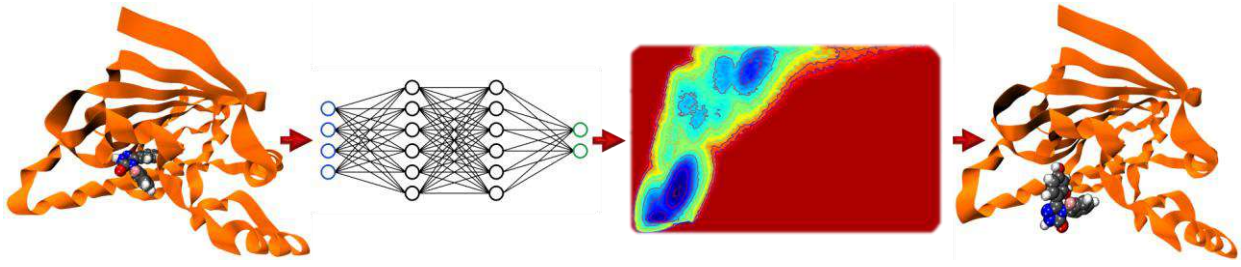

Figure 1: Summary representation of the kinetic and thermodynamic exploration process with visualisation of the binding/unbinding states of interest.

References:

[1] D. Mahalingam, R. Swords, J. S. Carew, S. T. Nawrocki, K. Bhalla, F. J. Giles, Br J Cancer 2009, 100, 1523 – 1529.
[2] M. Invernizzi, M. Parrinello, J. Phys. Chem. Lett. 2020, 11, 2731– 2736.
[3] E. Trizio, M. Parrinello, J. Phys. Chem. Lett. 2021, 12, 8621– 8626.
[4] T. Akiba, S. Sano, T. Yanase, T. Ohta, M. Koyama, KDD 2019, 2623 – 2631.
[5] R. Copeland, D. Pompiliano, T. Meek, Nat Rev Drug Discov 2006, 5, 730 – 739.

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FAR-PO-034

Investigation of Tau-Dependent Epigenetic Reprogramming in Alzheimer's Disease

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Tau is an intrinsically disordered protein mainly expressed in neuronal cells and has a crucial role in a group of neurodegenerative disorders, including Alzheimer's disease (AD). Targeting nuclear Tau or its cofactors might prevent nuclear accumulation and subsequent chromatin remodeling, which could lead to neuronal toxicity. TRIM28 is the only deeply investigated nuclear factor interacting with Tau, mediating its nuclear translocation. Moreover, the TRIM28 complex interacts with several enzyme families, such as histone deacetylases, and specific drugs can target this interaction. Specifically, Tau interacts with TRIM28, displacing HDAC1 from the complex, and consequently, HDAC1's nuclear function on chromatin remodeling is impaired.[1] Our research aims to reveal the nuclear Tau molecular mechanisms mediating gene expression alteration during AD disease's onset and progression. To address this goal, the design and functionalization of small molecules as modulators of the pathological Tau-dependent chromatin remodeling mechanisms are ongoing. A potent activator of HDAC1-mediated deacetylation, Exifone, with neuroprotective activity, was recently identified.[2] So, the work initially focused on identifying the allosteric binding site of Exifone in HDAC1 (**Figure 1**).

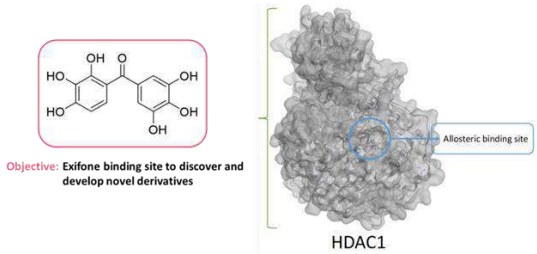

Figure 1: Identification of the allosteric binding site of Exifone in HDAC1.

The protein was studied using molecular dynamics (MD) simulations and docking calculations, and the allosteric binding site was identified. *In-silico* selection of candidate molecules and designed derivatives was performed. The novel-identified molecules will be screened to confirm their HDAC1 activation activity and, more generally, their neuroprotection activity.

References:

[1] G. Siano, G. Madaro, M.C. Caiazza, A. Allouch, M. Varisco, M. Mignanelli, A. Cattaneo, C. Di Primio, Front. Cell Dev. Biol. 2023, 17, 1151223.

[2] D. Patnaik D, P.C. Pao, W.N. Zhao, M.C. Silva, N.K. Hylton, P.S. Chindavong, L. Pan, L.H. Tsai, S.J. Haggarty, ACS Chem. Neurosci. 2021, 12 271–284.

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FAR-PO-035

Selective targeting of the bulge region in the (3+1) hybrid G-quadruplex of the PARP1 promoter through a Structure-Based Virtual Screening

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Poly(ADP-ribose) polymerase-1 (PARP1) has a key role in catalysing the polymerization of ADP-ribose units, connecting PAR polymers to itself or other proteins. Its structure comprises three domains that collectively manage PARP1's response to DNA damage. DNA lesions stemming from spontaneous single-strand breaks (SSBs) and base modifications can lead to alterations in base pairing and subsequent casual mutations associated with cancer. PARP1 binds to SSBs, starting the addition of PAR onto itself and the PARylation of other proteins, promoting mechanisms such as single-strand break repair (SSBR)[1]. Thus, in homologous recombination deficient (HRD) cancer cells, inhibiting PARP1 activity causes the increase of unrepaired single-strand DNA breaks that converge to double-stranded DNA breaks, inducing selective cell death. Consequently, several PARP1 inhibitors have been developed, showing promising outcomes in cancer treatment. However, acquired resistance to these inhibitors is a significant limitation, and alternative strategies need to be explored. A non-canonical G-quadruplex (G4) with a unique adenine bulge has been found in the promoter region of the PARP1 gene. This presents a highly selective target to disrupt PARP1 expression in cancer cells[2]. Therefore, through virtual screening of various databases, several compounds with a higher theoretical binding affinity to the non-canonical G4 compared to the G-quadruplex ligand RHPS4 have been identified. Further *in silico* analysis aimed to select compounds capable of binding to the G4 bulge region with high selectivity. Experimental studies are currently underway to validate their ability to bind to this form of G4 with this novel binding mode. If successful, these compounds could offer a promising and selective avenue for disrupting PARP1 expression in cancer cells.

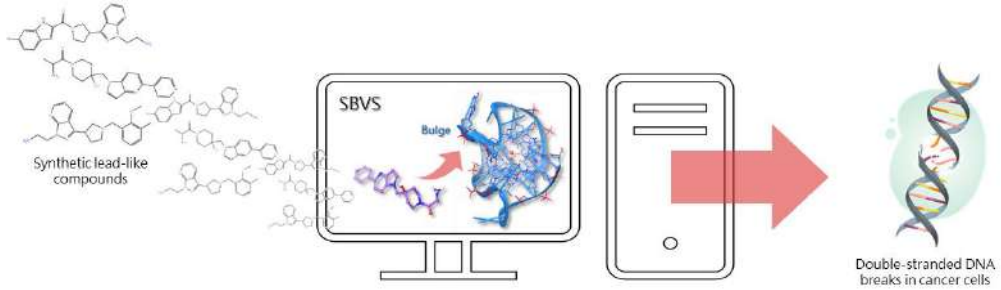

Figure 1: *In silico* identification of bulge selective binders towards non-canonical G4 in the PARP1 promoter.

References:

[1] Arnab Ray Chaudhuri, André Nussenzweig. *Nat Rev Mol Cell Biol*. **2017**, 18(10), 610-621.
[2] Anjali Sengar, J Jeya Vandana, et al. *Nucleic Acids Research*. **2019**, 47(3), 1564–1572.

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FAR-PO-036

Towards the development of a machine learning potential for Mg metal binding sites in proteins and nucleic acids.

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Rational drug design is facilitated by computational tools that enable precise predictions of interactions between small molecules and biological targets, including proteins, DNA, and RNA. In this context, a particular challenge is the modelling of metal ions, among which magnesium ions are of particular interest due to their essential role in numerous biological processes such as RNA folding and enzymatic catalysis. Molecular mechanics (MM) force fields often fall short in correctly representing the interactions of magnesium ions with their ligands, while quantum mechanics (QM and QM/MM) methods remain computationally demanding[1,2]. In recent years, machine learning demonstrated to be a powerful approach to constructing various forms of atomistic potentials. However, the extension of this approach to include metal ions is challenging, due to the highly diverse nature of the ligands and coordination geometries. To address this gap, we assembled a comprehensive dataset of magnesium organometallic complexes collected from the Protein Data Bank and the Cambridge Structural Database. Quantum chemical calculations at the wb97x/6-31g* DFT level of theory allowed to complement publicly available datasets of molecules built from second row elements. This data is used to run a first transfer learning experiment on a new network, dubbed OBIWAN[3], that we recently developed.

References:

[1] P. Li, K. M. Mertz, J Chem Theory Comput, 2014, 10, 289–297.
[2] P. Li, K. M. Mertz, Chem Rev, 2017, 117, 1564–1686.
[3] Martire S., Decherchi S., Cavalli A. OBIWAN: An Element-wise Scalable Feed-Forward Neural Network Potential, Submitted.

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FAR-PO-037

Development of a double-stable isotopic dilution LC-MS/MS method for the accurate determination of hyaluronic acid in biological matrices

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To date, analytical approaches to measure hyaluronic acid (HA) are based on the following steps: 1) protein removal and purification of HA; 2) enzymatic digestion of polysaccharides to the dimeric unit (*2-mer*, composed of D-glucuronic acid and N-acetylglucosamine); and 3) derivatization of the 2-*mer* unit and analysis of the adducts by LC-ESI-MS/MS. Most of the proposed methods do not include an internal standard (IS) to normalize HA extraction yield, hyaluronidase enzymatic efficiency and analyte response to MS analyzer. The innovation of the proposed method is the use of two isotope-labelled HA derivatives produced by recombinant technologies to meet these limitations. The method is based on direct enzymatic conversion of HA to the 4-*mer* oligomer by recombinant bacterial hyaluronidase from *Streptomyces koganeiensis* and its direct analysis without any derivatization and purification step by LC-ESI/MS-MS using a HILIC column. The yield of HA isolation and its enzymatic conversion to the 4-*mer* analyte was normalized by adding 100% ^{13}C-labeled HA to the sample before enzymatic conversion. Normalization of the MS response of the analyte was achieved by adding to the samples before mass analysis, a ^{13}C-4-*mer* isotope analogue obtained by enzymatic conversion of ^{13}C-HA enriched with 50% ^{13}C, followed by purification of the oligomers. HA enriched with 100% and 50% ^{13}C was bio-synthetically prepared using *Streptococcus equi* subsp. *equi* and D-glucose (U-$^{13}C_6$, 99%) as a carbon source in an animal-free minimal growth medium. Before precipitation, the HA produced was purified by active carbon filtration and ultrafiltration. Quantitative analysis of 4-*mer* was then carried out by multiple reaction monitoring (MRM) profiling, using *m/z* 757→554, *m/z* 785→574 and *m/z* 771→568 transitions for *4-mer* and its derivatives labelled 100% and 50% with ^{13}C, respectively. As expected, the use of the IS, normalizing the differences in extraction yield, enzyme efficiency and MS response of the analytes, greatly improved the precision and accuracy of the method. The R^2 value of the equation improved from 0.9312 to 0.9914 when constructed in the absence and presence of the double IS, respectively. Once validated, the method was then applied to measure HA in biological matrices and particularly in bovine vitreous humour and synovial fluid of healthy donors. In conclusion, the developed analytical method enabled the precise and accurate determination of HA in a complex biological matrix through the use of a double isotopic standard that can normalize the variation in enzyme efficiency and MS response of the analyte and can be easily adapted for HA determination in other biological and even pharmaceutical matrices.

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FAR-PO-038

Tackling Hepatocellular Carcinoma with Targeted Degraders of eIF6

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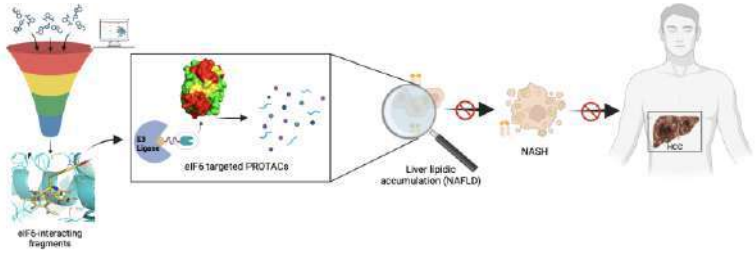
Translational control is the selective and regulated translation of specific mRNAs from the pool of the transcribed mRNAs. According to several studies, it is the major regulator of gene expression. eIF6 is a translation initiation factor that acts downstream the insulin pathway. Seminal work from Biffo's group has shown that mice heterozygous for eIF6 fail to upregulate protein synthesis in postprandial conditions, and simultaneously show a reduction in the accumulation of white fat. Subsequent studies have shown that translation factors amplify lipid accumulation by acting at the translational level. Increased lipid accumulation in the liver is known as non-alcoholic fatty liver disease (NAFLD), a prevalent condition in Western countries. Notably, fatty liver is the fastest growing cause of liver failure and hepatocellular carcinoma (HCC), the second leading cause of cancer-related death worldwide. Recently, it was observed that genetic eIF6 inhibition reduces lipid metabolism and the progression of NAFLD to HCC.

We hypothesize that eIF6 inhibition is an effective strategy for impairing the pathological evolution from a fatty liver (NAFLD) to non-alcoholic steatohepatitis (NASH) and then HCC, and the progression of HCC. To challenge this hypothesis, we aim to generate a set of small molecules able to selectively degrade eIF6, based on the emerging proteolysis targeting chimera (PROTAC) technology. Docking, molecular dynamics simulations and ligand binding free energy (by MM-GBSA approach) have been accomplished on compounds displaying promising in vitro activity on eIF6. The top scoring candidates are currently under development. The design strategy, chemical synthesis, and pharmacological investigation of this novel class of targeted protein degraders will be presented and discussed.



References:

[1] A. Scagliola, A. Miluzio, G. Ventura, S. Oliveto, C. Cordiglieri, N. Manfrini, D. Cirino, S. Ricciardi, L. Valenti, G. Baselli, R. D'Ambrosio, M. Maggioni, D. Brina, A. Bresciani, S. Biffo. Nat. Commun. 2021, 12(1), 4878.
[2] A. Scagliola, A. Miluzio, G. Mori, S. Ricciardi, S. Oliveto, N. Manfrini, S. Biffo S. Int. J. Mol. Sci. 2022, 23(14), 7720.

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FAR-PO-039

Exploiting the pyrazole scaffold for multipotent agents in Alzheimer disease

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Alzheimer disease (AD) represents a significant challenge in contemporary healthcare, and the urgency of finding effective treatments is underlined by the progressive increase in life expectancies and the resulting higher incidence of neurodegenerative diseases in aging population. Beyond the urgency of discovering a treatment for AD, there is the need to identify valid therapeutic targets that can combine the different pathological pathway of the disease.

GSK-3β is a serine/threonine kinase, ubiquitously expressed and widely found in central nervous system, where its dysregulation has been related to tau phosphorylation, Aβ deposition, reduced synaptic plasticity and inflammation. Since the primary function of kinases is to transfer a phosphate group from ATP to the substrate, targeting the ATP binding site proved to be a promising strategy to interfere with the activity of these enzymes. In this respect, designing drug candidates able to establish a network of hydrogen bonds with the hinge region is indeed a widely accepted strategy. The aminopyrazole can be considered a privileged scaffold, with a donor-acceptor-donor hydrogen bond pattern that could complementarily bind the hinge region of GSK-3β. Indeed, the acetamido derivative **A** (figure 1) emerged from a virtual screening as able to engage GSK-3β (IC_{50} = 39 μM).[1] Starting from this molecule, new derivatives were designed and in a first series a further amido-terminal group was introduced and different linkers were selected to connect the two functions. Moreover, the *N*-methylbenzyl terminal moiety was functionalized with *p*-H, *p*-OCH_3 and *p*-Cl. This series led to the hit compound **1c** (IC_{50} = 2.2 μM). In a second series of derivatives the maleic linker, which gave the best results, was maintained and substituents with different electronic and steric properties were introduced on the terminal benzyl ring. The compounds were tested for their GSK-3β inhibitory activity and for their ability to counteract Aβ aggregation. Moreover, due to their peculiar structure, the best compounds were also tested for their potential chelating properties towards some biometals overloaded in AD conditions.

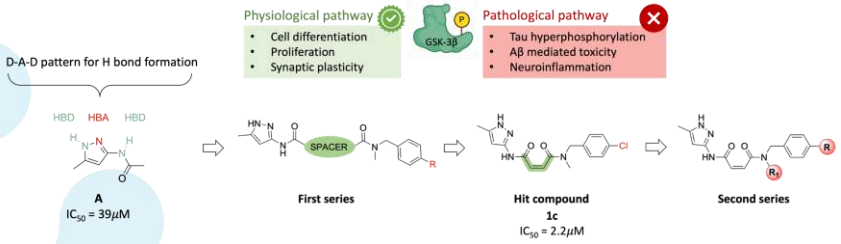

Figure 1. Design of the studied compounds

References:

[1] G. Bottegoni, M. Veronesi, P. Bisignano, P.Kacker, A. D. Favia, A. Cavalli, ChemMedChem2016,11, 1259–126

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FAR-PO-040

Optimization of human glutaminyl cyclase in vitro assay for inhibitor screening

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Glutaminyl cyclase (QC) is a zinc-dependent enzyme that converts N-terminal glutamine or glutamic acid residues into N-terminal pyroglutamate (pGlu or pE) residues through deamidation or dehydration. This conversion is important for enhancing protein stability against aminopeptidase activity and increasing protein hydrophobicity. QC is involved in stabilizing hormones, peptides, and proteins, but it has also been linked to neurodegenerative disorders such as Huntington's and Alzheimer's diseases. In Alzheimer's disease (AD), truncated and N-terminal modified Aβ species, particularly Aβ3pE and Aβ11pE, have recently gained significant attention due to their relevant presence in neuritic plaques. Additionally, the N-terminal pyroglutamate offers protection against in vivo proteolysis, increasing their potential as seeds for aggregate formation. Finally, compared to full-length Aβ, Aβ3pE was shown to be more toxic. This finding underscores that reducing the levels of pE-Aβ by inhibiting QC could be an effective strategy for treating AD[1]. Currently, available methods for in vitro evaluating QC activity and its inhibition are quite limited. *In vitro* QC activity bioassays available on the market are based on tandem reactions, which imply the use of an auxiliary enzyme, such as pyroglutamyl peptidase, to produce a measurable chromogenic product [2]. The direct evaluation of enzyme activity without the need for auxiliary enzymes would offer advantages in medicinal chemistry campaigns by reducing false positive outputs which may arise from a downstream interference with the report enzyme. In the search for a direct bioassay, our work builds upon a previously proposed method[3], that was set for ex-vivo quantification of QC activity. It involves the use of L-glutamine 7-amido-4-methylcoumarin hydrobromide as a substrate and quantification of product formation (per unit of time) by reverse phase chromatography (RP-HPLC) using a PATfix® HPLC system coupled with a UV-vis detection. The use of a C4 column with a 300A pore size ensures the separation of the enzyme from the substrate and product. Assay conditions were optimized in terms of protocol for reaction termination, substrate concentration, reaction time, assay buffer composition, and post-reaction stability prior to analysis. Finally, the optimized method was validated by assessing the inhibitory potency of PBD150, a well-known human QC inhibitor.

Acknowledgments: We acknowledge EU - NextGenerationEU with funds made available by the National Recovery and Resilience Plan (NRRP) Mission 4, Component 1, Investment 4.1 (M.D. 118/2023).

References:

[1] D.K. Vijayan, K.Y.J. Zhang, *Pharmacological Research*, 2019, 147, 104342-104354.
[2] S. Schilling, T. Hoffmann, M. Wermann *et al*, *Analytical Biochemistry*, 2002, 303, 49-56.
[3] A. Gunn, B. Wong, C. McLean *et al*, *Journal of Neurochemistry*, 2021, 156, 979-987.

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FAR-PO-041

New carbonic anhydrase modulators structurally related to histidine and histamine.

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Carbonic anhydrase (CA) was first discovered in 1933 by Meldrum and Roughton, who described its efficient catalysis for the reversible hydration of blood CO_2 to bicarbonate and protons.[1] This enzyme is so crucial for life that in over ninety years of studies it was found to be expressed in most if not all organisms. Eight families (α-ι) are known to date, among which the α family is the one expressed in human tissues. Many fundamental physiological processes have been correlated with the 15 human isoforms, such as electrolyte secretion, respiration, CO_2 transportation, gluconeogenesis, adipogenesis, ureagenesis, and more. Accordingly, altered activity or expression of these isoforms are correlated with numerous pathologies,[2] even if the role of some isoforms remains unclear. Several molecules behave as CA inhibitors (CAIs) by chelating the Zn^{2+} ion necessary for the catalytic activity, or as CA activators (CAAs) by increasing the catalytic rate of the enzyme. CAA are basic compounds that behave as proton shuttles, being part of a network formed of H-bonded water molecules and residues. Several X-ray structures of CA-activator complexes are available, including those of histamine (HST) and D- or *L*-histidine (HIS) with CA II.[3] Based on this information and on our group's effort in producing new piperazine scaffolds which already proved to generate some interesting selectivity,[4,5] we synthesized a series of rigid analogues of histidine (**figure 1**) as activator and then introduced a well known zinc-binding group to switch to inhibitors. The CA modulating properties and the isoform selectivity of the new compounds will be discussed in this presentation.

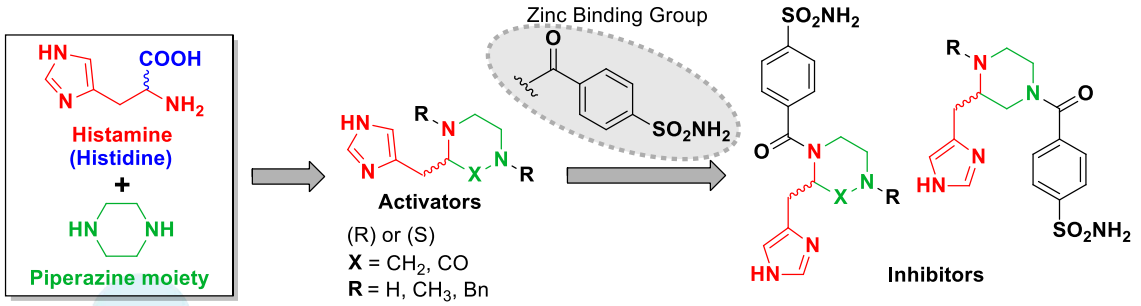

Figure 1: scheme of the work made. Merging the two structural moieties (box, left) allowed the obtaining of both CA activators and inhibitors.

References:

[1] N. U. Meldrum, F. J. W. Roughton, J. Physiol., 1933, 80, 113–142. [2] C. T. Supuran, Bioorg. Med. Chem. Lett., 2023, 93, 129411-129437. [3] C. Temperini et al, Chem. Eur. J., 2006, 12, 7057-7066. [4] N. Chiaramonte et al, Eur. J. Med. Chem., 2022, 228, 114026-114040. [5] N. Chiaramonte et al, Eur. J. Med. Chem., 2018, 151, 363–375.

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FAR-PO-042

Discovery of novel Tazemetostat analogs as dual inhibitors of EZH2 and HDAC

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It is well known that many pathways leading to cancer involve the overexpression of numerous epigenetic targets and/or depend mechanistically on their functions. Consequently, the epi-polypharmacological approach emerges as an effective tool to counteract cancer[1]. An interesting approach in this context is represented by the simultaneous inhibition of two or more targets involved in cancer pathogenesis, using hybrid molecules that possess different moieties and the ability to hit at the same time different targets. Epigenetic regulators like histone deacetylase inhibitors (HDACi) and EZH2 inhibitors have surfaced as potent instruments in cancer investigation, also in combination[2]. We based our work on Tazemetostat, a clinically approved EZH2 inhibitor, to develop new dual hybrids by incorporating HDAC enzyme inhibiting groups (EIG) such as *ortho*-aminoanilides and hydroxamic acids in its structure, and obtaining respectively the two lead compounds **MC4343** and **MC4355**. These compounds showed promising IC_{50} values in biochemical evaluation on both targets and were tested for their inhibition of proliferation in various B-cell lymphoma lines, including KARPAS422, Pfeiffer, SUDHL4, Toledo, and WSDL CL2. In particular, they showed a greater antiproliferative effect than Tazemetostat on SU-DHL-4 and Toledo, while maintaining comparable activity on other B-cell lymphoma lines. We also investigated the effect of such compounds on cell cycle using B-cell lymphoma lines and both compounds led to concentration-dependent increase in the pre-G1 phase, indicating potential apoptosis induction. Thus, we decided to merge the Tazemetostat scaffold with various both aromatic and aliphatic linkers, and then decorate them with hydroxamic acid and *ortho*-aminoanilide groups obtaining derivatives **1c-h** and **2c-f**. We also attempted to confer selectivity towards HDAC1-3 isoforms with two *o*-aminoanilides enriched with a fluorine atom in the *meta* position of the 2'-amino group and with a thiophene which, in the pharmacophoric model of HDACs inhibition, is able to confer selectivity for HDAC1/2[3], obtaining respectively **2a** and **2b**. Regarding EZH2, the new compounds showed inhibitory potency in the low nanomolar to single-digit picomolar range. Regarding HDAC isoforms, compound **2e** exhibited IC_{50} values in the low micromolar range for HDAC1-2, whereas **2c** demonstrated efficacy in specifically inhibiting HDAC6 at the nanomolar level. The most powerful compound was found to be **1e**, displaying selective inhibition against HDAC6 and 8 with IC_{50} values in the nanomolar range. Our new most potent inhibitors will be tested on various tumor lines to evaluate their antitumor potential.

References:

[1] H.Ü. Kaniskan, J. Jin, Curr Opin Chem Biol, 2017, 39, 100 - 108.
[2] X. Yang, L. Xu, L. Yang, Eur J Med Chem, 2023, 256, 115461.
[3] J. L. Methot, et al. Bioorg Med Chem Lett, 2008, 18 (3), 973-978.

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Development of dual PD-L1 and epigenetic-target based inhibitors as novel potential molecules for anticancer immunotherapy

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Research on cancer immunotherapy is recently making many strides, and the PD-1/PD-L1 signaling pathway is increasingly highlighted as a target to be inhibited to enhance the function of immune cells in cancer[1]. Interaction between PD-1 and its ligand PD-L1 leads to immunosuppression and blockade of T-cells' functionality, playing an important role in various malignancies where it can attenuate the host immune response to tumor cells[2]. Of note, impairments in the immune cycle, which are crucial for PD-1/PD-L1 immunotherapy resistance, could be restored by epigenetic modifications[3]. In particular, there is much scientific evidence about the efficacy given by the synergistic combination of PD-L1 antibodies and epigenetic drug inhibitors4. As an immune checkpoint in combination with epigenetic therapeutic agents, PD-L1 is able to improve immune recognition and tumor growth, leading to increased response rates in preclinical and clinical studies, recently summarized in[4]. Considering our experience in polypharmacology to overcome the main limitations of the single target therapy thus aiming at superior therapeutic effects, decreased adverse reactions, and a reduction of potential mechanism(s) of drug resistance caused by robustness and redundancy of biological pathways[5], we developed a series of dual inhibitor molecules which presented both PD-1/PD-L1 and various epi-target inhibiting properties. The developed compounds showed promising inhibiting activities in biochemical assays against the targets of interest, exhibiting balanced IC_{50} values against the PD-1/PD-L1 axis inhibition as well as against the chosen epigenetic targets (i.e., HDACs or LSD1). Currently, the most promising compounds are under evaluation in in vivo tumour xenograft mouse models.

References:

[1] Boussiotis, V. A. Molecular and Biochemical Aspects of the PD-1 Checkpoint Pathway. N Engl J Med 2016, 375 (18), 1767-1778. DOI: 10.1056/NEJMra1514296

[2] Keir, M. et al. PD-1 and its ligands in T-cell immunity. Curr Opin Immunol 2007, 19 (3), 309-314. DOI: 10.1016/j.coi.2007.04.012

[3] Kim, K.et al. Eradication of metastatic mouse cancers resistant to immune checkpoint blockade by suppression of myeloid-derived cells. Proc Natl Acad Sci U S A 2014, 111 (32), 11774-11779. DOI: 10.1073/pnas.1410626111

[4] Zwergel, C. et al. PD-L1 small-molecule modulators: A new hope in epigenetic-based multidrug cancer therapy? Drug Discov Today 2023, 28 (2), 103435. DOI: 10.1016/j.drudis.2022.103435

[5] Tomaselli, D.et al. Epigenetic polypharmacology: A new frontier for epi-drug discovery. Med Res Rev 2020, 40 (1), 190-244. DOI: 10.1002/med.21600

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Discovery of 2,3-Diaminoindole Derivatives as a Novel Class of NOD Antagonists

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NOD1 and NOD2 are the best characterized members of the NOD-like Receptor (NLR) family of proteins, a group including more than twenty pattern recognition receptors involved in the innate immune response to cellular injury and stress.[1] Overactivation of these proteins is implied in a wide range of human inflammatory disorders, and it has been related to the onset and progression of several human cancer types.[1] NOD antagonists would therefore represent valuable pharmacological tools to gain new insight into the role of these proteins, potentially leading to novel therapeutic strategies. Based on the chemical structure of Noditinib-1 (a potent and selective NOD1 antagonist),[2] herein we report the expansion of the chemical space of NOD1 antagonism via a multicomponent synthetic approach affording a novel chemotype, namely, 2,3-diaminoindoles.[3] This led to the identification of a new *hit compound* endowed with low micromolar affinity and moderate selectivity towards NOD1 *versus* NOD2. Importantly, both Noditinib-1 and our *hit compound* were studied through protein-based NMR experiments and fluoresce titration assays which provided, for the first time, proof-of-evidence of their direct binding to NOD1. Moreover, a combination of molecular modelling studies and ligand-based NMR competition experiments led to identify NOD1 nucleotide-binding domain (NBD) as its putative binding-site for these small molecule inhibitors, thus providing unprecedented knowledge for the future structure-based design of new potent and selective NOD1 antagonists.

References:

[1] K. Geddes, J. G. Magalhães, S. E. Girardin, Nat. Rev. Drug Disc., 2009, 8, 465–479.
[2] P. M. Khan, R. G. Correa, D. B. Divlianska, S. Peddibhotla, E. H. Sessions, G. Magnuson, B. Brown, E. Suyama, H. Yuan, A. Mangravita-Novo, M. Vicchiarelli, Y. Su, S.Vasile, L. H. Smith, P. W. Diaz, J. C. Reed, G. P. Roth, ACS Med. Chem. Lett., 2011, 2, 780–785.
[3] C. Russo, P. Russomanno, V. M. D'Amore, A I. Alfano, F. Santoro, S. Guzelj, M. Gobec, J. Amato, B. Pagano, L. Marinelli, A. Carotenuto, G. C. Tron, F. S. Di Leva, Z. Jakopin, D. Brancaccio, M. Giustiniano, J. Med. Chem., 2024, 67, 3004-3017.

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Reliable Evaluation of Selective hIDO1 Inhibitors in Cellular Models through LC-MS/MS Targeted Metabolomics of Kynurenine Pathway Intermediates

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L-Tryptophan, an essential amino acid, is metabolized *via* the kynurenine pathway (KP) with hIDO1 as a key enzyme. In cancer management, targeting the KP with hIDO1 inhibitors shows promise.[1] Bioanalytical chemistry, particularly quantitative liquid chromatography with tandem mass spectrometry (qLC-MS/MS), is vital for understanding the KP and exploring therapeutics. Profiling kynurenines is challenging due to their diverse properties, but qLC-MS/MS offers reliable and selective analysis.[2] Plasma, serum, and urine are commonly used to measure hIDO1 activity by evaluating the kynurenine/tryptophan ratio.[3] While cell culture supernatants provide a physiological environment for *in vitro* cancer research, there's a scarcity of LC-MS methods for quantifying kynurenines in these media, necessitating further development. This abstract introduces a validated LC-MS/MS method for quantifying multiple kynurenines in cell culture media (Figure 1). The method, validated per EMA, ICH, and FDA guidelines, was applied to study selective hIDO1 inhibition effects on the kynurenine pathway in melanoma, breast cancer, and glioblastoma cell lines, as well as to determine the *in vitro* efficacy of hIDO1 inhibitors (Figure 2). The proposed LC-MS/MS method is reliable, robust, and versatile, suitable for preclinical drug research and *in vitro* assays.

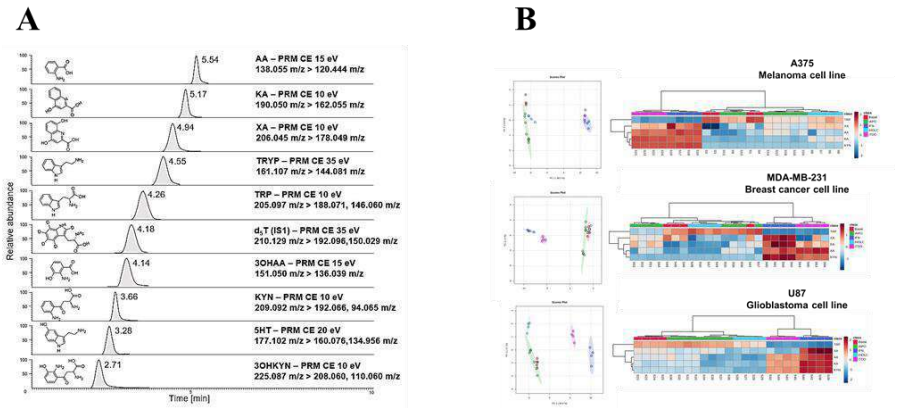

Figure 1: A - Mass chromatograms of KP catabolites. B - hIDO1 inhibition effects on the KP in cancer cell lines (A375 – melanoma, MDA-MB-231 – breast cancer, U87 – glioblastoma).

References:

[1] Roth, W.; Mohamadzadeh, M. IJMS 2021, 22 (6), 2973. https://doi.org/10.3390/ijms22062973.
[2] Yamada, K.; Tsuchiya, M. Journal of Chromatography B 2008, 867 (1), 57–61. https://doi.org/10.1016/j.jchromb.2008.03.010.
[3] Zhu, W.; Oefner, P. J. Anal Bioanal Chem 2011, 401 (10), 3249–3261. https://doi.org/10.1007/s00216-011-5436-y.

FAR-PO-046

Multitarget agents for overcoming resistance in glioblastoma therapy

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Glioblastoma Multiforme (GBM) is the most common primary brain tumour in the European Countries and USA. Its remarkably poor prognosis, with a 5-year survival rate of 4-5%, makes it an urgent unmet medical need for pharmaceutical R&D. The standard-of-care for the treatment of GBM is Temozolomide (TMZ): an imidazotetrazine derivative that acts as an alkylating agent, after its activation at physiological pH. The principal reason for the weakness of this treatment is the emergence of resistance phenomena.[1] Accordingly, our present project aims to the design, synthesis, and biological evaluation of TMZ-conjugates to overcome these current limitations. Our design is so focused on the merging of TMZ with other compounds with activity on well-known drug resistance pathways, such as: senescence-associated secretory phenotypes, escape from immune surveillance, and deregulation of epigenetic mechanisms. To this end, the application of advanced synthetic methodologies in late-stage approaches[2] enables access to libraries of MultiTarget Chemical Entities (MTCEs) as pharmacological tools to further study resistance phenomena in brain tumours.

References:

[1] R.Batash, N.Asna, P.Schaffer, N.Francis, M.Schaffer, Current Medicinal Chemistry, 2017, 24, 3002-3009
[2] T.Cernak, K.Dykstra, S.Tyagarajan, P.Vachal, S.Krska, Chem. Soc. Rev., 2016, 45, 546-576

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Selective extraction of bioactive compounds from *Olea europea* L. and *Curcubita moschata* leaves

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The agronomical and the food industries produce massive amounts of wastes, usually discarded although rich in bioactive and potentially used for nutraceutical and cosmeceutical purposes[1]. Leaves especially, one of the most abundant waste generated in this sector, are characterized by the presence of health-promoting functional components granting them antioxidant, antihypertensive, antiatherogenic, anti-inflammatory, hypoglycemic, and hypocholesterolemic properties[2].

Thus, leaves from *Olea europea* L. and *Curcubita moschata* have been selected to further evaluate the possibility to selectively extract some biologically active secondary metabolites. To this regard, an aqueous microwave assisted extraction of the olive leaves led us to obtain an oleuropein enriched extract, which was selectively isolated through solid phase adsorbtion (SPA) thanks to the use of lamellar solids. Finally, an eco-friendly, readily available, and reusable catalyst for the hydrolysis of Oleuropein in its two main components, hydroxytyrosol and elenolic acid (Fig.1). An extract enriched in the monoaldehydic dihydropyran form of elenolic acid was obtained by an acid-base work up and later characterized by GC-MS and NMR.

Different pumpkin leaf extracts of *Curcubita moschata* were tested *in vitro* for their pro-osteogenic properties and for their effects on intervertebral disc (IVD) degenerated cells. The acetone extract showed the most promising results, and after fractionation, the three most active subfraction were identified through GC-MS and NMR as 13-OH-9Z,11E,15E-octadecatrienoic acid, ferulic acid and p-coumaric acid (Fig.1).

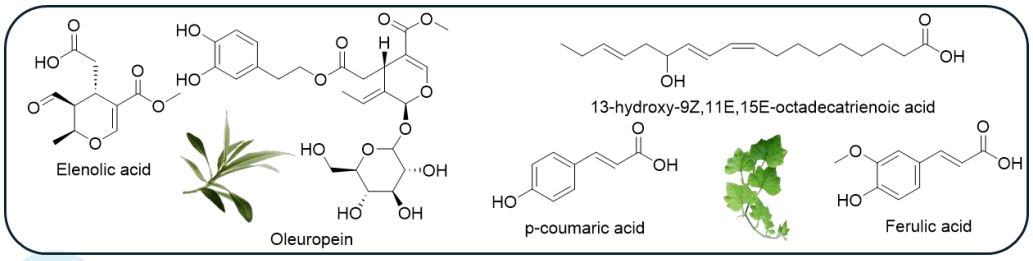

Figure 1: Main bioactive components found in the leaves of *Olea europea* L. and *Curcubita moschata*.

References:

[1] S. Selim, M. Albqmi, M.M. Al-Sanea, T.S. Alnusaire, M.S. Almuhayawi, H. AbdElgawad, S. Hussein, M. Warrad, M.T. El-Saadony, Front. Nutr. 2022, 9.

[2] S. Kar, S. Dutta, R. Yasmin, Food Chem. Adv. 2023, 3, 100505.

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The potential of (*S*)-Usnic Acid derivatives as antifungal agents

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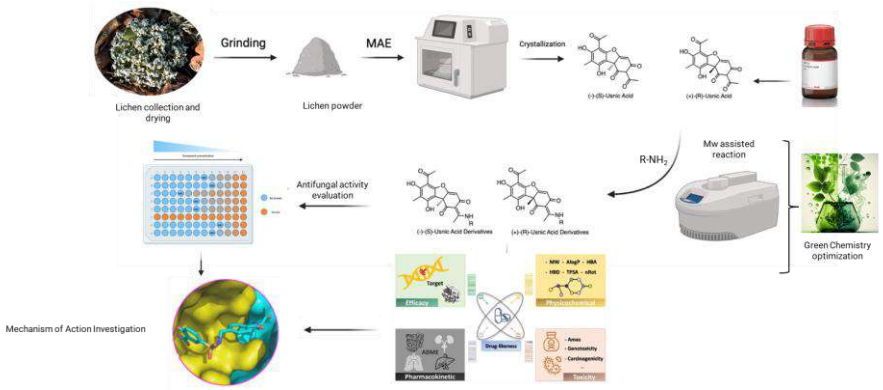
Lichen secondary metabolites are well-studied medicinal compounds with diverse pharmacological properties. One of the lichen secondary metabolites is Usnic Acid (UA), a dibenzofuran characterized by the presence of a stereogenic center. Both enantiomers occur in nature, depending on the producing organism. The most abundant in nature is (*R*)-UA[1]. It has a broad spectrum of biological activity: antimicrobial, antitumor, anti-inflammatory, and antiviral. However, UA is characterized by low solubility and hepatotoxicity issues[2].

In this work, we focused on the generation of a small series of novel semisynthetic compounds of both (*R*)- and (*S*)-UA derivatives and their potential antifungal activity against topical fungal infections such as *Candida albicans*, *Candida tropicalis*, and *Trichophyton rubrum*. In detail, (*S*)-UA was extracted from *Caldonia foliacea*[1], while the (*R*)-enantiomer was purchased and successively a small series of both enantiomers was synthesized. All compounds were characterized in terms of water solubility, cytocompatibility, and antifungal activity. The (*S*)-configured derivatives resulted to be the most potent compounds, showing antifungal activity in the µM to nM range, while maintaining good cytocompatibility. The mechanism of action is under investigation.



References:

[1] V. Cavalloro, G. Marrubini, R. Stabile, D. Rossi, P. Linciano, G. Gheza, S. Assini, E. Martino, S. Collina, Molecules 2021, 26, 455.

[2] X. Yu, Q. Guo, G. Su, A. Yang, Z. Hu, C. Qu, Z. Wan, R. Li, P. Tu, X. Chai, X. Yu et al. Journal of Natural Products 2016, 79(5), 1373–1380.

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Small molecule modulators of the activity of microRNA-21

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Although the majority of the human DNA codifies for non-coding RNAs (ncRNAs), biomolecules exerting important biological functions, the field of RNA targeting for therapeutic application is still at an early stage.[1] The recent approval of RNA-targeting small molecules by regulatory agencies, such as Risdiplam® and Ataluren®, has opened the way to small molecule RNA therapeutics. Among the variety of ncRNAs, micro-RNAs, consisting of 20-25 nucleotides, mediate post-transcriptional gene regulation as they bind to messenger RNAs inducing their degradation or translation inhibition.[2] Micro-RNA-21 (miR-21) is a potential interesting pharmacological target, being an essential element for cancer cell proliferation and survival.[3] Micro-RNA-21 is overexpressed in several cancer types,[3] and decreasing its cellular levels has been reported to sensitize cancer cells to chemotherapy.[4] Several small molecules targeting miR-21 have been reported in the literature;[5] however, there is still ample space to discover new compounds capable to decrease miR-21 levels in cells.
One of the approaches to reduce miR-21 in cells consists in finding compounds that bind to its precursor (pre-miR-21) thus preventing the cleavage by the ribonuclease Dicer.[6] With this idea in mind, we performed a medium-throughput screening campaign to assess the affinity to pre-miR-21 of *circa* 600 fluorinated fragments by ^{19}F-NMR technique.[7] The primary hits were subsequently tested in a biochemical assay to measure their Kd [8] From this screening campaign, several hit compounds emerged for their promising affinity to pre-miR-21. Among them, a compound bearing a pyrazolopyrimidine scaffold showed Kd in the low micromolar range: this compound was selected for further investigation. A ligand-based approach was applied to improve the affinity to pre-miR-21. Several derivatives were synthesized, leading to a few compounds with submicromolar affinity to pre-miR-21 and capable of inhibiting the Dicer-mediated processing.

References:

[1] Warner, K. D.; Hajdin, C. E.; Weeks, K. M. Nat. Rev. Drug Discov. 2018, 17 (8), 547–558.
[2] Treiber, T.; Treiber, N.; Meister, G. Nat. Rev. Mol. Cell Biol. 2019, 20 (1), 5–20.
[3] Huang, Y.; Yang, Y. B.; Zhang, X. H.; Yu, X. L.; Wang, Z. B.; Cheng, X. C. Med. Oncol. 2013, 30 (1), 376.
[4] Sicard, F.; Gayral, M.; Lulka, H.; Buscail, L.; Cordelier, P. Mol. Ther. 2013, 21 (5), 986–994.
[5] Shortridge, M. D.; Chaubey, et al, G. ACS Chem. Biol. 2023, 18 (2), 237–250.
[6] Shortridge, M. D.; Walker, M. J.; et al. ACS Chem. Biol. 2017, 12 (6), 1611–1620.
[7] Dalvit, C.; Vulpetti, A. J. Med. Chem. 2019, 62 (5), 2218–2244.
[8]Vo, D. D.; Duca, M. Drug Target miRNA: Methods and Protocols; Schmidt, M. F., Ed.; Methods in Molecular Biology; Springer: New York, NY, 2017; pp 137–154.

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Development of an Analytical Method for assessing Pharmaceutical Contaminants of Emerging Concern in agricultural water

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Water reuse is becoming increasingly important due to limitations in freshwater availability. Treated wastewater can be a reliable water supply, independent of seasonal droughts and weather changes. However, health and environmental protection must be considered when reusing wastewater. The EU Regulation 2020/741, effective June 2023, sets minimum monitoring and quality requirements for safe wastewater reuse in agricultural irrigation as part of the Circular Economy Action Plan[1]. Contaminants of emerging concern (CECs) are a pressing issue, encompassing various chemical compounds with potential ecological and health impacts. These CECs, including pharmaceuticals and personal care products, are not yet regulated under current environmental laws. Their global presence in aquatic systems is a cause for concern, exacerbated by the low efficiency of conventional wastewater treatment plants in removing these pollutants.[2] Proper identification and quantitation and the development of efficient removal procedures are crucial to reduce the threat to humans and ecosystems. In a collaborative project with the Department of Agriculture and Food Science (DISTAL) of the University of Bologna, we established an analytical protocol to monitor the presence of ten pharmaceutical CECs (Ph-CECs) which were selected based on previously published reports and literature. These selected Ph-CECs have varying physicochemical properties, with AlogP values ranging from -1.03 to 4.36 and pKa from 0.07 to 10.1. Although the concentration of Ph-CECs is anticipated to be low, ranging from ng/L to µg/L, their allowed limits are not yet regulated. Therefore, we optimized an isolation method using hyper-crosslinked hydroxylated polystyrene-divinylbenzene copolymer-based SPE cartridges to enhance analysis sensitivity. The optimized protocol allowed complete retention of all selected analytes despite their differences in hydrophilicity and ionization state. Elution with 100% organic solvent followed by solvent evaporation further contributed to the implementation of the method's sensitivity. Finally, for analyte quantitation, a high-performance liquid chromatography-electrospray ionization/mass spectrometry (HPLC-ESI/MS) method was developed and validated. This method will be applied to monitor the presence of the selected Ph-CECs in treated wastewater used for agricultural irrigation.

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References:

[1] https://environment.ec.europa.eu/topics/water/water-reuse_en
[2] M. Kumar, S. Sridharan, A.D. Sawarkar, A. Shakeel, P. Anerao, G. Mannina, P. Sharma, A. Pandey Sci Total Environ, 2023, 859, 160031.

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Antioxidant-based 8-amino-1,2,4-triazolo[4,3-a]pyrazin-3-ones: new adenosine A_{2A} receptor antagonists as neuroprotective agents in cerebral ischemia

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Adenosine A_{2A} receptor (AR) antagonists and antioxidant derivatives showed neuroprotective activity in animal models of cerebral ischemia.[1,2] Thus, to obtain new neuroprotective agents endowed with potentiated effect, a set of 8-amino-1,2,4-triazolo[4,3-a]pyrazine-3-ones were designed as hybrid compounds of our previously reported human (h)A_{2A} AR antagonist **A**[3] (K_i= 13 nM) and antioxidants, such as edaravone (EDA), a drug clinically used after ischemic stroke, and lipoic acid (LA). On the whole, the new derivatives proved to be potent hA_{2A} AR antagonists (K_i= 2.4-91 nM), and selective versus A_1, A_{2B} and A_3 ARs. The EDA-hybridized compounds showed antioxidant activity comparable to EDA (DPPH test). Selected triazolopyrazines proved to be effective in preventing irreversible blockade of neurotransmission and in decreasing neuronal damage induced by oxygen and glucose deprivation in the CA1 region of rat hippocampal slices. Molecular docking studies showed the best binding pose of these derivatives with the 2-phenyl ring positioned in the depth of the receptor cavity and the 6-substituent at the entrance, and oriented toward the extracellular environment.

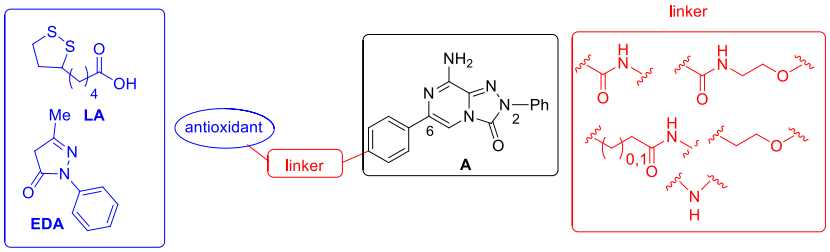

Figure 1

References:
[1] A. Melani, A.M. Pugliese, F. Pedata, Int. J. Rev. Neurobiol. 2014, 119, 309-348.
[2] Q. Wang, Q. Yu, M. Wu, Front. Pharmacol. 2022, 13, 948889.
[3] M. Falsini, L. Squarcialupi, D. Catarzi, F. Varano, M. Betti, D. Dal Ben, G. Marucci, M. Buccioni, R. Volpini, T. De Vita, A. Cavalli, V. Colotta. J. Med. Chem, 2017, 60, 5772-5790.

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FAR-PO-053

1,2,4-Triazole-Based Derivatives as Non-Competitive Heme Oxygenase-1 Inhibitors

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The stress-inducible enzyme, named HO-1, exerts an essential role in maintaining cellular homeostasis in response to oxidative stress in normal cells. On the other hand, overexpression of this isoform in cancer cells has been linked to tumor aggressiveness and drug resistance phenomena. Therefore, the association of non-competitive HO-1 inhibitors, such as imidazole derivatives, with FDA-approved drugs showed *in vitro* efficacy in enhancing antiproliferative effects.[1] Unfortunately, the clinical application as adjuvant chemotherapy of this class of compounds might be limited by their lack of selectivity towards other heme-dependent enzymes (i.e., cytochromes P450),[2] likely, due to the presence of an imidazole nucleus. Based on this premise, we selected any of our most potent HO-1 inhibitors among three different series reported so far,[3] that served as reference compounds for lead-optimization. Specifically, to keep potent enzyme inhibition activity and reduce potential off-target effects (i.e., CYP3A4, and CYP2D6 inhibition) we replaced the imidazole ring with a 1,2,4-triazole one (Figure 1, left). Thus, new derivatives were synthesized, characterized, and tested for their *in vitro* activity towards the selected target; while molecular modeling studies allowed us to analyze their binding modalities (Figure 1, right). Finally, the *in vitro* antiproliferative properties of the most potent compound and its co-administration (combo) with 5-FU have been tested in selected cancer cell lines (i.e., DU-145 and MCF-7) using the MTT assay.

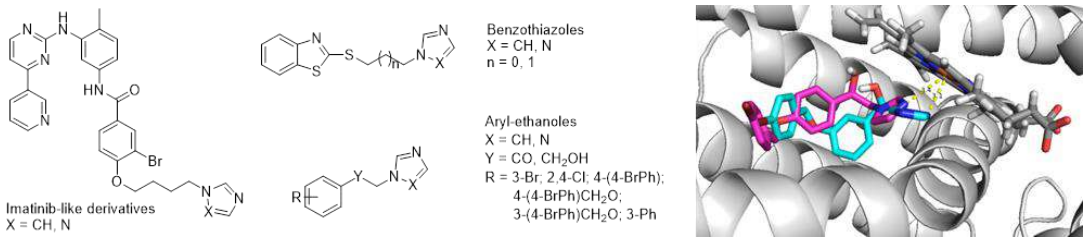

Figure 1: General structures and selected binding pose of 1,2,4-triazole-based derivatives.

References:

[1] P. Podkalicka, O. Mucha, A. Józkowicz, J. Dulak, A.A. Łoboda, Contemp. Oncol. 2018, 22, 23-32.
[2] M. Hum, B. E. McLaughlin, G. Roman, J. Z. Vlahakisnal, W. A. Szarek, K. Nakatsu, J. Pharmacol. Exp. Ther. 2010, 334, 981-987.
[3] S. Intagliata, L. Salerno, V. Ciaffaglione, C. Leonardi, A.N. Fallica, G. Carota, E. Amata, A. Marrazzo, V.Pittalà, G. Romeo. Eur. J. Med. Chem. 2019, 183, 111703.

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FAR-PO-054

Development of *bona-fide* NOX inhibitors: a novel therapeutic strategy

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NADPH oxidases (NOXs) are enzymes responsible for only generating reactive oxygen species (ROS). The seven NOX isoforms share the same catalytic core; despite this, each isoform presents peculiar items (tissue distribution, activation mechanism, and specific activities).[1] In cancers, dysregulation of NOX enzymes affects ROS production, leading to redox unbalance and tumor progression.[2] Our project focused on the molecular simplification of M41, a promising lead compound discovered through two ultra-large *in silico* screens of 350 million compounds, carried out by our collaborators. As the cocrystal structure of M41 with the NOX5 DH domain from *C. Stagnale* shows high adaptability of M41 for binding, we investigated the contributions of its various chemical groups, obtaining a first series of simplified derivatives. The reduction of the complexity of spiroamine has allowed us to obtain MC4876 and MC4854, which show potency and selectivity on NOX2 and NOX5, respectively, (**MC4876**: IC_{50} *h*NOX1 = 71.2 µM; IC_{50} *h*NOX2=7.7 µM; K_i (NOX2) = 7.3 µM; IC_{50} *h*NOX4 = 81.2 µM; IC_{50} *h*NOX5 = 63.5 µM; **MC4854**: IC_{50} *h*NOX1>100; IC_{50} *h*NOX2>100; IC_{50} *h*NOX4>100; IC_{50} *h*NOX5=1.6 µM). Given the good results obtained in vitro, we decided to better study MC4876 in cellulo (EC_{50} NOX2 = 5.7 µM; CETSA *h*NOX2 = + 1.1 °C).[3] Considering good results of MC4854 and MC4876, we designed and synthesized a second series of derivatives based on the two lead-compounds just mentioned. All the compounds synthesized have been tested against the full length of the various isoforms at Mattevi's laboratories at the University of Pavia. For some compounds, good isoform selectivity is maintained. Additionally, during the synthesis of the azetidine derivative MC4923 via Buchwald-Hartwig cross coupling reaction, we also obtained the bisquinoline derivative MC4921, that we decided to test. Surprisingly, this is, until now, our most potent compound (IC_{50} *h*NOX1>100, IC_{50} *h*NOX2 = 1.4 µM; IC_{50} *h*NOX4>100; IC_{50} *h*NOX5>100; K_i *h*NOX2 =2.1 µM; EC_{50} = *h*NOX2 = 0.77 µM; CETSA *h*NOX2: +6.0 °C). Additional biological studies are currently ongoing.

References:

[1] Augsburger, F., et al., 2019, Redox Biol, 26, 101272.
[2] Liou, G. Y., et al., 2010, Free Radic Res, 44 (5), 479-96.
[3] Reis, J., et al., 2023, Nat Chem Biol, 19 (12),1540-155.

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FAR-PO-056

Design of novel nucleic acid-based therapeutics targeting a long non-coding RNA for the treatment of melanoma

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Metastatic melanoma is a highly aggressive tumour with a high mortality rate. Recent findings have been proven that long noncoding RNAs (lncRNAs) are involved in the regulation of different cellular processes fundamental for the development/survival in several cancers including melanoma[1]. A common strategy to elicit the cellular activity of lncRNAs is to target them with chemically modified antisense oligonucleotides (ASOs)[2].

To identify the most suitable lncRNAs to be exploited for melanoma treatment with ASOs, we set up a systematic approach starting from the Lnc2Cancer v.3.0 database[3], integrated with GENCODE annotations[4]. Upon this search we selected BRAF-activated non-protein coding RNA (BANCR), a lncRNA whose expression is upregulated in melanoma[5]. The second step of our study was to verify the efficacy of DNA and RNA ASOs designed against BANCR lncRNA in melanoma cell lines.

First, the expression of BANCR was analysed in the A375 cell line using Quantitative Real-time PCR. Overall, our results demonstrated the presence of our lncRNA within the nucleus in the selected cell line.

Subsequently, the selection of accessible regions within BANCR to be targeted by ASOs was performed by using the structural predictions tool RNAfold (ViennaRNA Package)[6]. Additionally, BANCR's potential to sponge microRNAs was explored employing starBase[7] tool. We identified miR-205-5p as an attractive partner of BANCR for our goal. Therefore, we targeted the region of BANCR responsible for the binding to miR-205-5p with tailored DNA and RNA ASOs starting from the fully complementary sequences.

Hence, the interaction of BANCR with miR-205-5p, DNA and RNA ASOs were evaluated by circular dichroism (CD) and differential scanning calorimetry (DSC). Both the CD and DSC data confirmed the formation of the duplex complexes according to a fully reversible process. The efficiency capacity of the fully complementary DNA and RNA ASOs to displace the miR-205-5p from BANCR was confirmed.

These findings can provide proof-of-concept that the targeting of miR-205-5p binding region could be a new option for melanoma treatment through BANCR inhibition.

References:

[1] L. E. Davis, S. C. Shalin, 2019, 20, 1366–1379.
[2] T. Zhou, Y. Kim, 2016, 1402, 199-213.
[3] A. Frankish, S. Carbonell-Sala, 2023, 51, D942-D949.
[4] Y.Gao, S. Shang, 2021, 49, D1251-D1258.
[5] R. J. Flockhart, D. E. Webster, 2012, 22, 1006-1014.
[6] R. Lorenz, S. Bernhart, 2011, 6, 26.
[7] J.-H. Li, S. Liu, 2014, 42, D92-97.

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FAR-PO-057

Structural and mechanistic studies of cycloheptathiophene-3-carboxyamide based compounds as potent and broad-spectrum anti-influenza agents.

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The availability of novel and broad-spectrum anti-influenza virus (IV) drugs is a crucial weapon in the fight against future pandemic outbreaks, especially since drug resistance is a major concern for the limited number of approved anti-IV drugs. A promising target for the discovery of next-generation antivirals is RNA-dependent RNA polymerase (RdRP), which is essential for viral replication and evolution. It is a heterotrimeric complex that is highly conserved across IV strains and consists of PA, PB1 and PB2 subunits. Therefore, interfering with the formation of protein-protein interactions (PPIs) involved by RdRP subunits during the IV life cycle offers an innovative approach to identify anti-IV agents that reduce the ability of IV to develop drug resistance.[1] Starting from previously identified compound **1**, in this work I reported the structural exploration of the cycloheptathiophene-3-carboxamide (cHTC) core as well as the moieties at the C-2 and C-3 positions.[2-4] The investigation led to analogues capable of potent inhibition of IV replication in the nanomolar range against a panel of IV strains. (**Figure 1**) With the aim of clarifying the mechanism of action, in-depth studies were performed for the best compound **2**, which showed the ability to prevent PA-PB1 heterodimerization by binding PA_C. Finally, a more efficient and scalable chemical procedure was developed for the synthesis of these promising anti-IV agents.

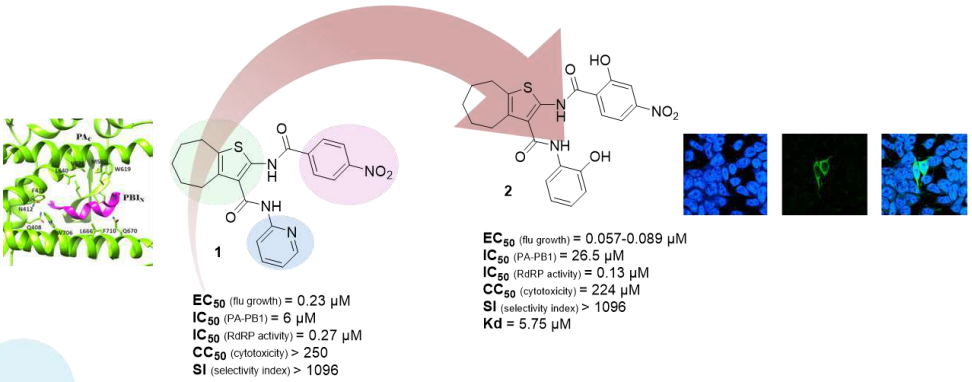

Figure 1: Schematic representation of the work herein reported.

References:

[1] Massari, S.; *et al.* ACS Infect. Dis. 2021, 7, 1332-1350.
[2] Massari, S.; *et al.* J. Med. Chem. 2013, 56, 10118-10131.
[3] Desantis, J.; *et al.* Eur. J. Med. Chem. 2017, 138, 128-139.
[4] Nannetti, G.; *et al.* Antiviral Res. 2019, 165, 55-64.

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FAR-PO-058

Advanced bioanalytic analyses of lipids with artificial intelligence: lipidomic landscape of inflammaging

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Lipids are the major constituents of cell membranes, very efficient energy sources, and key pathophysiological mediators of several intercellular and intracellular processes. Lipids are increasingly recognized as valuable markers for the early detection and assessment of various inflammatory diseases[1,2]. Investigating lipid profiles offers insights into cellular phenomena such as low-grade inflammation, which is prevalent in numerous conditions including cancer, neurodegenerative disorders, diabetes, and obesity. This study aimed to identify lipid signatures within an inflammatory cell model by employing sophisticated bioanalytical methods and Machine Learning techniques. The analysis utilized high-resolution mass spectrometry to compare the lipidome from TNF-α inflamed cells (R3/1 NF-κB reporter cells) against non-inflamed control cells, identifying 469 lipids. Notably, 20% were phosphatidylcholines (PCs) and phosphatidylethanolamines (PE), 10% were sphingomyelins (SM), and smaller percentages were other lipid types such as phosphatidylinositols (PI), ceramides (Cer), phosphatidylglycerols (PG), and phosphatidylserine (PS). The TNF-α inducer altered 88 lipids with a fold change greater than 1.5, with 71 upregulated and 17 downregulated, impacting several cellular pathways as shown by network analysis. To assess the model's validity, TNF-α inflamed cells were treated with polyphenols from thinned young apples (TAP), known for their anti-inflammatory effects. This treatment reversed the dysregulation observed in specific ceramides in the inflamed cells. Network analysis further revealed the modulation of arachidonic acid and TNF signaling pathways by these polyphenols. The findings underscore the utility of this inflammatory model and bioanalytical approach in characterizing lipid profiles within complex biological contexts. Furthermore, the lipids were analyzed using an artificial intelligence framework to pinpoint significant signatures and clusters that influence cellular conditions. Ultimately, this research demonstrates the potential of lipidomics paired with machine learning and illustrates how to develop and validate machine learning models for predicting inflammation based on lipid patterns.

References:

[1] C.N. Serhan, N. Chiang, T.E. Van Dyke. Nature Reviews Immunology 2008, 8, 349-361.
[2] A. Gomez-Munoz, N. Presa, A. Gomez-Larrauri, I.G. Rivera, M. Trueba, M. Ordonez. Progress in Lipid Research 2016, 61, 51-62.

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FAR-PO-059

Inhibition of SARS-CoV-2 Replication by 2-Phenylquinoline Derivatives Targeting nsp13 Helicase

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Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) emerged at the end of 2019 as a new deadly human betacoronavirus, responsible for COVID-19, a highly infectious and pathogenic disease. The RNA vaccines, approved in the early 2020, have represented the main weapon to successfully reduce the devastating impact of the outbreak, while the discovery of efficacious antivirals have lagged behind, with only three drugs that have approved to date. As a results, the development of SARS-CoV-2 antivirals is still a priority to address the limitations of the existing drugs and to effectively manage the future pandemics.

Due to its high conservation across coronaviruses, and being a crucial component of the replication transcription complex, the nsp13 helicase, which catalyses the RNA unwinding and ATP hydrolysis, could represent an alternative drug target.[1]

By screening a selection of small molecules from our in-house library, we have recently identified the 2-phenylquinoline (2-PhQ) as a promising scaffold to obtain new anti-SARS-CoV-2 agents. Indeed, the proper substitution pattern around the 2-PhQ nucleus furnished some compounds endowed with: broad anti-coronaviruses inhibition, being active in the low µM range against SARS-CoV-2 and two other human coronaviruses, HCoV-229E and HCoV-OC43; absence of toxicity up 100 µM concentration; µM inhibition of the helicase unwinding activity.[2]

Thus, guided by the preliminary SAR, a new series of 2-PhQ derivatives was synthesised by maintaining the 6,7-dimethoxytetrahydroisoquinoline at the C-4 position to guarantee the helicase recognition, while extensively modifying the C-2 substituent.

As an alternative approach to hit nsp13 helicase, the best 2-PhQs were also handled into hydrophobically tagged degraders.

The design, synthesis and biological evaluation of the new set of compounds will be object of the presentation.

References:

[1] Newman JA, Douangamath A, Yadzani S, Yosaatmadja Y, Aimon A, Brandão-Neto J, Dunnett L, Gorrie-Stone T, Skyner R, Fearon D, Schapira M, von Delft F, Gileadi O. *Nat Commun.* **2021**, 12, 4848-4859.

[2] Nizi MG, Persoons L, Corona A, Felicetti T, Cernicchi G, Massari S, Manfroni G, Vangeel L, Barreca ML, Esposito F, Jochmans D, Milia J, Cecchetti V, Schols D, Neyts J, Tramontano E, Sabatini S, De Jonghe S, Tabarrini O. *ACS Med Chem Lett.* **2022**,13, 855-864.

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FAR-PO-060

Leveraging a modular and reliable chemistry to accelerate PROTACs and hydrophobic tags synthesis

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Over the past few years, there has been a rapid expansion in the development of new chemical modalities and innovative approaches for modulating cellular pathways and addressing biological targets previously deemed undruggable.[1] One of the most significant advancements in this field has been the emergence of targeted protein degradation technologies, which have catalysed a paradigm shift in therapeutic strategies and opened up new avenues for drug design. Among them, proteolysis targeting chimeras (PROTACs) have resulted in promising clinical candidates, unlocking opportunities for biopharmaceutical innovation.[2] In parallel, hydrophobic tags (HyTs) have emerged as a promising platform in drug discovery, leveraging their lower molecular weight and reduced number of hydrogen bond donors/acceptors compared to PROTACs.[3] Despite the advances achieved to date, PROTACs synthesis remains complex, often involving multi-step approaches and orthogonal protection strategies. These challenges pose a bottleneck in PROTAC development, hindering synthetic throughput and efficiency. To address this limitation, we have devised an innovative synthetic platform that capitalizes on multicomponent reactions (MCRs) to accelerate PROTAC drug discovery, leveraging the modular nature of both PROTACs and MCRs.[4] To broaden the applicability of this platform and unlock its full potential in advancing drug discovery efforts, we have successfully applied the platform to the one-pot synthesis of novel BRD4-targeting HyTs, as well as to PROTACs targeting indoleamine 2,3-dioxygenase 1 (IDO1), a moonlighting protein that play a pivotal role in cancer immunotherapy,[5] and against transient receptor potential vanilloid 1 (TRPV1), also known as capsaicin receptor, involved in pain and itch.[6]

References:

[1] M.-J. Blanco, K.M. Gardinier, *ACS Med. Chem. Lett.* 2020, 11, 228 – 231.
[2] M.J. Bond, C.M. Crews, *RSC Chem. Biol.* 2021, 2, 725 – 742.
[3] S. Xie, J. Zhu, J. Li, F. Zhan, H. Yao, J. Xu, S. Xu, *J. Med. Chem.* 2023, 66, 10917 - 10933.
[4] I.P. Bhela, A. Ranza, F.C. Balestrero, M. Serafini, S. Aprile, R.M.C. Di Martino, F. Condorelli, T. Pirali. *J. Med. Chem.* 2022, 65, 15282 – 99.
[5] M. Serafini, E. Torre, S. Aprile, E. Del Grosso, A. Gesù, A. Griglio, G. Colombo, C. Travelli, S. Paiella, A. Adamo, E. Orecchini, A. Coletti, M.T. Pallotta, S. Ugel, A. Massarotti, T. Pirali, S. Fallarini *J. Med. Chem.* 2020, 63, 3047-3065.
[6] M. Serafini, A. Griglio, S. Aprile, F. Seiti, C. Travelli, F. Pattarino, G. Grosa, G. Sorba, A.A. Genazzani, Gonzalez-Rodriguez, S.; Butron, L.; Devesa, I.; A. Fernandez-Carvajal, T. Pirali, A. Ferrer-Montiel, *J. Med. Chem.* 2018, 61, 4436 - 4455.

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FAR-PO-061

Design and synthesis of heterobifunctional small molecules for neuroinflammation

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Neuroinflammation has been identified as a precursor to the onset of several neurodegenerative diseases, including Alzheimer's disease (AD). Understanding and managing the intricate interplay between the central nervous system (CNS) and the immune system is crucial from a physiological standpoint, as well as from pharmacological point of view. In an attempt to develop therapeutic approaches to prevent/delay disease's progression,[1] in the framework of the Italian National Recovery and Resilience Plan (PNRR) extended partnership (PE) 12 titled "A multiscale integrated approach to the study of the nervous system in health and disease" (MNESYS), a small molecule hit as been identified. It shows an intriguing inhibitory activity toward a neutrophil-specific enzyme implicated in AD neuroinflammation. (Patent Pending) This molecule has become the starting point for the development of innovative heterobifunctional small molecules exhibiting degrading behavior, that exploit the cellular proteasome machinery to degrade the identified target enzyme.[2] In these heterobifunctional molecules, the hit compound is connected, through different linker, to a recruiter of CRBN E3 ubiquitin ligase, i.e., thalidomide. (Figure 1) We develop a library of heterobifunctional molecules modifying the linker's characteristics: length, composition, and rigidity. An *in vitro* bioassay on the isolated target to perform SAR studies has been selected for a preliminary evaluation of the impact of the structural modifications on the binding/activity towards the target enzyme. The therapeutic potential of these heterobifunctional small molecules is currently under evaluation in neuroinflammatory cell models.

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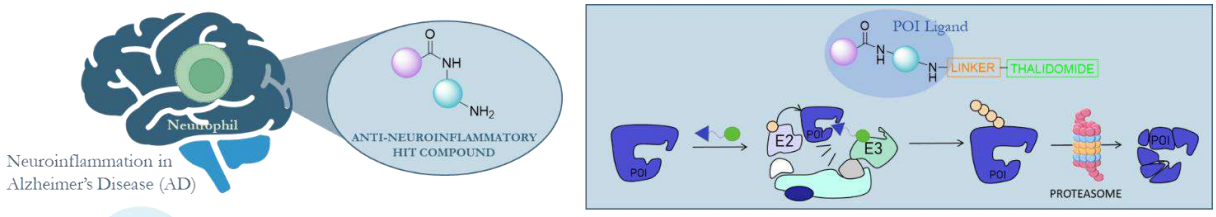

Figure 1. General structure and mechanism of action of heterobifunctional small molecules.

References:

[1] Kiraly, M., Foss, J.F. & Giordano, T. J Prev Alzheimers Dis 2023, 10, 686–698.
[2] Li K, Crews CM. Chem Soc Rev. 2022, 51(12), 5214-5236.

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FAR-PO-062

Late-stage functionalization: a green strategy for the optimization of PCSK9 inhibitors

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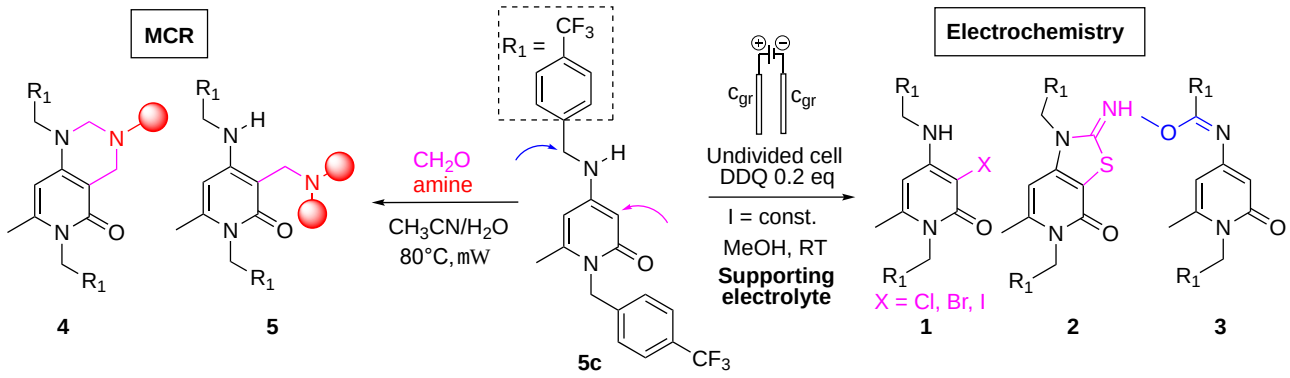
Late-stage functionalization (LSF) allows the chemo- and site-selective diversification of already complex and polyfunctionalized compounds, often exploiting green chemistry tools.[1] We recently identified the 4-amino-2-pyridone **5c** as promising lead compound for the development of novel small molecule PCSK9 inhibitors.[2] Aiming to both study the under-investigated reactivity of such 4-amino-2-pyridone scaffold and improve the pharmacokinetic profile of **5c**, LSF represents the best option for achieving these two goals concomitantly. The combination of the LSF strategy with other intrinsically green synthetic tools, as electrochemistry and multi-component reaction (MCR) allowed the set-up of innovative and green procedures for the obtainment of a small collection of derivatives. Exocyclic N, aromatic C3 and benzylic C11, as likely metabolic soft spots, were selected as sites of functionalization. On one hand, electrochemically driven modifications led to the synthesis of halogenated derivatives **1**, the novel bicyclic compound **2**, and the Shono-type product **3**. On the other hand, μW-assisted MCR allowed the synthesis of two different classes of products (**4** and **5**).[3] Biological studies on the newly synthesized analogue of **5c** are currently ongoing.



Scheme 1: LSF of compound **5c**.

References:

[1] S. J. Miller, T. Ritter, *Chem. Rev.* **2023**, *123* (24), 13867–13868.
[2] L. Giannessi, M.G. Lupo, I. Rossi, M.G. Martina, A. Vilella, M. Bodria, D. Giuliani, F. Zimetti, I. Zanotti, F. Potì, F. Bernini, N. Ferri, M. Radi, *Eur. J. Med. Chem.* **2024**, *265*, 116063.
[3] Manuscript in preparation

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FAR-PO-063

Innovative Approaches to Combat Tuberculosis: Exploring Dual-Acting Inhibitors Targeting *Mt*MetAP1c and MbtI

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Tuberculosis (TB) is the world's second-leading cause of death from a single infectious agent, remaining a significant global issue. Approximately 10 million new cases and 1.4 million deaths are reported annually by the World Health Organization (WHO). Moreover, the spread of multi-drug-resistant strains of *Mycobacterium tuberculosis* (*Mtb*) requires the urgent development of new therapeutic approaches.[1]

The mycobacterial methionine aminopeptidase family (*Mt*MetAP) has recently emerged as a promising target for the development of anti-TB agents due to its essential role in the protein synthesis pathway. Considering that recent studies identified *Mt*MetAP1c as essential for *Mtb* survival, our focus was primarily on this isoform.[2,3]

Hence, we prepared different substrates and known inhibitors to assess the functionality of *Mt*MetAP1c and develop an assay for the evaluation of new candidates.[4] In a literature survey, we observed that a 5-phenylfuran-2-carboxylic acid derivative had been identified as a *Mt*MetAP inhibitor.[2] Considering that this scaffold was also the core of a class of inhibitors of the salicylate synthase (MbtI) from *Mtb*, identified by our research group,[5] we envisaged that we could develop a series of potential dual inhibitors, maximizing their antimycobacterial effect by blocking two distinct pathways. Our preliminary data will be discussed, laying the foundation for the discovery of dual-acting enzymatic inhibitors for the treatment of *Mtb* infections.

References:

[1] Global Tuberculosis Report 2023, 2023.
[2] J. P. Lu, S. C. Chai, Q. Z. Ye, J. Med. Chem. 2010, 53, 1329–1337.
[3] C. Onyenaka, K. A. Idowu, N. P. Ha, E. A. Graviss, O. A. Olaleye, Int. J. Mol. Sci. 2023, 24, 17142.
[4] S. F. John, E. Aniemeke, N. P. Ha, C. R. Chong, P. Gu, J. Zhou, Y. Zhang, E. A. Graviss, J. O. Liu, O. A. Olaleye, Tuberculosis 2016, 101, S73–S77.
[5] L. R. Chiarelli, M. Mori, D. Barlocco, G. Beretta, A. Gelain, E. Pini, M. Porcino, G. Mori, G. Stelitano, L. Costantino, M. Lapillo, D. Bonanni, G. Poli, T. Tuccinardi, S. Villa, F. Meneghetti, Eur. J. Med. Chem. 2018, 155, 754–763.

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FAR-PO-064

Exploring the Inhibition of Iron Acquisition in *M. abscessus* as a Potential Anti-Virulence Strategy in People with Cystic Fibrosis

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M. abscessus (*Mab*), an opportunistic pathogen belonging to the class of non-tuberculous mycobacteria (NTM), causes chronic pulmonary infections in sensitive individuals, especially cystic fibrosis (CF) patients. Despite its incidence is on the rise, the available therapeutic strategies have only a limited efficacy and are very burdensome for the patients. Hence, due to the intrinsic resilience of NTM to treatments and the dramatic spread of resistant strains, new pharmacological approaches are urgently needed.[1]

In this context, iron acquisition has been recently proposed as an interesting target in the phylogenetically close *M. tuberculosis* (*Mtb*), due to the involvement of this metal in the pathogenesis and survival of the microorganism in the host.[2] Therefore, we decided to investigate the targeting of mycobacterium-specific iron chelators as a possible anti-virulence approach against *Mab*. In detail, we focused on the first enzyme involved in the siderophore biosynthetic pathway, a salicylate synthase (SaS) that has been successfully studied to identify antitubercular agents against *Mtb*. Due to the structural conservation of the active site in the two congeners, we approached this study by screening an in-house library of *Mtb*-SaS inhibitors. This initial investigation led to the identification of the first hit compounds against *Mab*-SaS.[3] Moreover, considering the high plasticity of the active site, we performed crystallization studies to solve the structure of *Mab*-SaS, providing a solid base to structure-based drug design efforts. The obtaining of the first 3D-model of this enzyme allowed us to characterize its orthosteric site and study the peculiar area around it.[4] Our promising results will be presented, along with preliminary data on the use of the new structure for the development of optimized inhibitors.

References:

[1] A. van Dorn, Lancet Respir. Med. 2016, 5, 1-15.
[2] G. Stelitano, M. Cocorullo, M. Mori, S. Villa, F. Meneghetti, L.R. Chiarelli, Int. J. Mol. Sci. 2023, 24, 6181.
[3] M. Mori, G. Stelitano, G. Cazzaniga, A. Gelain, A. Tresoldi, M. Cocorullo, M. Roversi, L.R. Chiarelli, M. Tomaiuolo, P. Delre, G.F. Mangiatordi, A. Griego, L. Rizzello, A. Cassetta, S. Covaceuszach, S. Villa, F. Meneghetti, Pharmaceutics 2023, 15, 502.
[4] M. Mori, M. Cocorullo, A. Tresoldi, G. Cazzaniga, A. Gelain, G. Stelitano, L.R. Chiarelli, M. Tomaiuolo, P. Delre, G.F. Mangiatordi, M. Garofalo, A. Cassetta, S. Covaceuszach, S. Villa, F. Meneghetti, Eur. J. Med. Chem. 2024, 265, 116073.

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FAR-PO-065

Evaluation of Novel *Pf*DHODH Enzyme Inhibitors Using 3D-QSAR Studies, Molecular Docking, Molecular Dynamic Simulation, and ADMET Properties of *Pf*DHODH Enzyme for the Treatment of Malaria

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This research explores new possibilities for antimalarial drugs by focusing on the *Plasmodium falciparum* Dihydroorotate Dehydrogenase (*Pf*DHODH) enzyme, a critical enzyme in the parasite's pyrimidine biosynthesis pathway. Unlike humans, the malaria parasite cannot salvage pyrimidines, making *Pf*DHODH an ideal target[1]. The study combines various techniques, including 3D-QSAR, molecular docking, molecular dynamics (MD) simulations. A dataset of 99 triazolopyrimidine derivatives was examined using CoMFA and CoMSIA models, and the best ranked molecules were evaluated through molecular docking and MD simulations, confirming the stability of these inhibitors within *Pf*DHODH bindng site and reinforcing their potential as effective inhibitors. The best 25 triazolopyrimidine analogues derived from *in silico* studies has been synthetized, and their *in vitro* enzymatic activity will be here discussed. In summary, this research provides a robust approach for the design and of *Pf*DHODH inhibitors as novel leads for the treatment of malaria, offering hope in the fight against this deadly disease.

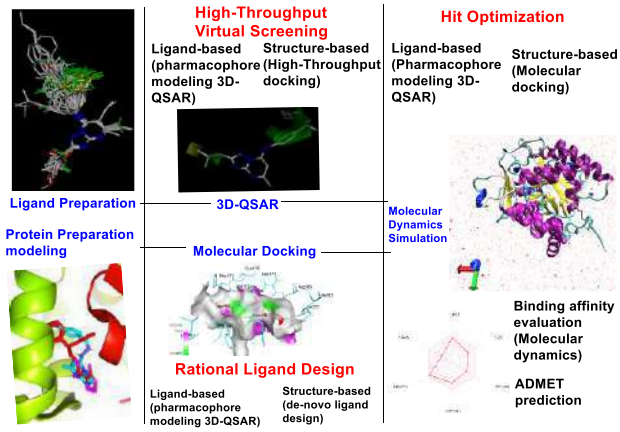

Figure 1: General workflow of the project.

References:

[1] V.K. Vyas, *et al.* Comput. Biol. Chem. (2022) 107787.

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FAR-PO-066

A sustainable one-pot three-step approach for the synthesis of 3,5-disubstituted 1,2,4-triazines as versatile pharmacological tools

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1,2,4-Triazines are an important class of six-membered aromatic heterocycles which have demonstrated a wide range of pharmacological applications, showcasing properties that extend to anticonvulsant, antithrombotic, antibacterial, antimalarial, antiviral, anti-inflammatory, and anticancer activities.[1,2] While various strategies for synthesizing 1,2,4-triazines have been reported, they often require multiple steps/purifications, harsh reaction conditions, activation by toxic metals/oxidants, longer reaction times, use of complex synthetic precursors, and sometime lead to the formation of multiple regioisomers.[2] We report herein the first microwave-assisted one-pot three-step metal-free [4+2] procedure for the synthesis of 3-hydrazinyl-1,2,4-triazine directly from commercially available aromatic and heteroaromatic ketones (**1**). The optimized protocol allowed us to quickly generate substituted 5-aryl/heteroaryl-3-hydrazineyl-1,2,4-triazines (**5**) in good overall yields which were further elaborated by a μW-assisted condensation with a wide range of aldehydes/ketones to provide a collection of hydrazone-derivatives (**7**). The developed synthetic approach proceeds under mild conditions, with good functional group compatibility and represent a versatile, rapid, and efficient tool for the generation of new highly functionalized 1,2,4-triazines derivatives of potential biological interest.[3]

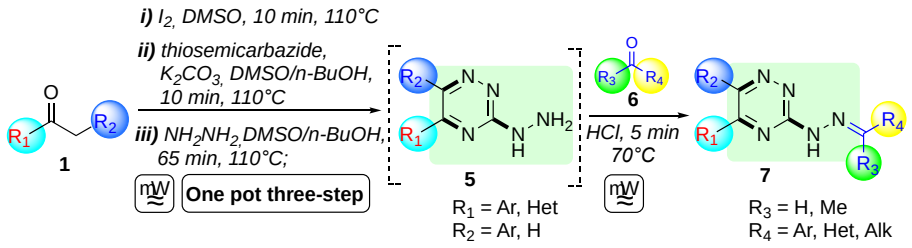

Figure 1: Synthetic route to obtain 1,2,4-triazine based derivatives.

References:

[1] R. Kumar, T. S. Sirohi, H. Singh, R. Yadav, R. K. Roy, A. Chaudhary, S. N. Pandeya, **2014**, *Mini-Rev. Med. Chem.*, *14* (2), 168–207.
[2] F. G. Zhang, Z. Chen, X. Tang, J. A. Ma, **2021**, *Chem. Rev.*, *121* (23), 14555–14593.
[3] Manuscript under revision.

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FAR-PO-067

The heme scavenging process in S. aureus IsdB-hemoglobin complex explained via atomistic simulations

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Staphylococcus aureus uses the Iron-regulated surface determinant (Isd) system, including the IsdB receptor, to extract heme from hemoglobin in human hosts and obtain iron for its growth. This process involves hemolysins to release hemoglobin, IsdB receptor to extract heme, and other Isd proteins to transfer and oxidize heme to release iron for the bacteria's needs. Given its key role in heme scavenging, IsdB could represent the basis for the development of new biotechnological approaches to scavenge free and toxic hemoglobin in the blood, however the specific mechanism and the pathway of heme extraction at the IsdB-hemoglobin interface has not been reported yet.

In this work we simulated, for the first time to Authors' knowledge, the heme transfer in the IsdB-hemoglobin complex, an event that cannot be trapped by structural biology, nor clarified at the atomistic level by spectroscopy. Taking advantage of a protocol we previously devised for protein-ligand binding[1], we employed enhanced sampling molecular dynamics (MD) simulations to identify key residues involved in this process as well as interdomain motions and hotspots at the protein-protein interface. Furthermore, wild-type and deficient IsdB variant were expressed and purified, and spectroscopical assays were carried out to confirm simulations outcomes. In particular, our results highlight the importance of Tyr444 residue for heme extraction from human hemoglobin, laying the bases for a molecular understanding of the staphylococcal IsdB-human hemoglobin interaction.

References:

[1] M. Bertazzo, D. Gobbo, S. Decherchi, A. Cavalli. Machine learning and enhanced sampling simulations for computing the potential of mean force and standard binding free energy. Journal of chemical theory and computation. 2021 Jul 14;17(8):5287-300.

FAR-PO-068

Looking for new active metabolites: how to merge drug discovery and biodiversity conservation

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The 83% of the chemical scaffolds found in nature are unique, due to the lack of commercially available synthons or prohibitive synthetic procedures.[1] This data prompted many researchers to consider libraries of secondary metabolites as the starting point of the drug discovery process. As a result, more than one hundred databases of NPs have been developed, among which 85% focus on data concerning terrestrial plants. Among this 85%, only 1% reports on plants from Europe, making clear how Europe's biodiversity is largely under-considered in the Nature-Aided Drug Discovery scenario.[2]

In this work we built a library containing almost 6000 secondary metabolites produced by plants growing in Pavia countryside and linked them to their SMILES code and producing organism. Thus, one of our purposes was to promote biodiversity conservation in Lombardy, particularly in Pavia countryside, being it a very underestimated hotspot of biodiversity. Next, we set up a pharmacophoric model exploiting Ligand Scout software to identify potential proteasome inhibitors and so potential anti-cancer agents. This target was selected being already available proteasome inhibitors associated with several side effects, which can cause a dose limitation or a complete suspension of the therapy. The following virtual screening allowed us to identify seven new potential proteasome inhibitors, which were next purchased or extracted to validate their activity via in vitro assays. These metabolites can be considered hit compounds in the fight against cancer and further research is ongoing to improve their pharmacokinetic and pharmacodynamic profiles. Of note, the herein presented approach allows merging the conservation of biodiversity and the identification of new active metabolites. This is due to the preliminary computational studies that avoid concerns related to harvesting high amounts of natural matrices for preliminary screening.

References:

[1] J. Hert, J.J. Irwin, C. Laggner, M.J. Keiser, B.K. Shoichet, B.K. Nat. Chem. Biol. 2009, 5, 479–483.
[2] M. Sorokina, C. Steinbeck, J. Cheminform., 2020, 12, 20.

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FAR-PO-069

4-(3-Phenyl-4-(3,4,5-trimethoxybenzoyl) -1*H*-pyrrol-1- yl)benzenesulfonamide, a Novel Carbonic Anhydrase and Wnt/β-Catenin Signaling Pathway Dual-Targeting Inhibitor with Potent Activity against Multidrug Resistant Cancer Cells

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Carbonic anhydrases (CAs) are ubiquitous enzymes that catalyze the reversible hydration of carbon dioxide to produce monohydrogen carbonate and H^+ ions. The CA isoforms play key roles in many physiological processes: signal transduction, cell differentiation and proliferation, and onco-genesis[1]. The project starts from the relevance of the sulfonamide group as inhibitor of several isoforms of carbonic anhydrase. We decided to start from different derivatives, active as tubulin polymerization inhibitors, introducing a sulfonamide group, to selectively inhibit CA IX and CA XII isoforms, which are triggered by hypoxia-inducible factor 1 in many types of cancer. Novel pyrrole and indole derivatives have been synthesized as human carbonic anhydrase (hCA) inhibitors. The presence of both N1-(4-sulfonamidophenyl) and 3-(3,4,5-trimethoxyphenyl) substituents was essential for strong hCA inhibitors. Notably, compound 15, the most potent hCA XII inhibitor (Ki = 6.8 nM), demonstrated a dual target inhibition by effectively suppressing the Wnt/β-catenin signaling pathway as well, which is found to be dysregulated in some solid tumors, its target genes MYC, Fgf20, and Sall4 and exhibited the typical markers of apoptosis[2]. Docking experiments were performed to gain insights into the molecular details of the binding modes of the reported compounds. Several compounds exhibited promising activity against different tumor cell lines, including colorectal cancer and triple-negative breast cancer, highlighting their potential as therapeutic agents.

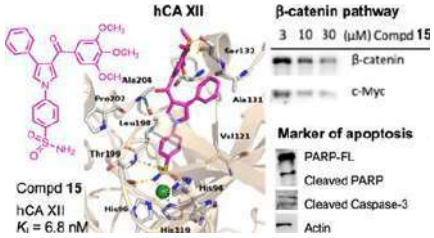

Figure 1: Compound 15 showed strong inhibition of viability in a panel of cancer cells.

References:

[1] C.T. Supuran, Bioorg. Med. Chem. **2013**, 21, 1377−1378.
[2] D. Masci, *et al*., Journal of Medicinal Chemistry **2023**, 66 (21), 14824−14842.

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FAR-PO-070

Predicting UGT-mediated metabolism by ligand and structure-based models

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The in silico prediction of drug metabolism is gaining a growing interest due to the possibility to process large datasets allowing the stability and safety of new drug candidates to be evaluated in the early stages of drug discovery process. To date, in silico models for metabolism prediction mainly exploits the physicochemical and stereo-electronic properties of the training molecules in order to predict the occurrence of a given metabolic reaction and/or the reactive site involved in the predicted biotransformation.[1] However, recent reports suggested that structure-based methods, such as docking simulations, can be conveniently integrated with ligand-based (LB) approaches for drug metabolism prediction purpose, with the advantages to predict if a given molecule can fit the enzyme active site and which moiety approaches the catalytic residues.[2] On this ground, this work aimed at developing ML predictive models for UDP-glucuronosyltransferase (UGT)-mediated metabolism by combining both ligand- and structure-based (SB) approaches. UGT enzymes catalyse a phase II metabolism reaction consisting of the glucuronidation of nucleophilic sites of the substrate. Specifically, our study was focused on UGT2B7 and UGT2B15 isoforms as they are widely implicated in the clearance of many drugs as well as in clinically relevant drug-drug and drug-xenobiotics interactions. First, a computational study, including docking and molecular dynamics (MD) simulations, was performed to investigate the binding order of cofactor and substrate to UGT2B7 and UGT2B15, exploiting their three-dimensional models available on AlphaFold repository. The analysis of MD trajectories allowed an appropriate conformation of both UGT isoforms to be identified for the development of ML classification models. For this purpose, a set of UGT substrates and non-substrates was collected from the manually curated MetaQSAR database[3] and split into training and test sets. SB models were trained on a set of scoring functions computed by docking and rescoring calculations and protein-ligand fingerprints. Instead, the LB classifiers were generated using a set of physicochemical and constitutional descriptors. All models were internally validated by ten-fold cross validation and evaluated on the test set. In addition, a further validation was carried out on an external test set containing molecules retrieved from GOSTAR database. Overall, the generated models displayed a good ability to correctly identify UGT substrates, with the SB classifiers outperforming the LB models when evaluated on the GOSTAR external dataset. Moreover, inspection of docking poses provided useful hints about the structural motifs that are most likely to undergo glucuronidation.

References:

[1] S.R. Kazmi, R.Jun, M.S. Yu, C. Jung, D. Na, Computers in Biology and Medicine 2019, 106, 54 – 64.
[2] L.J. Kingsley, G.L. Wilson, M.E. Essex, M. A. Lill, Pharmaceutical Research 2015, 32, 986 – 1001.
[3] A. Pedretti, A. Mazzolari, G. Vistoli, B. Testa, Journal of Medicinal Chemistry 2018, 61, 1019-1030.

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FAR-PO-071

Identification of New Heterocyclic Compounds as Protein Disulfide Isomerase A Inhibitors

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Protein disulfide isomerases (PDIs) are redox chaperone proteins that belong to the thioredoxin oxidoreductase superfamily and are able to catalyze dithiol-disulphide exchange reactions.[1] In the last years, the scientific community paid much attention to PDIA3 isoform, because altered expression and activity of this protein has been associated with several human diseases, such as cancer, neurodegenerative diseases, and also viral infection.[2] Indeed, the presence of PDIA3 on the cell surface has been related with the entry of different viruses in human cells. During influenza A virus (IAV) infection, PDIA3 is involved in the hemagglutinin protein maturation and IAV replication, suggesting a potential role as target to counteract IAV infection. Moreover, in human coronaviruses (HCoVs), PDIA3 is associated with the effective oxidative folding and trimerization of HCoV Spike (S) protein by catalyzing the formation of disulphide bonds that could mediate the interaction between the envelope and S protein. Therefore, PDIA3 may be viewed as an interesting pharmacological target with a huge potential for the development of innovative antiviral agents. Also considering its presence in human cells and not in the viruses, PDIA3 offers the opportunity to discovery new drugs as putative broad-spectrum antiviral agents, overcoming problems such as drug resistance.

In previous studies, 16F16 was reported as a covalent inhibitor of PDIA1 and PDIA3 proteins due to the presence of a chloroacetyl group that irreversibly binds to free cysteine thiols.[3] Starting from the chemical structure of 16F16, we designed and synthesized a small set of structural analogues, characterized by a tetrahydro-β-carbolines core endowed with a chloroacetyl group in 2-position as PDIA3 inhibitors, to further explore the structure activity relationship. The data coming from the biochemical assays will be shown and discussed.

References:

[1] Chichiarelli, S.; Altieri, F.; Paglia, G.; Rubini, E.; Minacori, M.; Eufemi, M. ERp57/PDIA3: new insight. *CMBL.* **2022**, *27(1)*, 12. https://doi.org/10.1186/s11658-022-00315-x.

[2] Medinas, D.B.; Rozas, P.; Hetz, C. Critical roles of protein disulfide isomerases in balancing proteostasis in the nervous system. *J Biol Chem*. **2022**, *298(7)*, 102087. https://doi.org/10.1016/j.jbc.2022.102087.

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FAR-PO-072

Characterisation of Persistence, Bioaccumulation and Toxicity of Biologically Active Compounds with Machine Learning-based Methods

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Assessing Persistence, Bioaccumulation, and Toxicity (PBT) is crucial for understanding the potential risk associated to the release of chemicals in the environment. Screening for PBT is still a challenging process due to the scarcity and poor quality of available data. This highlights the need for accurate and readily available methods to better predict the environmental impact of chemicals. PBT can be concisely expressed by the PBT index, defined thanks to a traditional QSPR model based on four structural molecular descriptors.[1] However, the accuracy of traditional QSP(A)R models tend to decrease when applied to large and heterogeneous datasets. The aim of this project is to apply advanced machine learning (ML) algorithms to predict the PBT index of pharmaceutically relevant molecules, overcoming the limitations of more traditional approaches. Chemprop, a message passing neural network (MPNN) was employed for this purpose.[2] First, we assembled a comprehensive dataset of compounds already annotated by public agencies. After removing ambiguous and duplicated compounds, our final dataset encompassed 5129 molecules univocally labelled as PBT or non-PBT. Part of this collection (training set) was used to train a binary classification model that assigns each compound a PBT or non-PBT label based on features extracted from its structure. Once trained, the model was used to make predictions on the remaining molecules (test set). We further enhanced the robustness and stability of our PBT prediction model by increasing structural dissimilarity between training set and test set molecules by means of a clustering strategy. When applied to the test set, the figures of merit show how the model achieved an accuracy (g) of 0.90, and a recall rate (r) of 0.92. Overall, this study highlights the potential of ML models for predicting PBT properties, thereby focusing on enhancing model's generalizability. Moreover, using Chemprop's built-in 'interpret' function,[2] we are able to extract PBT-related significant substructures that are responsible for the PBT prediction in order to provide guarantees of model explainability for the PBT assessment. Lastly, a dataset of compounds of pharmaceutical interest (619 cmpds) extracted from DrugBank database will be tested to the proposed Chemprop model in order to identify potential PBTs among pharmaceuticals defined as contaminants of emerging concern.[3]

References:

[1] Papa, E. & Gramatica, P. QSPR as a support for the EU REACH regulation and rational design of environmentally safer chemicals: PBT identification from molecular structure. *Green Chem.* **12**, 836–84 (2010).
[2] Heid, E. *et al.* Chemprop: A Machine Learning Package for Chemical Property Prediction. *J. Chem. Inf. Model.* **64**, 9–17 (2024).
[3] Patel, M. *et al.* Pharmaceuticals of emerging concern in aquatic systems: Chemistry, occurrence, effects, and removal methods. *Chem. Rev.* **119**, 3510–3673 (2019).

FAR-PO-073

DELTA: Database of Enhanced Ligands and TArgets for drug discovery and activity prediction

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Given the large extent of information on ligands and targets involved in diseases available in public databases, increasing efforts have been made over the last decades on the application of in silico strategies. Among these, inverse screening approaches are attracting increasing great interest due to its many applications in the drug discovery process. For example, it allows the identification of both the mechanism of action of a new molecule and of secondary targets for investigated drugs or natural compounds, enabling the prediction of possible side effects and toxicity but also suggesting new potential therapeutic uses[1,2]. Different strategies to perform inverse screening have been developed in the last decades[3,4], they however present significant limitations due to an unsuitable number of target structures, which can result in an inefficient screening or in a too high computational and time requirement.

On these grounds, we developed a dataset of therapeutically relevant targets, consisting in 485 proteins associated with specific diseases and for which either an approved drug or a drug under clinical trial is available. For each target, we also collected a dataset of ligands with experimentally determined activity on the targets, including an equal number of active and inactive compounds depending on a defined activity threshold, reasonably covering all the involved chemical space. Both targets and ligands structures have been refined and optimized. The major applications of these datasets include the possibility to perform reverse screening campaigns and develop predictive models to identify targets for a specific query molecule. Some examples of relevant applications will be presented.

References:

[1] E. March-Vila et al, Front Pharmacol 2017, 8.
[2] M. J. Keiser et al, Nature 2009, 462, 175–181.
[3] H. Li et al, Nucleic Acids Res 2006, 34, 214-224.
[4] Y.Z. Chen, D.G. Zhi, Proteins: Structure, Function, and Bioinformatics 2001, 43, 217-226.

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FAR-PO-074

Carbon Monoxide: a New Ally Against Multidrug Resistance.

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Despite all the efforts in recent decades cancer remains one of the leading causes of death. Among different treatments, chemotherapy is still the method of choice, however, the emergence of drug resistance could seriously undermine its effectiveness.[1] Indeed, cancer cells can develop resistance to several drugs with a different mechanism of action (MultiDrug Resistance) that represents a serious obstacle to the use of chemotherapeutics. In the past, we have found that gaseous signalling molecules, such as nitrogen monoxide (NO) and hydrogen sulfide (H_2S), could help overcoming the resistance of cancer cell to chemotherapeutics. Here we present the use of another gaseous messenger – CO, as a sensitizer of cancer cells.

The controlled delivery of CO to target tissue remains a challenge in medicinal chemistry. Several CO-releasing molecules (CORMs) have been proposed as alternatives to direct CO administration.[2] Here we decided to use non-metallic CORM (**1**) that release carbon monoxide after hydrolytic activation (**Scheme 1**).

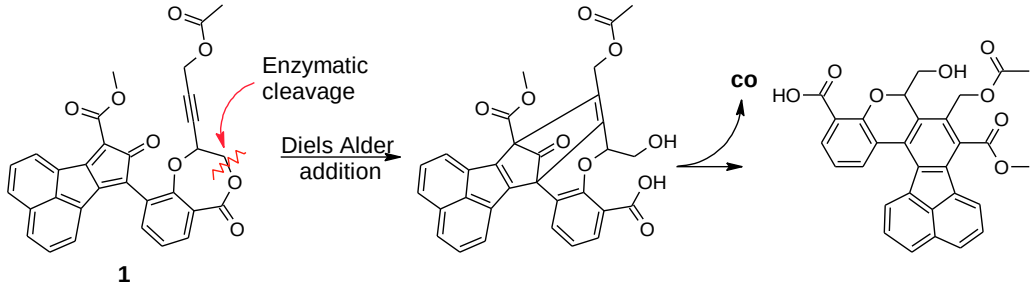

Figure 1: Mechanism of carbon monoxide release from **1**.

The toxicity of **1** alone and in combination with chemotherapeutic was evaluated in tumour cell lines known for their intrinsic resistance to chemotherapy. We have found the **1** itself reduced the viability of tumour cells at 0.1 – 1 μM concentration, while its toxicity in corresponding non-transformed cells was significantly lower. When **1** was co-incubated with increasing concentrations of cisplatin, doxorubicin, docetaxel or gemcitabine, i.e., the first line-treatments for corresponding tumour types a pronounced decrease in cell viability was observed. It seems that the mechanism responsible for sensitizing of resistant tumour cells include the mitochondrial damaged with a high level of mitochondrial ROS production due to CO production.

References:

[1] J.Q. Wang et.al., Drug Resist Updat 2021, 54, 100743.
[2] F. Zobi, Future Med Chem 2013, 5(2), 175-188.

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FAR-PO-075

Epigenetics and myocardial Ischemia-Reperfusion Injury: novel insights into the role of SIRT5

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Myocardial infarction (MI) is the leading cause of morbidity and mortality worldwide. Its pathomechanism includes the oxygen/nutrients deprivation of the myocardium, leading to cardiac damage[1]. Timely restoration of coronary flow is necessary to decrease the infarct size (IS) and to rescue the hypoxic myocardium. Paradoxically, reperfusion leads to additional cardiac injury leading to cardiomyocyte dysfunction, referred to as "reperfusion injury"[2,3]. Sirtuins are epigenetic enzymes that catalyze the removal of acetyl groups from both histones' tails and non-histone proteins via a NAD^+-dependent mechanism[4]. Several studies reported the implication of sirtuins in ischemia/reperfusion injury (IRI)[5,6,7]. However, their cardioprotective potential is elusive and is based primarily on studies exploiting non-specific SIRT agonists. Therefore, we chose to test three novel SIRT agonists that we previously synthesized, namely MC2606, MC2789 and MC3215, exhibiting SIRT1, SIRT3 and SIRT5 agonism respectively, as confirmed by the Mass Spectrometry (MS)-based assay[8]. We tested the compounds *in vitro*, in cardiomyoblasts (H9c2 cells) and human endothelial cells (EA.hy-926 cells), in order to identify the cytoprotective effect of our compounds in hypoxia/reoxigenation conditions and to assess their target engagement in the selected cell lines with western blot analysis. Furthermore, we assessed the cardioprotective potential of SIRT agonists in an *in vivo* model of IRI (30min Ischemia/2h and 24h reperfusion) in C57BL6/J male mice and assessed the IS. Among the three compounds, the SIRT5 agonist exhibited the greater cardioprotective potential, by reducing IS compared to controls both at 2 and 24h of reperfusion. Therefore, SIRT5 agonist was selected for further molecular experiments in order to identify its underlying cardioprotective mechanism, providing useful and novel insights on the role of SIRT5 in IRI.

References:

[1] T. Kalogeris, C.P. Baines, *Int Rev Cell Mol Biol.* **2012**; 298: 229–317. [2] H.M. Piper, D. Garcìa-Dorado, *Cardiovascular Research*, 38 **1998** 291–300. [3] S. Verma, P. Fedak, *Circulation* **2002**;105:2332-2336. [4] AA Sauve, C. Wolberger, *Annu Rev Biochem* **2006**, 75, 435-65. [5] CP Hsu, P. Zhai, *Circulation* 122: 2170 –2182, **2010**. [6] GA Porter, WR Urciuoli, *Am J Physiol Heart Circ Physiol* 306: H1602–H1609, **2014**. [7] R. Zoua, W. Shi, *European Journal of Pharmacology* 818 (**2018**) 410-418. [8] B. Suenkel, S. Valente, *J. Med. Chem*. **2022**, 65, 14015−14031.

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FAR-PO-076

PPARγ non-agonists: a new frontier in the treatment of metabolic diseases

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Insulin resistance is a pathological condition characterized by attenuated tissue response to normal or elevated insulin production. Type 2 diabetes mellitus (T2DM) and Metabolic Syndrome are the most common clinical pathologies associated with IR [1]. Most of glitazones, the traditional anti-diabetic drugs, which act as Peroxisome Proliferator-Activated Receptor γ (PPARγ) agonist, have been withdrawn from the market. To avoid the serious adverse effects related to the PPARγ agonism profile, a new opportunity is represented by the development of inhibitors of the PPARγ phosphorylation by the cyclin-dependent kinase 5 (Cdk5). Their mechanism of action is mediated by the stabilization of the PPARγ β-sheet containing Ser245 [2].

Recently, we disclosed the PPARγ non-agonist activity of 4-(4-bromophenyl)-3-hydroxy-5-(3-hydroxyphenyl)furan-2(5H)-one (**1**), which is able to block the phosphorylation of the enzyme without direct inhibition effect of both CDK5 and PPARγ [2]. We combined computational strategies and crystallographic experiments to deeply investigate the interaction of **1** with PPARγ and design innovative candidates, endowed with higher affinity for the target. The new derivatives, characterized by K_D values in the nanomolar range, improved the affinity for PPARγ of more than ten times compared to that of **1**. Furthermore, we successfully employed a bioisostere strategy to effectively improve the biostability of our compounds, thereby optimizing their pharmacokinetic profiles and therapeutic potential.

Of note, an innovative green synthetic approach was tackled in several steps, where the traditional organic solvents were replaced with bio-based solvents derived from biowaste, or from very cheap and easily accessible natural sources [3].

Overall, these outcomes, obtained combining computational, crystallographic, and innovative synthetic approaches, proved that the γ-hydroxy-lactone scaffold may provide a promising template for the development of novel anti-diabetic agents targeting PPARγ, without any transactivation potential or agonist activity. This innovative strategy could transform the treatment landscape for millions of individuals suffering from metabolic disorders, allowing the development of a safe treatment of insulin resistance.

References:

[1] International Diabetes Federation, IDF Diabetes Atlas 10th edition, 2021
[2] Capelli, D.; Cazzaniga G.; Mori, M.; Laghezza, A.; Loiodice, F.; Quaglia, M.; Negro, E.; Meneghetti, F.; Villa, S.; Roberta Montanari, R. Biomolecules 2023, 13, 694
[3] Cazzaniga, G.; Tresoldi, A.; Gelain, A.; Meneghetti, F.; Mori, M.; Villa, S. Chem. Biodiversity 2024, e202301729

FAR-PO-077

Exploring Substituent Effects on π-π Stacking Interactions: Investigation of Benzene Dimers

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Noncovalent interactions are pivotal factors in controlling structural and energetical aspects of molecular recognition/sensing and self-assembling/engineering[1,2]. Particularly, π-π stacking stands out in the biological context, where these interactions commonly occur among the nucleobases and the aromatic amino acid residues. Despite their biological significance, our knowledge of these fundamental nonbonded interactions is still far from being complete, and our ability to predict their strength is limited. In this context, we are yet unable to correctly parametrize the role of aromatic substituents although they can influence the energy interaction and may provide a way to tune π-π interactions. Such insights may also help the design of new bioactive molecules and materials with desired physical and chemical properties. Thus, we decided to analyze these intramolecular interactions with high-level theoretical methods in order to determine the contribution of each substituent to the energy landscape. In this study, we used *ab initio* and density functional theory (DFT) to study π-π stacking interaction energies of benzene dimers. Specifically, we assessed substituent effects by introducing various electron-donating and -accepting groups on one benzene ring, examining the dimer across three configurations (T-shaped, sandwich, and parallel display) throughout its potential energy curves. The energies of the π-π interactions were compared with those of couple cluster (CC) one, widely considered the "gold standard" in quantum chemistry. Concomitantly, the influence of aromatic substituent on π–π interactions was also experimentally investigated. For this purpose, we performed HPLC analyses of the analytes on different chromatographic stationary phases.

References:

[1] J. W. Steed, J. L. Atwood, Supramolecular Chemistry: A Concise Introduction; Wiley: New York, 2000.
[2] C. D. Sherril, T. Takatani, E. G. Hohenstein, J. Phys. Chem. A 2009, 113, 10146–10159.

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FAR-PO-078

Modulation of the aspartic acid scaffold to identify a new septin-4 covalent binder with anti-metastatic activity in a mouse model of melanoma

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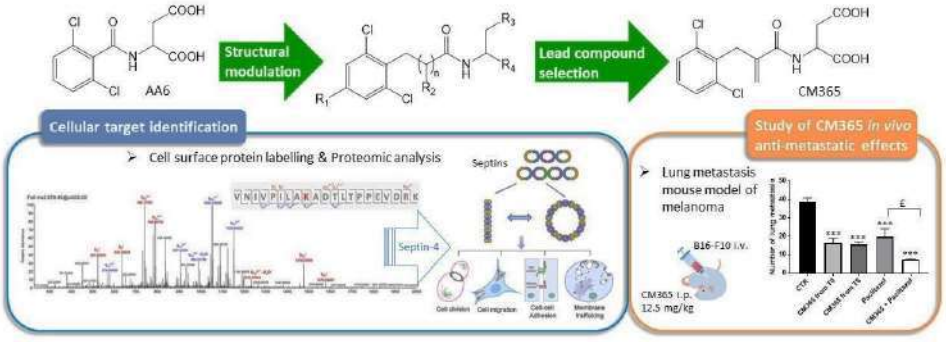
Tumour metastases are still the leading cause of cancer-related death, being often responsible for the failure of current therapies.[1] In our previous work, we have developed a compound, AA6, that proved able to counteract the metastatic spread in a mouse model of breast cancer.[2] To identify the essential structural elements and the cellular target involved in the activity of our lead compound, a new series of AA6-derivatives was designed and synthesised. New compounds were tested for the inhibitory activity on tumour cell invasion, migration and adhesion in B16-F10 melanoma cells. From the *in vitro* results, compound CM365 was selected as the most promising derivative, showing good efficacy and most likely able to interact with the target through covalent binding. To pinpoint the cellular target, a proteomic analysis was carried out and this allowed to select septin-4 as the most likely protein involved. Septins are GTP-binding proteins, able to assemble into large filaments on the plasma membrane, modifying its rigidity in migrating cells and promoting tumour metastasis.[3] To study and compare the binding modes of the two derivatives, AA6 and CM365, with the molecular target, computational analyses were performed. Finally, the anti-metastatic properties of CM365 were evaluated *in vivo* in a murine model of metastatic melanoma. This compound proved capable of reducing metastases dissemination at different times of administration and of enhancing the antitumour effect of a known anticancer drug, paclitaxel, when administered in combination. The discovery of septin-4 as a new molecular target for the prevention of metastatic spread may encourage the future development of more specific inhibitors.



References:
[1] A. Chatterjee, E. J. Roger et all, Semin. Cancer Biol., 2018, 51, 149–159.
[2] S. Atlante, A. Visentin, Cell Death Dis., 2018, 9, 756
[3] C. Poüs, L. Klipfel, Front. Cell Dev. Biol., 2016, 4, 126.

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FAR-PO-079

Chemical Space Exploration of ALDH1A3 Inhibitor NR6 for Anticancer Agents Development

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Cancer is the second global cause of mortality, accounting for nearly 10 million deaths in 2022.[1] Despite significant advancements in oncological treatments, poor outcomes are still associated with chemoresistance, metastasis, and the rise of cancer stem cells (CSCs). Targeting these latter represents a promising approach for overcoming the limits of the traditional cancer treatments. In this context, the Aldehyde Dehydrogenase (ALDH, EC: 1.2.1.3) family recently garnered significant attention from the scientific community, with the isoform1A3 being identified as a CSC marker[2] and overexpressed in several tumors, *e.g.,* glioblastoma multiforme. Our research group developed a library of diphenyl imidazo[1,2-*a*]pyridines as potent ALDH1A3 inhibitors and **NR6**, showing a 2,6-substitution pattern, emerged with a subnanomolar EC_{50} on ALDH1A3-overexpressing cell lines and an IC_{50} value of 5.3 µM in enzymatic inhibition assays.[3] Noteworthy, the presence of 3-cyanophenyl substitution in position 6 in **NR6** seems to play a key role in interacting with the enzyme, as suggested by crystallographic studies.[4] Aiming to improve solubility and enhance the inhibitory potency of such compounds, we explored the effect of different substitutions on the phenyl ring at position 2 of the heterocyclic core, thereby generating a novel series of **NR6** derivatives which allowed the construction of structure-activity relationships and address the synthetic efforts in the lead optimization process.

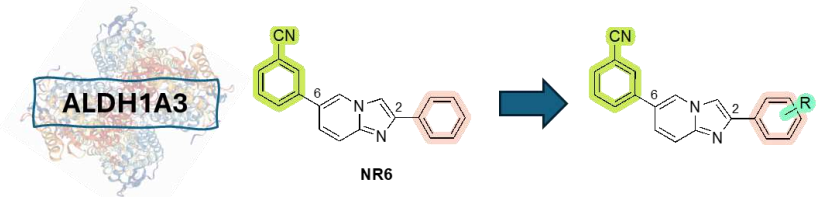

Figure 1: Chemical structure of NR6 and its derivatives series herein investigated.

References:

[1] Cancer Today, Global Cancer Observatory, https://gco.iarc.who.int. Accessed on 28/03/2024
[2] P. Marcato, C. A. Dean, D. Pan, R. Araslanova, M. Gillis, M. Joshi, L. Helyer, L. Pan, A. Leidal, S. Gujar, C. A. Giacomantonio, P. W. K. Lee, Stem Cells 2011, 29, 32–45.
[3] L. Quattrini, E. L. M. Gelardi, V. Coviello, S. Sartini, D. M. Ferraris, M. Mori, I. Nakano, S. Garavaglia, C. La Motta, J. Med. Chem. 2020, 63, 4603–4616.
[4] E. L. M. Gelardi, G. Colombo, F. Picarazzi, D. M. Ferraris, A. Mangione, G. Petrarolo, E. Aronica, M. Rizzi, M. Mori, C. La Motta, S. Garavaglia, Cancers 2021, 13, 356.

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FAR-PO-080

Investigating the interactions between direct-acting oral anticoagulants (DOACs) and human serum albumin using surface plasmon resonance and molecular docking

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Human serum albumin (HSA) is the most abundant protein in plasma, playing an important role in drug transport and pharmacokinetics. Many nutrients and food bioactive compounds are strong HSA binders, affecting by competition the HSA binding of drugs.[1]

Although no significant interactions with foods, dietary supplements, and herbs by direct-acting oral anticoagulants (DOACs) have been shown, some recent clinical observations suggested that food ingredients can modulate bioavailability and activity of DOACs by affecting the plasma concentration of the drugs.[2]

Herein, applying surface plasmon resonance (SPR),[3] and fluorescence spectroscopy in competition experiments, we investigated how some nutrients, such as flavonoids (catechin, quercetin), caffeine and saturated fatty acids (myristic and palmitic acids) interfere with the HSA binding of DOACs, namely rivaroxaban, edoxaban, apixaban and dabigatran etexilate, as compared to the classical oral anticoagulant warfarin. The binding interactions were also investigated by molecular docking calculations.

Figure 1. 3-D Structures of edoxaban and human serum albumin (HSA), and SPR sensorgrams in affinity experimental determination.

Drug	HSA, K_D (μM)	
	SPR	*literature*
edoxaban	16.8 ± 1.3	10.1 ± 0.5
rivaroxaban	5.60 ± 0.51	7.5 ± 0.10
Warfarin	3.85 ± 0.30	3.30 ± 0.33

References:

[1] Mariño-Ocampo, N., Rodríguez, D.F., Guerra Díaz, D., Zúñiga-Núñez, D., Duarte, Y., Fuentealba, D., Zacconi, F.C. Int. J. Mol. Sci. 2023, 24, 4900.
[2] Grześk, G., Rogowicz, D., Wołowiec, Ł., Ratajczak, A., Gilewski, W., Chudzińska, M., Sinkiewicz, A., Banach, J., Int. J. Mol. Sci., 2021, 22, 8531.
[3] Purgatorio, R., de Candia, M., Catto, M., Rullo, M., Pisani, L., Denora, N., Carrieri, A., Nevskaya, A.A., Voskressensky, L.G., Altomare, C.D., ChemMedChem, 2021, 16, 589-598.

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FAR-PO-081

Targeting RNA for degradation with small molecules: design and synthesis of selective RNA binders and development of ribonuclease targeting chimeras (RIBOTACs)

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RNA has been successfully targeted by small molecules for drug discovery purposes, by taking advantage of binding sites available upon rearrangement of RNA into secondary and tertiary structures.[1] A validated RNA target is pre-miR-21, a non-coding RNA, linked to various cancers and other pathologies.[2] This project aims to develop selective binders to target pre-miRNA21 and in turn decrease miRNA21 levels. To identify RNA ligands, we used a virtual screening, taking advantage of RNA binders reported in literature. Those compounds were docked against different possible conformations of pre-miRNA21. Here, the best compounds were selected for further synthesis. We identified two fragments, selected for a fragment growth campaign. Indeed, by following an optimized synthetic strategy, we obtained several derivatives that have been tested for their binding affinity to the short pre-miR-21 construct by high-resolution mass spectroscopy (MS) under native conditions. Binding data from native MS will guide ongoing structure–activity relationship (SAR) studies for the expansion of ligand library and the development of more potent and selective pre-miRNA21 ligands. Subsequently, pre-miRNA21 ligands will be employed as warheads to synthesize Ribonuclease Targeting Chimeras (RIBOTACs), a class of RNA-degraders.[3] RIBOTAC includes an RNA-binder conjugated by a linker to an RNase L recruiter, ultimately to induce enzymatic cleavage the RNA of Interest (ROI). (Figure 1).

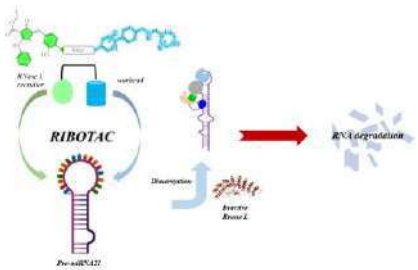

Figure 1: Formation of a ternary complex between RNA-RIBOTAC-RNase L which induces the consequent selective degradation of the ROI (RNA Of Interest).

References:

[1] A. Hargrove et al., E. Chem Commun 2020, 56, 14744-14756
[2] M. D. Disney et al., PNAS, 2020, 117, 33197–33203
[3] M. D. Disney et al., J. Am. Chem. Soc. 2021, 143, 13044–13055

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FAR-PO-082

New Biofilm Inhibitors to Fight Antibiotic Resistance

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Biofilms are aggregates of bacteria embedded in a self-produced matrix, that is composed of exopolysaccharides, proteins and nucleic acids.[1] Nowadays biofilm is considered a serious threat in infectious disease management, due to its ability to confer the bacterial cells a higher degree of resistance to antibiotics: indeed, its structure works as a barrier impeding the penetration of the drug or other xenobiotics into the cell.[2]

There are many mechanisms involved in the formation of biofilm, one of which is the Quorum Sensing (QS), a complex machinery governing the assembly of the structural components of biofilms, via the secretion of signalling molecules called autoinducers.[3] Based on these premises, as a continuation of a previous research, we designed new compounds acting as QS antagonists to prevent biofilm formation or to disrupt already formed biofilm in different strains of Gram-negative bacteria (figure 1).

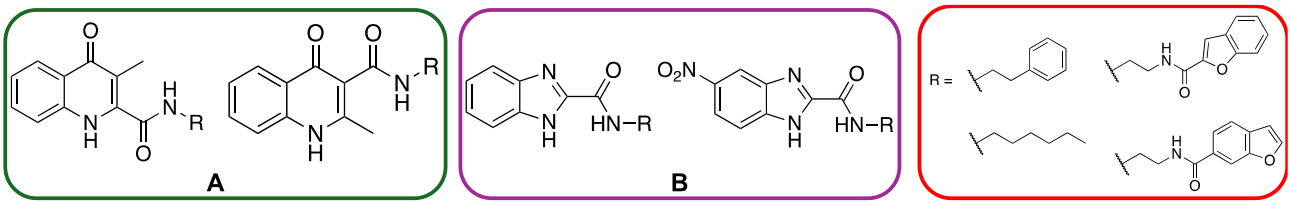

Figure 1: New molecules acting as biofilm inhibitors.

Compounds belonging to series A were based on the structure of 2-alkyl-4(1*H*)-quinolone derivatives, a group of potent autoinducers involved in QS signalling of *P. Aeruginosa*, while those in series B were conceived by drawing inspiration from some benzimidazole hybrids acting as anti-QS agents.[3] Both series of molecules have a common motif composed by a heterocyclic head, an amide spacer, and a side chain R carrying moieties with different steric and electronic features.

Early *in vitro* assays were performed on *B. Cenocepacia*, showing a promising ability of such compounds to reduce the biofilm formation up to 30%, while those on *P. Aeruginosa* and other Gram-negative bacteria are currently underway. These results enabled us shed lights on the structural features required for an anti-biofilm profile, thus constituting a starting point for a further optimization of the QS antagonist activity.

References:

[1] L.K. Vestby, T. Gronseth, R. Simm, L.L. Nesse, *Antibiotics* **2020**, 9, 59 – 87.
[2] N.K.D. Ragupathi, B. Veeraraghavan, E. Karunakaran, P.N. Monk, *Front. Med*. **2022**, 9, 987011.
[3] M. Duplantier, E. Lohou, P. Sonnet, *Pharmaceuticals* **2021**, 14, 1262 – 1296.

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FAR-PO-083

Design and synthesis of Rad51-BRCA2 protein-protein interaction disruptors to trigger synthetic lethality in pancreatic cancer cells

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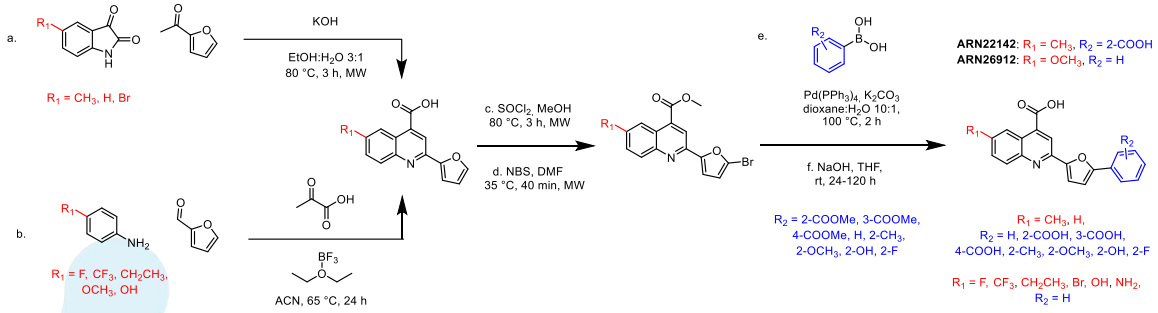
Synthetic lethality (SL) is a phenotypic condition in which cells do not survive due to the combination of two genetic perturbations that, taken individually, do not induce cell death. A successful application is the use of PARP inhibitors in cancer patients with BRCA2 mutations. One of the key mechanisms of BRCA2 is to recruit the Rad51 to the site of double-strand breaks where it performs homologous recombination repair.[1] Our research project focuses on the development of Rad51-BRCA2 protein-protein interaction (PPI) disruptors that mimic the BRCA2 mutation to trigger fully small organic molecule SL in combination with Olaparib in BRCA2-functional pancreatic cancer cells.[2,3]

Through a virtual screening campaign on a PP critical "hotspot" on Rad51 surface, a quinoline-structured Rad51-BRCA2 disruptor (**ARN22142**, Scheme 1) has been identified. To discover more effective compounds and depict general structure-activity relationship studies, the chemical space around **ARN22142** has been explored by optimizing a general synthetic strategy and building a library of quinolinic analogues modified in two moieties of interest (red and blue residues, Scheme 1). Among the synthetized compounds, **ARN26912** (Scheme 1) has showed synergism on the antiproliferative efficacy with Olaparib in BRCA2-proficient pancreatic cancer cell lines. This supports the idea that small organic molecules can mimic genetic mutations. Further in vitro biological studies will be done with this promising compound.

Funding: This work is financially supported by the Italian Association for Cancer Research AIRC (IG 2018, id 21386).



Scheme 1. Synthetic route to **ARN22142** and analogues.

References:

[1] Pellegrini, L. et al., 2002, Nature, 420, 287-93;
[2] Falchi F. et al., 2017, ACS Chem. Biol., 12 (10), 2491–97;
[3] Bagnolini, G. et al., 2020, J. Med. Chem. 63, 2588–2619.

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FAR-PO-084

Exploring metallophore-antibiotic conjugates as a novel antimicrobial strategy that exploits *Pseudomonas aeruginosa* zinc dependence

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Pseudomonas aeruginosa (*PA*) is a ubiquitous Gram-negative bacterium. Pulmonary infections caused by *PA* represent a serious threat, especially to patients with cystic fibrosis (CF). This risk is further exacerbated by the increasing spread of bacterial strains that show antibiotic resistance[1]. The ease with which *PA* can colonize the respiratory tract depends on its ability to proliferate even in environments where essential metals (such as Zn) are present in low concentration. In particular, zinc plays a fundamental role, as it is present in many bacterial proteins crucial for virulence. A peculiar tactic of *PA* to obtain zinc involves the secretion of pseudopaline (Fig. 1), that is a low molecular weight zinc chelating molecule, capable of binding zinc present in the external environment, extracting it also from proteins present in the host, and deliver it inside the bacterial cell[2]. The mechanism by which the zinc pseudopaline complex is transported into the bacterial cell has not yet been completely defined.

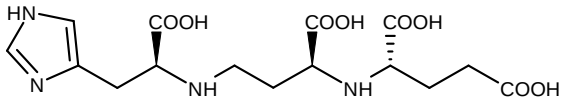

Figure 1: structure of pseudopaline.

The use of pseudopaline to chelate zinc represents a potential vulnerability of the pathogen, which can be exploited to allow antibiotics to enter the cell via the Trojan horse approach[3]. The aim of this study is to synthesize simplified analogs of pseudopaline, to evaluate the minimal structural requirements needed to participate in the zinc transport process of *PA*. These simplified zincophore compounds, simpler to synthesize than pseudopaline, can be more easily conjugated to various antibiotics that are still in use and active against these *PA* (such as aztreonam or ampicillin), to facilitate their entry into the bacterial cell through a preferential pathway. The antibacterial activity of these conjugates is evaluated against different *PA* strains to confirm the involvement of the zinc recovery pathway and demonstrate the proof of concept of the Trojan horse approach.

References:

[1] Diggle SP, Whiteley M. Microbiology (Reading). 2020, 166, 30-33.
[2] Ghssein G, Ezzeddine Z. Biology (Basel). 2022, 11, 17-11.
[3] Budzikiewicz, H. et al. Curr. Top. Med. Chem. 2001, 1, 73–82.

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FAR-PO-085

Structure-Based Virtual Screening (SBVS) for the discovery of Sirtuin-2 inhibitors

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Sirtuin-2 (SIRT2) is a (NAD^+)-dependent enzyme with deacetylase activity[1]. Dysregulation in SIRT2 activity was shown to be related to a plethora of diseases, such as neurodegenerative disorders, cancer and metabolic syndromes[2]. Several conformationally diverse X-Ray structure of SIRT2 are available at the Protein Data Bank (PDB), both in the holo- and apo-states. With the aim to discover novel SIRT2 inhibitors (SIRT2Is) via structure-based virtual screening (SBVS), a preliminary study for the evaluation of the available SIRT2 PDB structures for the following VS was performed, scouting single- and multiple- protein conformation approaches. The structure ability to select SIRT2Is within a set of decoys was evaluated by Receiver Operating Characteristic AUC (ROC-AUC). The best system was chosen to screen the ChemDiv commercial library (>22,000 compounds), guiding the discovery of novel chemo-types endowed with modest SIRT2 inhibitory ability. This piece of information paved the way for the following SBVS of novel pyrazolo-pyrimidines and thiazole-based compounds exhibiting ameliorated SIRT2 inhibitory ability[3,4] (Figure 1).

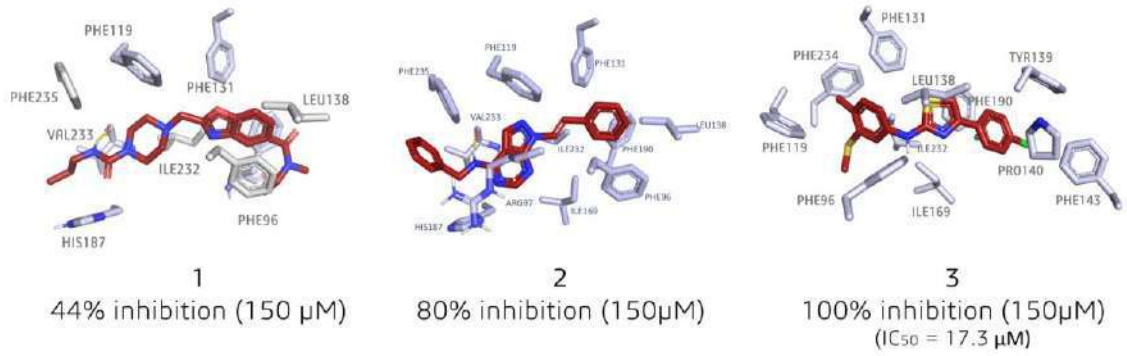

Figure 1: Hit compounds retrieved with the structure-based drug design approach.

References:

[1] S. Lee, Z. Chen, G. Zhang, Cell Chemical Biology 2017, vol. 24, 248–249.
[2] Y. Wang, J. Yang, T. Hong, X. Chen, L. Cui, Ageing Research Reviews 2019, vol. 55, 100961.
[3] N. Scarano, E. Abbotto, F. Musumeci, E. Cichero et al., Int J Mol Sci 2023, 24(11):9363.
[4] E. Abbotto, B.Casini, F. Piacente, E.Cichero et al, Pharmaceuticals 2023, 16(9), 1316.

FAR-PO-086

A Computational Facility for Lead Identification integrated within VITALITY enabling Platform for Drug Discovery

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After the challenges posed by the Covid-19 pandemic, and by leveraging funds from the National Recovery and Resilience Plan to stimulate growth and foster resilience, universities and other institutions from Central Italy capitalised on their expertise to establish a platform to devise innovative therapeutic approaches within the context of VITALITY project (Figure 1). As a key objective, our research group is setting up a computational facility accessible to third parties to speed up preclinical stages of drug discovery programs through virtuous iterative design-make-analyse cycles.

At the core of the initiative, an HPC platform at the University of Urbino has been set-up consisting of a small cluster endowed with GPUs, enabling the application of deep learning algorithms and the acceleration of molecular simulations. Workflows ready for virtual screening campaigns have been devised, including ultra-large library screening approaches and post-processing tools for rescoring.

Neural networks to prioritize compounds for physics-based scoring[1] and the integration of one-dimensional shape screening with structure-based techniques[2] have been included as capabilities effectively enabling large-scale campaigns. For this purpose, libraries in a format suitable for docking calculations are available to end-users, including diversity sets, biomimetics, covalent ligands classified by their reactive warhead, the entire Enamine REAL stored as binary fingerprints, and a curated academic library of pre-synthesized compounds.

Semi-automated pipelines, including fast rescoring of docking poses via free-energy methods[3] and a pharmacophore-based utility for covalent ligand identification, complement those assets. Finally, a series of scripts allowing for batch interrogation of online databases allow for library filtering and annotation, for target identification in phenotypic screening and for off-targets de-risking.

Figure 1: Logo of the PNRR Vitality project.

References:
[1] Y. Yang et al., J. Chem. Theory Comput. 2021, 17, 11, 7106–7119
[2] M. Michino et al., ACS Bio. Med. Chem. Au 2023, 3, 6, 507–515.
[3] K.J. Cutrona et al., J. Chem. Inf. Model. 2020, 60, 4403–4415.

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FAR-PO-087

A new class of selective SARS-COV-2 nsp13 Helicase and NTP-ase inhibitors: Pyridobenzothiazolones (PBTZS)

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In COVID-19 pandemic context, the scientific community mobilized extensive efforts to speed up the discovery of effective vaccines and potent antiviral drugs to counteract the rapid transmission and infection of SARS-CoV-2[1]. Particular attention has been devoted to SARS-CoV-2 essential targets in the viral life cycle, notably the main protease (M^{pro}) and polymerase, with small focus on the helicase[2]. Our research interest has been directed towards the helicase of SARS-CoV-2 (NSP13), the less explored target, but highly conserved across coronavirus family, indicating its potential as a target for pan-coronavirus antiviral therapies[3,4].

Previous studies have reported Pyridobenzothiazolones (PBTZS) as NS5 polymerase inhibitors of different Flavivirus in cell lines with potency ranging from low to sub-μM levels, and importantly, without toxicity[5]. The PBTZs' activity as "pan-Flaviviruses' inhibitors" induced us to explore their potential activity as Coronaviruses inhibitors. Therefore, we set up a screening cascade for SARS-CoV-2 that consisted in: i) antiviral phenotypic screening; ii) enzymatic assays M^{pro}, polymerase and helicase. Remarkably, all compounds demonstrated specific inhibition of the helicase and NTPase functionalities of NSP13 with an IC_{50} from 0.2 to 20 μM. One of the most identified hit showed IC_{50} = 0.32 ± 0.22 μM in helicase assay, and 4.4 ± 1.1 μM NTPase assay, with an antiviral potency EC_{50} = 10.37 ± 1.3 μM in VeroE6-GFP cells, and CC_{50}> 100 μM. We proceeded with the design of a small set of novel analogues to further investigate this new class of NSP13 helicase and NTPase inhibitors. In the absence of a co-crystal structure, our design strategy relied on a ligand-based structure-activity relationship (SAR) study. Two derivatives, namely F2F-2020406 and F2F-2020400, exhibited enhanced activity and selectivity.

Considering the current state of art of NSP13 inhibitors, this initial exploration identified a novel class of inhibitors with low μM antiviral activities of NSP13 helicase and NTPase enzymatic functionalities and importantly demonstrating activity against SARS-CoV-2 replication in cell-based assays.

References:

[1] C.S. Adamson et al. Royal Society of Chemistry 2021, 50, 3647-3655
[2] G. Li et al. Nature Reviews Drug Discovery 2023 vol. 22 449–475
[3] J.A. Newman et al. Nature Communications 2021, 12:4848
[4] A. Corona et al. ACS Pharmacol. Transl. Sci. 2022, 5, 226−239
[5] R. Cannalire et al., Antiviral Research 167 (2019) 6-12

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FAR-PO-088

Privileged scaffolds for potent and specific inhibitors of PARPs subfamilies.

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ADP-ribosylation, a reversible post-translational modification of proteins, is catalysed by a large family of enzymes (17 in humans) known as PARPs. While poly-ADP ribosylating enzymes (poly-ARTs) are well characterized with some approved anticancer compounds that represented an important step forward towards targeted therapy, mono-ADP ribosylating enzymes (mono-ARTs) still remain less understood. However, the interest toward these enzymes has grown due to their pivotal roles in various cellular processes such as cell replication, immune modulation, apoptosis, stress response, and neurodevelopment. Furthermore, targeting mono-ARTs shows promise in treating not only cancer but also inflammation and neurological disorders.[1] Despite the hot topic of this research field, the mono-ARTs inhibitors development is still at an early stage. Being the NAD pocket highly conserved among all the PARPs subfamilies and since most of the inhibitors work as NAD mimetics, the development of highly selective ARTs inhibitors still remains one of the major challenges to fight with.[1]

In this scenario, by exploring innovative heterocycles as new nicotinamide mimicking scaffolds, we have recently identified the most potent PARP10 and dual PARP10/PARP15 inhibitors described to date.[2,3] Based on these valid starting points and aiming to increase even more the selectivity and inhibit other specific enzymes within the mono-ARTs subfamily, a further SAR exploration has been performed. In particular, taking advantages of the available co-crystallographic structures, various modifications were made to reach some less conserved regions (*e.g.* D-loop or mono-ARTs hydrophobic cavity) of the PARPs catalytic domain for achieving specificity.

All of the synthesized compounds were tested against a wide panel of PARPs, from which interesting derivatives with new SAR insights emerged; the best derivatives were also characterized in cellular context and preliminarely studied for their ADMET properties. The results will be the object of the presentation.

References:

[1] Nizi, M.G.; Maksimainen, M.M.; Lehtiö, L.; Tabarrini, O. *J. Med. Chem.* ,**2022**, 65, 7532–7560.
[2] Murthy, S.; Nizi, M G.; Maksimainen, M.M.; Massari, S.; Alaviuhkola, J.; Lippok, B.E.; Vagaggini, C.; Sowa, S. T.; Galera-Prat, A.; Ashok, Y.; Venkannagari, H.; Prunskaite-Hyyryläinen, R.; Dreassi, E.; Lüscher, B.; Korn, P.; Tabarrini, O.; Lehtiö, L. *J. Med. Chem.* ,**2023**, 66, 1301-1320.
[3] Nizi, M G.; Maksimainen, M.M.; Murthy, S.; Massari, S.; Alaviuhkola, J.; Lippok, B.E.; Sowa, S.T.; Galera-Prat, A.; Prunskaite-Hyyryläinen, R.; Lüscher, B.; Korn, P.; Lehtiö, L.; Tabarrini, O. *Eur*..*J. Med*. *Chem*. ,**2022**, 66, 114362.

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FAR-PO-089

Discovery of multi-target directed ligands: screening of library compounds at adenosine receptors

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Neurodegenerative diseases (NDs) and cancer represent a global health problem. For NDs treatments, the current focus is on different targets including cholinesterase, monoamine oxidases (MAOs) and adenosine receptors (ARs). Due to their higher density in the brain, the most involved ARs are A_1R and $A_{2A}R$. Evidence indicates that $A_{2A}R$ plays a crucial role in the pathogenesis of Parkinson's disease (PD), linked to motor impairment managing and neuroprotection. Epidemiologic studies show an inverse correlation between the consumption of caffeine (a methylxanthine antagonist of AR) and the risk of developing PD [1][2]. The activity of A_1R and $A_{2A}R$, controlling the release of neurotransmitters (e.g. glutamate and acetylcholine) take part in modulating and integrating cognition and memory functions [3][4]. Studies suggest that in both Alzheimer's disease mouse models and humans, caffeine prevents the acute memory impairment [5][6]. For cancer monoamine oxidases, matrix metalloproteinases (MMPs) and ARs are attractive targets. It has been discovered that adenosine, which increases in hypoxic regions of solid tumours, can hinder the immune system's ability to recognize tumour cells by cytolytic effector cells [7][8]. We have selected compounds among an in-house chemical library with known activity as inhibitors of MMP 2 and 9, acetylcholinesterase, MAO A and B. The aim of this work is to identify additional activities targeting at ARs conferring to our molecules a multitarget activity profile. Thus, compounds bearing different scaffolds (coumarins, hydroxamic acids and barbituric acids) have been screened on the different adenosine receptors (A_1, A_{2A}, A_{2B}, A_3). The Bioluminescence Resonance Energy Transfer Assay using CHO cells expressing human adenosine receptors is being employed to assess the biological activity. Multitarget activity profile of previously disclosed inhibitors will be presented.

References:

[1] G. W. Ross, R.D. Abbott, H. Petrovitch, D. M. Morens, A. Grandinetti, K. H. Tung, C. M. Tanner, K. H. Masaki, P. L. Blanchette, J. D. Curb, J. S. Popper, L. R. White, JAMA 283 (2000) 2674–2679.
[2] A. Ascherio, S. M. Zhang, M. A. Hernán, I. Kawachi, G. A. Colditz, F. E. Speizer, W.C. Willett, Ann. Neurol. 50 (2001) 56–63.
[3] R. A. Cunha, P. M. Agostinho, J. Alzheimers Dis. 20 (Suppl 1) (2010) S 95–116.
[4] J. A. Ribeiro, A. M. Sebastião, A. de Mendonça, Prog. Neurobiol. 68 (2002) 377–392.
[5] W. Riedel, E. Hogervorst, R. Leboux, F. Verhey, H. van Praag, J. Jolles, Psychopharmacology (Berl) 122 (1995) 158–168.
[6] P. H. Botton, M. S. Costa, A. P. Ardais, S. Mioranzza, D. O. Souza, J. B. T. da Rocha, L. O. Porciúncula, Behav. Brain Res. 214 (2010) 254–259.
[7] J. Blay, T. D. White, D.W. Hoskin, Cancer Res. 57 (1997) 2602–2605.
[8] S. Merighi, P. Mirandola, K. Varani, S. Gessi, E. Leung, P. G. Baraldi, M. A. Tabrizi, P. A. Borea, Pharmacol. Ther. 100 (2003) 31–48.

FAR-PO-091

Unlocking the Potential of Biocatalytic Oxidative Systems: A Pathway to Sustainable Synthesis of Pharmaceuticals from Food Waste

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Selective oxyfunctionalisation of non-activated C-H, C-C and C=C bonds is a highly desirable transformation with broad implications in various product syntheses, including pharmaceuticals. However, the introduction of functionalities into the inert backbones of organic molecules is challenging. Biocatalysis is emerging as a powerful tool that exploits the substrate specificity, chemo-, enantio- and regioselectivity of enzymes under mild conditions.[1] Fungal unspecific peroxygenases (UPOs), a class of simple and robust haem thiolate-containing enzymes, catalyse a range of C-H oxyfunctionalisation reactions. When activated by H_2O_2, UPOs exhibit a kaleidoscope of oxyfunctionalisation reactions, positioning them as promising biocatalysts in synthetic chemistry.[2] The exploration of the biotransformation of food waste into high-value compounds via biocatalysis has attracted considerable interest, particularly in medicinal chemistry. Cashew nutshell liquid (CNSL), a by-product of cashew nut processing, is a natural source of phenolic compounds with a pentadecyl alkyl side chain with varying degrees of unsaturation.[3] While CNSL is a promising source of drug precursors, its biocatalytic functionalisation to drugs remains unexplored. As an alternative approach, we propose to functionalise the pentadecyl alkyl side chain of CNSL derivatives using biocatalytic oxidative systems, providing a sustainable alternative. Ongoing investigations aim to further elucidate the potential of this methodology in advancing drug discovery efforts for neglected tropical diseases (NTDs), highlighting the promising role of biocatalysis in sustainable synthetic pathways.

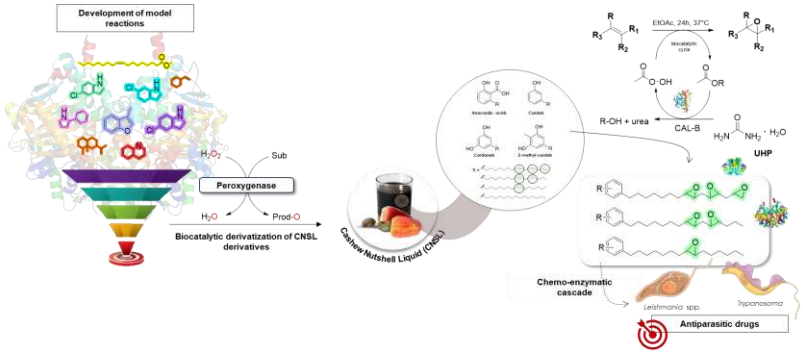

Figure 1: Biocatalytic derivatization of natural lipids, building blocks, and CNSL derivatives.

References:

[1] Winkler, C. K.; *et al.* ACS Cent. Sci. **2021**, 7 (1), 55–71.
[2] Monterrey, D. T.; *et al.* Curr. Opin. Green Sustain. Chem. **2023**, 41, 100786.
[3] Espro, C.; *et al.* Chem. Soc. Rev. **2021**, 50 (20), 11191–11207.

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FAR-PO-092

Novel Focal Adhesion Kinase Inhibitors Inducing Immunogenic Cell Death in Pancreatic Cancers

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Focal adhesion kinase (FAK) is a nonreceptor tyrosine kinase overexpressed in numerous solid cancers playing a crucial role in regulation of cell adhesion, migration and invasion. Additionally, FAK modulates both cellular and molecular composition of the immunosuppressive tumour microenvironment. Recently, we described the synthesis and the antiproliferative activity of a series of 3-(imidazo[2,1-*b*][1,3,4]thiadiazol-2-yl)-1*H*-indole derivatives, which showed potent *in vitro* antiproliferative and antimigratory activity against numerous cancer cell lines belonging to the NCI full panel and PDAC panel, with GI_{50} values ranging from micromolar to sub-micromolar level.[1] Further studies identified the inhibition of phosphorylation of PTK2/FAK as the mechanism of action of this class of compounds. Based on the interesting antiproliferative activity observed for the imidazothiadiazole scaffold and the FAK inhibitory activity described in literature for pyridine compounds[2] we synthesized new derivatives bearing 3-pyridinyl and 4-pyridinyl nucleus at position 6 of the imidazothiadiazole nucleus, with the aim to obtain new anticancer agents targeting FAK.
Interestingly, some of the synthesized compounds exhibited an outstanding antiproliferative activity against several human cancer cell lines, being able to induce cancer immunogenic cell death (ICD).

References:

[1] S. Cascioferro, G.L. Petri, B. Parrino, D. Carbone, N. Funel, C. Bergonzini, G. Mantini, H. Dekker, D. Geerke, G.J. Peters, G. Cirrincione, E. Giovannetti, P. Diana, Eur. J. Med. Chem. 2020, 189, 112088.

[2] M. Mustafa, A. A. Abd El-Hafeez, D. Abdelhamid, G. D. Katkar, Y. A. Mostafa, P. Ghosh, h, A. M. Hayallah, G. El-Din A. Abuo-Rahma, Eur. J. Med. Chem. 2021, 222, 113569.

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FAR-PO-093

Development of heterobifunctional small molecules for prion diseases

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Prion diseases are a group of lethal, infectious neurodegenerative diseases, involving a protein infectious agent that propagates the disease by transmitting protein conformational changes. The conversion of the cellular prion protein (PrP^{C}) into misfolded isoforms (PrP^{Sc}) is the main event in prion diseases. However, the mechanism by which this process results in brain damage and disease is largely unknown. Such unorthodox nature makes the search of effective anti-prion compounds highly challenging.[1] As a result, there is not a viable cure yet. Given the extensive validation of the PrP hypothesis, there have been several efforts to develop PrP-lowering therapies, but proximity-based modalities aimed to induce PrP degradation (and to lower its cellular level), have so far been never exploited. Thus, we sought to harness proteolysis-targeting chimeras (PROTACs, Figure 1), a leading proximity-based modality in drug discovery.[2] Thanks to their bifunctional nature, PROTACs may induce proximity between the PrP protein and a ubiquitin E3 ligase to trigger targeted PrP ubiquitination and subsequent degradation.

Following visual inspection of the available PrP-ligand complexes, an initial set of potential PrP-directed PROTACs was designed and synthesized by tethering a diphenylmethane-based PrP ligand with an E3 binder via different linkers. Preliminary investigation in noninfected neuronal N2a cells and RML strain scrapie-infected N2a (ScN2a-RML) cells to evaluate cytotoxicity and anti-prion activity is being performed.

Encouraged by their success with undruggable proteins, PROTACs hold enormous potential to unlock drug discovery efforts against this challenging target and to find an effective cure for prion diseases.

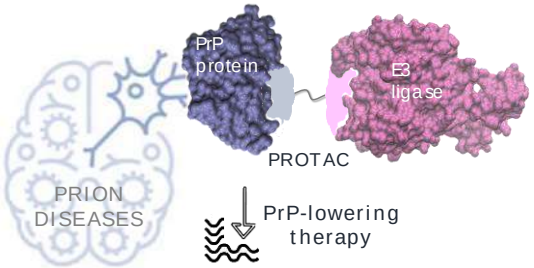

Figure 1: Bifunctional PROTACs directed to PrP.

References:

[1] E. Uliassi, L. Nikolic, M.L. Bolognesi, G. Legname, Cell Tissue Res. 2023, 392, 337-347.
[2] X. Liu, A. Ciulli, ACS Cent. Sci. 2023, 9, 7, 1269–1284.

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Novel FtsZ inhibitors identified by virtual screening and Adaptive Steered Molecular Dynamics

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Filamentous temperature-sensitive Z (FtsZ) protein represents a promising antibacterial target owing to its essential role in bacterial cell division[1]. Serving as the prokaryotic functional homologue of tubulin, FtsZ polymerizes into protofilaments orchestrating the formation of the Z-ring during binary fission.

A molecular docking and pharmacophore based virtual screening campaign resulted in the discovery of a novel FtsZ polymerization inhibitor exhibiting an IC_{50} potency of 48 μM. The promising in-vivo MIC of 2 mg/mL was achieved in presence of a efflux pump inhibitor (PaβN[2]). To enhance potency and diminish affinity towards efflux pumps, an Adaptive Steered Molecular Dynamics (ASMD) based drug design approach was employed.

ASMD[3] presents a refinement of the Steered Molecular Dynamics (SMD) technique where the driving of a steered particle (i.e. the unbinding of a ligand) is performed by a time-dependent harmonic force in stages. Unlike SMD, which requires a large number of replicas to encompass all potential unbinding configurations and generate a reliable Potential of Mean Force (PMF) along the reaction coordinates using Jarzynski's Equality (JE), ASMD optimize this process by segmenting the unbinding pathway into stages and discarding trajectories that significantly deviate from the equilibrium path at the conclusion of each stage.

Structural analogues of the discovered inhibitor were purchased and tested to build preliminary structure-activity relationships (SAR) and the trends in inhibitory activities were retrospectively predicted by ASMD. The optimized parameters obtained from this analysis were utilized in the rational design a new derivative, featuring chemical moieties tailored towards mitigating bacterial efflux and enhancing potency.

References:

[1] E. Ferrer-González, J. Fujita, T. Yoshizawa, J. M. Nelson, A. J. Pilch, E. Hillman, M. Ozawa, N. Kuroda, H. M. Al-Tameemi, J. M. Boyd, E. J. LaVoie, H. Matsumura, D. S. Pilch, Scientific reports 2019, 9, 20092.
[2] R. P. Lamers, J. F. Cavallari, L. L. Burrows, PLoS One 2013, 8(3), e60666.
[3] Y. Zhuang, H. R. Bureau, S. Quirk, R. Hernandez, Molecular Simulation 2021, 47(5), 408-419.

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Design and Synthesis of Benzothiazole-based Proteolysis Targeting Chimeras for targeted degradation of Casein kinase 1 (CK1) implicated in Circadian Clock Dysregulation of Alzheimer's disease (AD)

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PROteolysis TArgeting Chimeras (PROTACs) are heterobifunctional small molecules which, by recruiting specific proteins of interest (POI) for ubiquitin-mediated degradation, control protein levels rather than modulating its function.[1] Alzheimer's disease (AD) is a complex neurodegenerative disorder characterized by the accumulation of misfolded proteins, synaptic dysfunction, and progressive cognitive decline and with no effective treatment up to date. Emerging evidence suggests a significant involvement of circadian rhythm dysregulation in the pathogenesis of AD, with protein kinases, such as CK1, playing a crucial role in modulating circadian processes.[2]

For that purpose, a small library of CK1-targeting PROTACs was designed based on benzothiazole derivatives originally developed for Amyotrophic Lateral Sclerosis (ALS), with promising potency, proven BBB permeability and already explored SAR.[3] Within this series, a combination of three different positions on POI ligand, two on cereblon recruiter, and two different linker lengths will be examined to determine optimal geometry for formation of effective ternary complexes. Currently, synthesis is in progress and, once obtained, compounds will be tested for in vitro potency and initial pharmacological and ADMET evaluation. Cell proof of concept studies will demonstrate effective degradation of the POI.

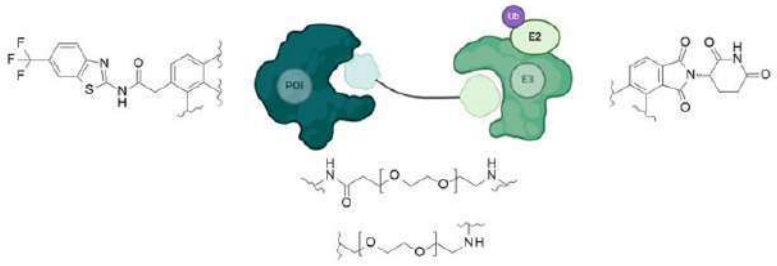

Figure 1: Design of first CK1-directed PROTACs analogues.

References:
[1] A. C. Lai, C. M. Crews, Nat Rev Drug Discov. 2017 February; 16(2): 101–114
[2] E. S. Musiek et al., Exp Mol Med. 2015; 47(3): e148
[3] I. G. Salado er al., J. Med. Chem. 2014, 57, 6, 2755–2772

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FAR-PO-096

Exploring Novel Strategies for Targeting NDM-1: Integrating PPI-FIT Technology in Drug Discovery to Identify Non-Conventional Degraders

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Metallo-β-Lactamases (MBLs) are enzymes able to catalyze the hydrolysis of a broad range of β-lactam antibiotics, including carbapenems.[1] Among these, the New Delhi Metallo-β-lactamase-1 (NDM-1) variant confers resistance to a wide variety of antibiotics, such as penicillins, cephalosporins, and carbapenems. The rapid global dissemination of NDM-1 is causing growing concern in the scientific community due to its wide spectrum of action, ability to select variants, and transferability, posing a significant risk of a new bacterial pandemic. Despite the availability of various Serine-β-lactamase mechanism-based inhibitors in therapy, there is currently a lack of specific and effective inhibitors against NDM-1 in clinical practice.[2] Consequently, there is an urgent need to identify clinically useful inhibitors of MBLs that can be co-administered with existing β-lactams to restore their antibacterial activity. To address this emerging challenge, we employed the Pharmacological Protein Inactivation by Folding Intermediate Targeting (PPI-FIT) technology to discover non-conventional degraders of NDM-1.[3] PPI-FIT represents a novel and advanced drug discovery approach based on the concept of regulating protein levels by targeting folding intermediates. Using this approach, we identify potential druggable pockets within a relevant folding intermediate of NDM-1, distinct from its native conformation and catalytic site. Subsequently, a structure-based virtual screening was exploited, leading to the identification of virtual hits. In this study, we outline our strategy, which integrates medicinal chemistry, structural biology, biochemical testing, and microbiological profiling, to identify novel non-conventional degraders of NDM-1.

References:

[1] Santajit, S. & Indrawattana, N. Mechanisms of Antimicrobial Resistance in ESKAPE Pathogens. BioMed Research International, 2016, (2016).
[2] Li, X., et al. X. Enzyme inhibitors: The best strategy to tackle superbug ndm-1 and its variants. Int. J. Mol. Sci. 23, (2022).
[3] Spagnolli, G. et al. Pharmacological inactivation of the prion protein by targeting a folding intermediate. Commun. Biol. 4, 1–16 (2021).

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FAR-PO-097

Towards the development of novel Multi-target-Directed Ligands modulating circadian clock dysfunction in Alzheimer's Disease

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Alzheimer's disease (AD) is an intricate neurodegenerative disorder with no effective cure, thus necessitating new therapeutic approaches. Recent research indicates a significant association between disturbances in the circadian rhythm and the development of AD, underscoring the circadian clock (CC), as a promising point of intervention[1]. In this context, we envisioned the development of Multi-target-Directed Ligands (MTDLs)[2] to modulate CC dysfunction in AD. We focused on the selective modulation of two kinases, glycogen synthase kinase-3 beta (GSK3-β) and casein kinase 1-delta (CK1-δ), which have been identified as pivotal regulators of CC. We designed a novel set of MTDLs starting from highly potent, BBB permeable, and GSK3-β and CK1-δ selective inhibitors reported in the literature. By identifying common structural requirements of each kinase and employing *in silico* calculations, we have identified the maleimide core as an optimal scaffold to generate dual GSK3-β/CKI-δ inhibitors. The optimization of the synthetic route is currently being performed to provide an initial set of potential maleimide-based MTDLs. These will be subsequently evaluated *in vitro* for their inhibitory profile against GSK3-β and CKI-δ, ADMET properties and cytotoxicity.

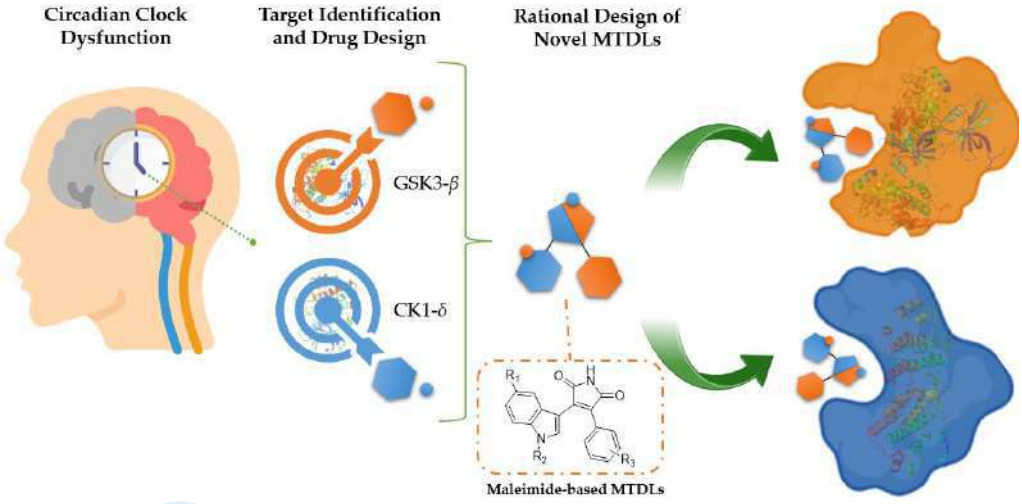

Figure 1: Design of the first set of potential MTDLs against GSK3-β and CK1$_\delta$

References:
[1] Musiek ES, Holtzman DM, Science, 2016, 354(6315),1004-1008.
[2] Prati, F., Uliassi, E., Bolognesi, M. L., Med. Chem. Commun., 2014, 5, 853–861.

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FAR-PO-098

Exploring Novel Compounds Targeting Mycobacterium tuberculosis Dihydroorotate Dehydrogenase: SAR Analysis and Biological Activity

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Tuberculosis (TB), caused by the bacillus Mycobacterium Tuberculosis (MTB), persists as one of the oldest diseases despite being curable. However, it remains the world's second leading cause of death from a single infectious agent, with 7.5 million new cases diagnosed globally in 2022[1], underscoring the urgent need for novel treatments, especially in the face of emerging drug-resistant MTB strains. Inhibition of crucial enzymes and pathways in MTB has been a focal point in the development of new drugs. Enzymes involved in nucleotide biosynthesis have emerged as promising targets due to their vital role in providing building blocks for DNA and RNA. Perturbations in cell metabolism can profoundly affect the proliferation of both infected cells and pathogens, rendering these enzymes pivotal targets for therapeutic interventions.

In the tuberculosis mycobacterium, dihydroorotate dehydrogenase (*mt*DHODH), a crucial enzyme of the *de novo* pyrimidine biosynthesis pathway, is indispensable for its replication. Our recent efforts have focused on characterizing the full-length *mt*DHODH, resulting in the successful determination of the crystal structure of the protein[2]. Through screening our *in-house* compound library, we have identified MEDS322 as the first inhibitor of *mt*DHODH known so far.

Here, we present the synthesis and biological evaluation of MEDS322 and its analogues based on a thiazolidinone ring scaffold as the first *mt*DHODH inhbitors.

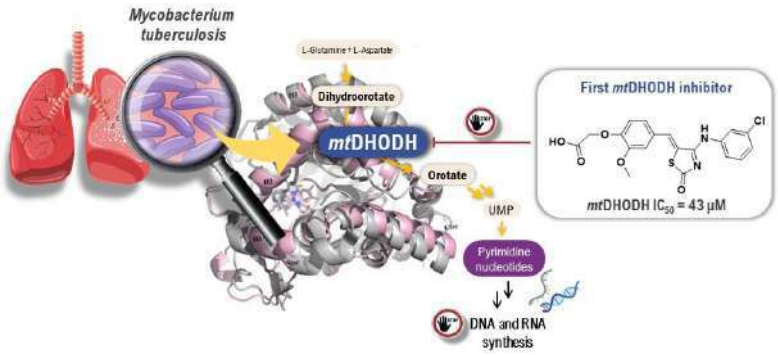

Figure 1: Representation of the *Mt*DHODH crystal structure and the first inhibitor of the series.

References:

[1] Global tuberculosis report **2023**. World Health Organization, Geneva.
[2] Alberti M. et al. FEBS Letters 2023, 597, 2119 - 2132.

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FAR-PO-099

Discovery of 1,3,4-Oxadiazole Derivatives as Broad-Spectrum Low-Toxicity Agents for the Treatment of Vector-Borne Parasitic Diseases

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Vector-borne parasitic diseases (VBPDs) pose a significant threat to public health on a global scale. Collectively, Human African Trypanosomiasis (HAT), Leishmaniasis and Malaria threaten millions of people particularly in developing countries. Climate change might alter the transmission and spread of VBPDs, leading to a global burden of these diseases. Thus, novel agents are urgently needed to expand the therapeutic options and limit the spread of drug-resistance parasites.

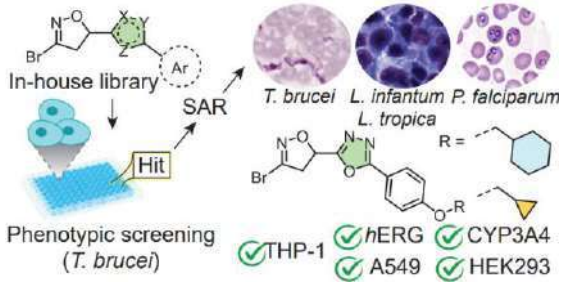

Figure 1: Strategy for the discovery of novel 1,3,4-oxadiazole derivatives

We screened an in-house library of antileishmanial and antimalarial compounds[1] towards *Trypanosoma brucei* (*T. brucei*) and we identified a 1,3,4-oxadiazole derivative as an anti-*T. brucei* hit compound, with predicted blood-brain-barrier permeability. Subsequently, extensive SAR studies around the lipophilic tail of our hit compound, led to a potent antitrypanosomal and antimalarial compound, with moderate potency also towards *Leishmania infantum* (*L. infantum*) and *L. tropica*. In addition, we discovered a pan-active antiparasitic molecule, showing low micromolar IC_{50}s towards *T. brucei* and *Leishmania* spp. promastigotes and amastigotes, and nanomolar IC_{50} against *Plasmodium falciparum*, together with high selectivity for the parasites over mammalian cells (THP-1). Early ADME-toxicity assays were used to assess the safety profile of the newly discovered compounds.

References:

[1] A. Galbiati, A. Zana, C. Coser, L. Tamborini, N. Basilico, S. Parapini, D. Taramelli, P. Conti. ACS Medicinal Chemistry Letters 2021 12 (11), 1726-1732.

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FAR-PO-100

In-Silico Research of σRs/HDACs *Multi-Target* Ligands

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Multi-Target-Directed ligands (MTDLs), with more than one pharmacological activity, are more efficient than single-target ligands, particularly for the treatment of multifactorial diseases such as cancer and neurodegenerative diseases. Sigma receptors (σRs) and histone deacetylase enzymes (HDACs) are under much attention due to their involvement in these diseases.[1,2] Therefore, the design and synthesis of multi-target σRs/HDACi ligands were conceived for their possible use in addressing these pathologies.[3]

The project uses computational tools to research molecules with hybrid activity for σRs and HDACs. First, the docking procedure was validated, ensuring that it reproduces the experimental K_i of known molecules, testing the method with decoys, and calculating the simulated K_i of other reported σRs and HDACs ligands.

Meanwhile, the Pharmacophore-Based Virtual Screening (PBVS) of many databases was accomplished using the Pharmit server; for all targets, the results were filtered through the Lipinski rule of five and ADMET properties and collected in a database for σRs and one for HDACs. The resulting databases were further analysed through PBVS to the other target. Molecules matching both σRs and HDACs PBVS were processed through docking simulation with YASARA. Results were carefully analyzed visually through BIOVIA Discovery Studio and selected for their fundamental interactions.

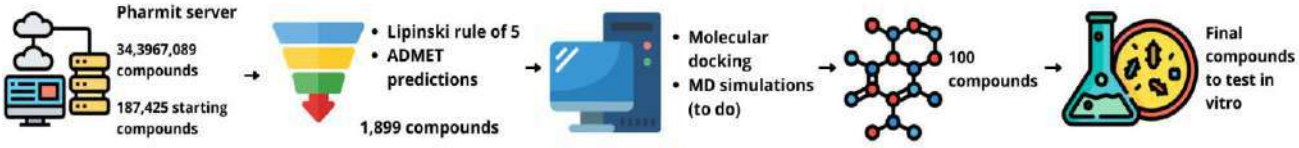

Figure 1: Virtual screening, compound filtration, and prospects workflow.

One hundred compounds were found with a high score for σRs and HDACs. From the literature some of the resulting molecules have already correlations with the σRs or HDACs, but none was studied for multi-target activity on both targets, and many of the resulting compounds are unrelated to these targets. These results will be further validated with molecular dynamic simulation, and best three compounds will be tested in vitro.

References:

[1] J. M. Brimson, S. Brimson, C. Chomchoei, T. Tencomnao, Expert Opin. Ther. Targets 2020, 24, 1009–1028.
[2] D. A. Rodrigues, P. de S. M. Pinheiro, F. S. Sagrillo, M. L. Bolognesi, C. A. M. Fraga, Med. Res. Rev. 2020, 40, 2177–2211.
[3] C. Barbaraci, V. di Giacomo, A. Maruca, V. Patamia, R. Rocca, M. Dichiara, A. Di Rienzo, I. Cacciatore, A. Cataldi, M. Balaha, M. Rapino, C. Zagni, D. Zampieri, L. Pasquinucci, C. Parenti, E. Amata, A. Rescifina, S. Alcaro, A. Marrazzo, Bioorg. Chem. 2023, 140, 106794.

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FAR-PO-101

KLig Enumerator: a Tool for Library Creation Based on Kinase X-Ray Structures.

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Kinases encompass one of the widest groups of proteins targeted in drug discovery campaigns. Not only due to their involvement in several diseases, kinases are often object of study in the context of multi – target drug discovery programs.[1]

Despite the different pockets and binding modes reported in literature for specific kinases or chemotypes, the so-called hinge region of the ATP binding site results is a conserved hot – spot for inhibitor design.[2] Furthermore, a plethora of co – crystal structures are available in the RCSB PDB and several information about ligand binding are now encoded in the KLIFS database.[3] Therefore, embedding moieties, whose binding mode in the proximity of the hinge is already known by means of crystallography, into another scaffold might be a strategy for increasing the chance of obtaining tailored kinase inhibitors and also for developing "fused" multi-target compounds.

Herein, KLig compound enumerator, a tool able to extract the fragments binding the hinge region from a list of kinase co-crystals and to connect them to a user defined scaffold, is presented.

The computational pipeline has been indeed employed to generate two libraries of potential dual inhibitors for the treatment of several multifactorial diseases, starting from a list of 4381 kinase complexes and two privileged cores. Nevertheless, further code implementations aimed at performing fully combinatorial library generation or at targeting different kinase regions are under evaluation.

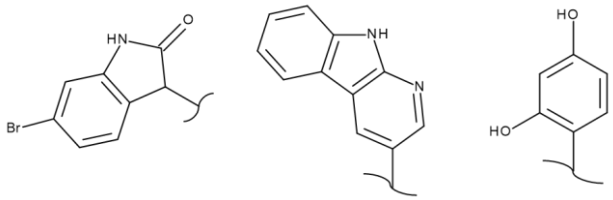

Figure 1: *Examples of hinge interacting fragments extracted by KLig.*

References:
[1] RMC. Di Martino et al., ChemMedChem 2020, 15(11), 949 - 954.
[2] L. Xing et al., J Comput Aided Mol Des 2014, 28(1), 13 - 23.
[3] OP. van Linden et al., J Med Chem 2014, 57(2), 249 - 77

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FAR-PO-102

Structure-Based Virtual Screening targeting APSR to discover Covalent and Non-covalent Inhibitors.

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The discovery of inhibitors targeting adenosine 5′-phosphosulphate reductase (APSR), an essential enzyme involved in the reduction of inorganic sulphate to sulphite, crucial for synthesizing biomolecules,[1] offers a promising strategy for limiting *Pseudomonas aeruginosa* growth and antibiotic resistance. APSR enzymatic activity is attributed to its catalytic cysteine, located in the highly mobile *C*-terminal tail and executing a nucleophilic attack on the sulphur atom of the endogenous ligand adenosine phosphosulphate (APS), leading to the formation of the inactivated enzyme-thiosulphonate intermediate.[2]

To investigate the enzyme inhibition mechanism, two alternative approaches were considered to retrieve both non-covalent and covalent inhibitors. The first virtual screening workflow has been applied starting from an ultra-large library of over 6.5 billion compounds, relying on an initial shape screening protocol,[3] wherein the Enamine REAL compound collection was screened against the structure of the endogenous ligand (APS). Consequently, 100,000 compounds that displayed a higher degree of similarity, were submitted to a docking refinement procedure within the catalytic site, excluding compounds unable to fit within the protein environment. Moreover, the virtual screening workflow was complemented with short metadynamics simulations, assessing the ligand binding mode stability.

As an alternative strategy, a virtual screening campaign was set-up to discover covalent compounds targeting the catalytic cysteine. Since the crystallographic structure of APSR lacks the C-terminal tail, precluding the resolution of the Cys256, this region was built exploiting the AlphaFold model as a template for structural prediction. The obtained structure bound with different warheads was used to generate pharmacophore models able to screen and retain compounds forming reactive Michaelis complexes, to be processed with covalent docking calculations.

Our final selection of compounds, to be tested in enzymatic and cellular assays, explore alternative modalities to obtain enzymatic inhibition and an antiproliferative activity.

References:

[1] J. Hummerjohann et al., Microbiology. 1998, 144, 1375-86
[2] J. Chartron, et al., J. Mol. Biol. 2006, 364, 152-69.
[3] S.L. Dixon et al., J. Med. Chem. 2001, 44, 3795-809

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FAR-PO-103

From iloperidone to new sigma-1 receptor agonists: a structure-based approach

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Huntington's disease (HD) is a hereditary condition caused by a mutation in the HTT gene, resulting in the progressive degeneration and death of neurons in certain areas of the brain. Unfortunately, there are currently no effective treatments capable of halting or preventing the onset of this debilitating disease. However, an increasing number of research suggests that the sigma-1 receptor (σ1R) may play a role in the management of various neurodegenerative disorders, including HD[1]. The σ1R is a relatively small and poorly understood membrane receptor found in the central nervous system. Its three-dimensional structure has recently been elucidated through X-ray crystallography, and it responds to various synthetic ligands, such as (+)-pentazocine (an agonist) and haloperidol (an antagonist). Studies have shown that agonists possess neuroprotective properties against neurodegenerative diseases. Nevertheless, the structural mechanisms underlying agonism or antagonism at the σ1R are not fully understood. Generally, the overall conformation of the receptor when bound to an agonist is similar to that when bound to an antagonist, except for a shift in the α4 helix by approximately 1.8Å[2]. This shift likely contributes to the agonists' ability to decrease the oligomeric state of the protein and may serves as a discriminative factor for agonist classification. Through structure-based computational methods, we designed new Iloperidone analogues as potential σ1R agonists. Indeed, very recently, a high binding affinity for σ1R of the antipsychotic Iloperidone has been demonstrated[3]. From our computational studies, including cross-docking procedures and molecular dynamics simulations, the pharmacophoric groups have emerged. In detail, the most stable interactions are established by the nitrogen atom of the piperidine ring of Iloperidone, which is positively charged at physiological pH. Starting to these data, the chemical structure of this antipsychotic drug has been modified applying a scaffold hopping approach, to obtain a pronounced and selective agonist of the σ1R. We synthesized new small molecules that retained the piperidine core and replacing the benzoisoxazole ring (responsible for a generic π-π interaction) with oximes. Additionally, we have functionalized the oxygen atom of the oxime group to enhance steric hindrance between the α5 and α4 helices, with shifts in the latter. Biological assay data will be presented and discussed.

References:

[1] N. Ye, W. Qin, S. Tian, Q. Xu, E.A. Wold, J. Zhou, X.C Zhen, J. Med. Chem. 2020, 63, 15187-15217.
[2] H.R. Schmidt, R.M. Betz, R.O. Dror, A.C. Kruse, Nat. Struct. Mol. Biol. 2018, 25, 981-987.
[3] G. Pascarella, L. Antonelli, D. Narzi, T. Battista, A. Fiorillo, G. Colotti, L. Guidoni, V. Morea, A. Ilari, Int. J. Mol. Sci. 2023, 24(7), 6367.

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FAR-PO-104

New Nitrogen Based Derivatives as SARS-CoV-2 Nsp13 Inhibitors

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The coronavirus disease 19 (COVID-19) is a highly transmittable and pathogenic viral infection caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which spread around the world and caused the 2019–2020 pandemic. Even though successful vaccination programs to combat COVID-19 are available worldwide, little has been accomplished in the development of antivirals to treat the disease. The disparity in COVID-19 vaccination coverage, vaccine resistance, the emergence of several SARS-CoV-2 variants, and the increased transmission ability emphasize the importance of developing antiviral drugs to treat SARS-CoV-2 infections.[1] The development of new antiviral agents is, therefore, of utmost importance. The SARS-CoV-2 non-structural protein 13 (nsp13) has been identified as a promising drug target for the development of antivirals due to its crucial role in viral replication. The CoVs nsp13 is a multidomain enzyme that targets the natural nucleotides and deoxynucleotides as substrates when performing its adenosine triphosphatase (ATPase) activity, utilizing the energy of nucleotide triphosphate hydrolysis to unwind DNA or RNA. Moreover, nsp13 is the most conserved non-structural protein within the coronavirus family.[2] Several compounds have been reported to inhibit SARS-CoV-1 nsp13 and, very recently, also SARS-CoV-2 nsp13 has been actively explored as drug target, with some reports describing small molecules as inhibitors of SARS-CoV-2 nsp13. Among them, aryl diketo acids (DKAs), have been reported as inhibitors of SARS-CoV-2 nsp13.[3] On the other hand, the DKA chain suffers from several limits related to the pharmacokinetic and pharmacodynamic profiles. Therefore, to overcome the limits of the DKA moiety, a variety of compounds were developed by transferring the DKA chain to scaffolds characterized by improved druglike qualities. Therefore, we carried out a semi-random screening on our in-house library of non-DKA derivatives, identifying a promising hit compound as micromolar nsp13 inhibitor. We synthesized a set of derivatives structurally correlated with the hit, obtaining a new series of dual inhibitors of both the SARS-CoV-2 nsp13-associated activities. The data coming from the biological assays will be shown and discussed.

References:

1. Shereen, MA; Khan, S; Kazmi, A; Bashir, N; Siddique, R. J Adv Res. **2020**; 24:91-98.
2. Hardenbrook, NJ; Zhang, P. Curr Opin Virol. **2022**; 52:123-134.
3. Corona, A.; Madia, V.N.; De Santis, R.; Manelfi, C.; Emmolo, R.; Ialongo, D.; Patacchini, E.; Messore, A.; Amatore, D.; Faggioni, G.; Artico, M.; Iaconis, D.; Talarico, C.; Di Santo, R.; Lista, F.; Costi, R.; Tramontano, E. *Antiviral Res.* **2023**, *217*, 105697.

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FAR-PO-105

Unvealing Newly Discovered Small Molecules as ACE2-Spike Inhibitors Against SARS-CoV-2

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The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is an RNA virus with a positive strand, responsible for the ongoing global pandemic of coronavirus disease 2019 (COVID-19). It is crucial to expedite the discovery of drugs to combat this pressing global health crisis. The interaction between the spike (S) protein of SARS-CoV-2 and the cell surface receptor angiotensin-converting enzyme 2 (ACE2) facilitates the virus's infectivity, enabling its entry into host cells. ACE2 functions as a ligand-receptor pair that initiates viral attachment and cellular entry. Specifically, the receptor-binding domain (RBD) of the S protein binds to the membrane-distal portion of the ACE2 proteine.[1] Notably, current vaccines stimulate antibody responses to the S protein, with most neutralizing antibodies targeting the RBD. Therefore, disrupting the binding between the S protein and the ACE2 receptor is promising as approach to impede virus entry. [2] Inhibitors targeting the protein-protein interaction between the S protein and human ACE2 are of significant interest as potential antiviral agents because this interaction initiates membrane fusion and virus entry, occurring at an accessible extracellular site. [3] While developing protein-protein interaction inhibitors with small molecules presents challenges compared to antibodies, small-molecule inhibitors could offer alternatives that are less susceptible to strain variations and mutations, suitable for oral or inhaled administration, and more controllable and less immunogenic. This strategy has already proven successful in inhibiting viral entry for other viruses, exemplified by two FDA-approved drugs, maraviroc and enfuvirtide. This study aimed to identify potent antiviral drugs against SARS-CoV-2 by targeting well-established proteins crucial to the viral cycle using high-throughput screening (HTS) techniques. A recombinant RBD of SARS-CoV-2 and ACE2 receptor, constructed with two different tags by collaborators at IP Paris, was utilized for HTS to identify molecules interfering with the interaction between the RBD and ACE2. Twenty-one candidates were selected from HTS based on a robust homogeneous time-resolved fluorescence (HTRF) assay. Among them, two hits were identified, demonstrating inhibitions of 51.4% and 25.6% and IC_{50} values of 1 and 2.42 µM against ACE2 and 0.44 and 3.58 µM against RBD, respectively. However, both hits exhibited cytotoxicity against SARS-CoV-2 infected cells. Therefore, to mitigate the cytotoxicity and enhance druggability, analogues of these compounds were designed. The data from the biological assays will be presented and discussed.

References:

[1] S. Borkotoky, D. Dey, Z. Hazarika, *Mol Biol Rep*. 2023 Mar;50(3):2713-2721.
[2] M. Dong, JM. Galvan Achi, R. Du, L. Rong, Q. Cui, *Cell Insight*. 2024 Jan 30;3(1):100144
[3] A. Wu, K. Shi, J. Wang, R. Zhang, Y. Wang, *European Journal of Medicinal Chemistry*, 263, 2024, 115923.

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FAR-PO-106

Development of first in class HDAC6-MAGL inhibitors

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Monoacylglycerol lipase (MAGL) is a serine hydrolase responsible for catabolizing 2-arachidonoylglicerol (2-AG). Targeting the catalytic S122 residue of MAGL a robust impairment of enzymatic functionality is attained, thus indirectly activating cannabinoid receptors and prompting neuroprotective and anti-inflammatory outcomes.[1] Amongst the scientific efforts focused on the development of potent and selective MAGL inhibitors, beta-lactam-based irreversible MAGL inhibitors effectively reached the aimed goals.[2,3] Particularly, they harbour a branched aromatic motif, a N-containing linker and an electrophilic moiety embedding a good leaving group, detached by MAGL S122 thus leading to enzyme acylation, as demonstrated by the X-ray analysis.[3]

Histone deacetylase 6 (HDAC6) is a unique isoenzyme, being located in the cytoplasm and primarily interacting with non-histonic proteins. Lots of reports suggest that HDAC6 may play a pivotal role in triggering neurodegenerative and proinflammatory processes.[4] HDAC6 is a metalloenzyme, therefore a typical inhibitor embeds a Zn^{2+} binding group (ZBG) (commonly an hydroxamic acid), an aromatic or aliphatic linker, accommodated into a hydrophobic tunnel connecting the active site of the targeted protein to the outer region, and a bulky cap motif, responsible for isoform selectivity.[5]

We recently undertook the development of novel dual HDAC6-MAGL inhibitors. By merging the pharmacophoric elements useful for inhibiting the two targeted proteins, we designed two sets of compounds. The new molecules belonging to Set A bear the ZBG on a p-phenyl substituted feature and harbour several N-containing five member heterocycles. In Set B, an azole-based moiety was employed as a novel ZBG supporting motif; several potential ZBGs were installed on this heterocyclic nucleus. Notably, computational analysis underline that the presence of an EW group on position 4 of pyrazole ring allow to better delocalize the negative charge of TS intermediate, facilitating expulsion of the leaving group by S122. The new inhibitors may hold promise as in inflammatory and/or neurodegenerative-based diseases.

Enzymatic data displayed interesting SARs and selected analogues effectively inhibit both enzymes, thus representing promising hits to further develop novel pyrazole-based HDAC6-MAGL hybrid inhibitors.

References:

[1] F. Seghetti, et al., Curr. Med. Chem., 2022, 329(28), 4796-4830.
[2] M. Brindisi, et al., J. Med. Chem., 2016, 59, 2612–2632.
[3] S. Butini, et al., J. Med. Chem., 2024, 67(3), 1758-1782.
[4] S. Shukla, et al., Front Pharmacol, 2020, 11, 537.
[5] G. Campiani, et al. J Med Chem, 2021, 64, 9960–9988.

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FAR-PO-107

From Hit to Lead: Exploring Natural Compounds as Potential Inhibitors of SARS-CoV-2 NSP13 Helicase for COVID-19 treatment

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In the current medical landscape, there is an urgent need to discover new effective drugs to enhance the therapeutic options for COVID-19. The SARS-CoV-2 non-structural protein 13 (NSP13) helicase enzyme has emerged as a promising target for the development of novel COVID-19 inhibitors. In this study, our objective was to identify potent natural products capable of inhibiting NSP13 through virtual screening of 96,402 compounds from the COCONUT Database. These compounds were docked into the NTPase active site, and Canvas similarity clustering was employed to categorize them into different scaffolds for further analysis. Subsequently, based on commercial availability, ten compounds were selected for in vitro testing. Among these, one compound exhibited significant NSP13 inhibitory activity with potency in a micromolar range (Figure 1). Building upon this finding, GBPM and ligand designer tools aided in the lead optimization process. The most promising chemical candidates will be synthesized and evaluated for their antiviral activity against SARS-CoV-2. This work is funded by the PANVIRIDE project[1].

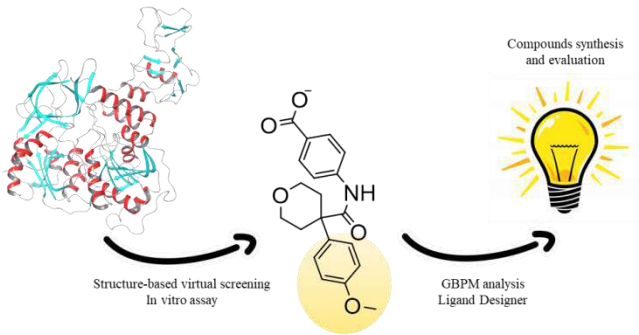

Figure 1: Workflow for identification of promising inhibitors against SARS-CoV-2 helicase.

References:

[1] COC-1-2023-CNR – Progetto INF-ACT Spoke 5 New therapeutic strategies.

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FAR-PO-108

Development of Lubeluzole Analogues Endowed with Reduced Cardiac Liability Evaluated as Possible Skeletal Muscle Sodium Channel Inhibitors

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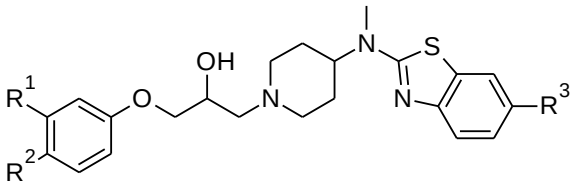
Lubeluzole is an optically active benzothiazole derivative originally investigated as a neuroprotective agent for the treatment of ischemic stroke whose clinical trials were discontinued due to a lack of benefits in terms of survival. Moreover, a significant increase in heart conduction disorders was observed in some of the treated patients.[1] We demonstrated that lubeluzole is a potent inhibitor of skeletal muscle voltage-gated sodium channels hNav1.4, showing potent antimyotonic activity in an animal model of myotonia congenita.[2] Furthermore, we demonstrated that lubeluzole can inhibit the human ether-à-go-go-related gene (hERG) channel.[1] A series of lubeluzole congeners have been prepared and tested on hERG, Nav1.4, and Nav1.5 channels. The most promising compound has been evaluated in vivo in a rat model of myotonia.



(*S*)-**1**: $R^1 = R^2 = F$, $R^3 = H$ (lubeluzole); (*RS*)-**1-12**: R^1, R^2, R^3 = H, F, OH, OCH_3, CF_3

Figure 1: structures of lubeluzole and analogues.

References:

[1] R. Gualdani, M. M. Cavalluzzi, F. Tadini-Buoninsegni, et al. Cell Physiol. Biochem. 2018, 45, 2233–2245.
[2] J. -F. Desaphy, R. Carbonara, T. Costanza, G.; Lentini, M. M. Cavalluzzi, et al. Mol. Pharmacol. 2013, 83, 406–415.

FAR-PO-109

OneHealthdrugs, a new perspective for environmentally friendly NID drugs

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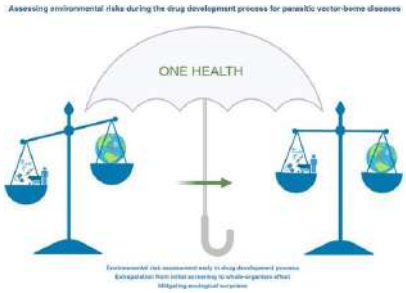
Nearly 75% of emerging human infections worldwide originate from animals. Current drugs for both human and animal (H&A) vector-borne diseases (VBD) are in short supply and have limited efficacy, potential toxicity, and limited resources. Emerging environmental issues in pharmaceutical use/manufacturing are increasing attention in this area. Currently, the two drug pipelines are being developed independently. Collaboration and research between different expertise is therefore essential to define how new drugs can be developed using a more sustainable approach. OneHealth*drugs*[1], a COST Action, is dedicated to the development of innovative strategies for the supply of drugs with a more environmentally friendly profile and low environmental impact[2]. The new drugs aim to combat H&A VBD while maintaining the principles of an optimal profile for both organisms, improving the quality of the drugs and associated delivery technologies. R&D experts from various fields, including chemical/biological/human/veterinary and earth sciences, are working together to propose guidelines and improve existing drug discovery tools in the field of NID discovery. The platform includes preclinical drug discovery, animal studies and drug delivery. Approaches such as compound and target database generation, bioinformatics and omics studies, medicinal chemistry strategies and nanotechnology tools will be implemented.



We expect the results of OneHealthdrugs to have a significant impact both in Europe and in disease-endemic countries. The latest advances in the compound database, including the greener principles derived properties[3] and the drug targets database managed by adopting reduced off-target species filtered with appropriate software, as well as the sustainable drug profiles in H&A health, will be presented together with the progress made within the OneHealthdrugs initiative.

References:

[1] www.onehealthdrugs.com.
[2] K. Ilbeigi et al.. ACS Infectious Diseases **2024,** *10*, 1026-1033.
[3] G. Orive, G. et al. , Greening the pharmacy, Science, 2022, 377, 259–260.

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FAR-PO-110

FPR2 and brimstone: a novel approach for the treatment of neuroinflammation

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Neurodegenerative diseases like Parkinson's Disease and Alzheimer's Disease involve several pathological phenomena that result in a diffuse neuroinflammatory state, exacerbating tissue damage via oxidative stress. Neuroinflammation is a multifaceted pathological factor involving several cell types, receptors, and mediators, and its resolution could help alter disease progression[1].

Formyl Peptide Receptor 2 (FPR2) is a G protein-coupled receptor (GPCR) expressed in microglia. It controls several aspects of the immune response and could thus be a key target for the resolution of neuroinflammation. Our research efforts have resulted in developing the ureidopropanamide class of FPR2 agonists[2].

We have set out to enhance the anti-inflammatory capabilities of these compounds by incorporating an H_2S-releasing moiety into their scaffold. H_2S is a gaseous neuromodulator and neuroprotector, regulating calcium influx and exerting anti-inflammatory and antioxidant effects at low doses[3]. Thus, the ureido and amide moieties of our compounds were converted into the corresponding thioureas or thioamides.

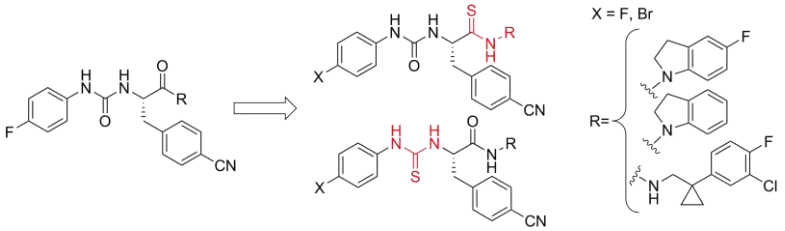

Figure 1: scaffolds of ureidopropanamide FPR2 agonists and their thioureido and thioamide counterparts.

These compounds were tested as FPR2 agonists, for their capacity as H_2S releasers, and their neuroprotective activity in models of neuroinflammation, showing a promising activity profile and demonstrating their potential as lead compounds for a new generation of anti-neuroinflammatory drugs.

References:

[1] Teleanu, D.M. et al., An Overview of Oxidative Stress, Neuroinflammation, and Neurodegenerative Diseases. Int J Mol Sci 2022, 23, 5938

[2] Mastromarino, M. et al., Design, Synthesis, Biological Evaluation, and Computational Studies of Novel Ureidopropanamides as Formyl Peptide Receptor 2 (FPR2) Agonists to Target the Resolution of Inflammation in Central Nervous System Disorders. J Med Chem 2022, 65, 5004–5028

[3] Dilek, N. et al., Hydrogen Sulfide: An Endogenous Regulator of the Immune System. Pharmacol Res 2020, 161, 105119

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FAR-PO-111

Novel pro-autophagic urolithin analogues as promising neuroprotective agents.

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Neurodegenerative diseases are one of the most significant health problems of the last decades, due to the absence of resolutive therapies. Over time, researchers turned their gaze toward natural substances with interesting biological activities in order to find new scaffolds to work on and synthesise new drugs[1]. Within this vast environment, ellagitannins (ETs) are a large group of bioactive compounds found in plant-source foods, such as pomegranates and berries. Ellagic acid is the aglycon portion of ETs, but the beneficial effects observed following the consumption of ET-containing foods are explained by their extensive metabolism to urolithins[2]. In particular, Urolithin A (UA) shows good antioxidant, anti-inflammatory and neuroprotective properties[2]. In this work, we describe the synthesis of a small library of urolithin analogues obtained through the decoration of the UA-scaffold, and the biological evaluation. *In vitro* preliminary results showed that new derivatives were able to promote autophagy using Urolithin A as a reference activity. The most active compounds were selected for further evaluation in a preclinical model for Alzheimer's diseases of *Caenorhabditis elegans*. In this poster I will discuss the results of these assays and the future perspectives that come with them.

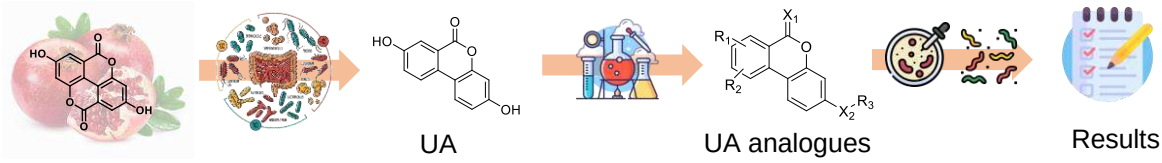

Figure 1: Workflow summary.

References:
[1] R. García-Villalba, et al. Mol. Asp. Med. 2022, 89, 101109.
[2] A. Bacci, M. Runfola, S. Sestito, S. Rapposelli, Antioxidants 2021, 10, 367.

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FAR-PO-112

Targeting AKT1 in Cancer Therapy: Novel Inhibitors for Acute Myeloid Leukemia

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Acute myeloid leukemia (AML) is a heterogeneous hematopoietic cancer characterized by an abnormal proliferation of the progenitor cells of myeloid strains. In more than 60% of AML cases, the PI3K/AKT/mTOR signaling pathway becomes overactive, resulting in changes that are exacerbated by chemotherapy, leading to drug resistance.[1] Particularity, a pivotal role in this pathway is shown by the serine/threonine kinase (AKT or PKB), making it a particularly interesting drug target for precision cancer therapy. Against this backdrop, our research group has focused on the development of AKT1 inhibitors in AML treatment. In particular, compound 5,6,7,8-tetrahydrobenzo[4,5]thieno[2,3-d]pyrimidin-4(3H)-one (**T126**) has emerged as the most interesting compound with an IC_{50} = 1.99 ± 0.11 μM and a ligand efficiency (LE) of 0.35.[2] Further investigation of **T126** showed its ability to bind the AKT1 ATP-binding pocket preventing growth and inducing apoptosis in a panel of AML cells in the low micromolar range.[2]

In this work, we focused our attention on the identification of AKT1 allosteric inhibitors. In particular, the most potent AKT1 allosteric inhibitors reported in the literature were used to build a pharmacophore model. Then, the pharmacophore features and **T126** core were joined to generate a small set of AKT1 allosteric inhibitors (**Figure 1**). Among the synthesized compounds, one showed a very interesting profile, exhibiting an IC_{50} value in the low micromolar range and strong inhibitory activity against two mutated AML cell lines over wild-type.

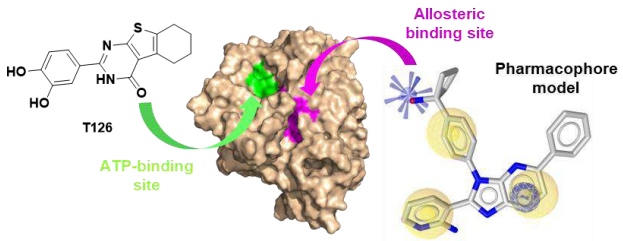

Figure 1: Schematic representation of rational design of AKT1 allosteric inhibitors reported in this work.

References:

[1] J. Bhutani, A. Sheikh, A.K. Niazi, Infect. Agent. Cancer, 2013, 8, 49.
[2] A. Astolfi, F. Milano, D. Palazzotti, J. Brea, M.C. Pismataro, M. Morlando, O. Tabarrini, M.I. Loza, S. Massari, M.P. Martelli, M.L. Barreca, Pharmaceutics, 2022, 14, 2295.

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FAR-PO-113

New hydroxypyrazole inhibitors of *Plasmodium falciparum* dihydroorotate dehydrogenase: physical-chemical characterization and biological evaluation

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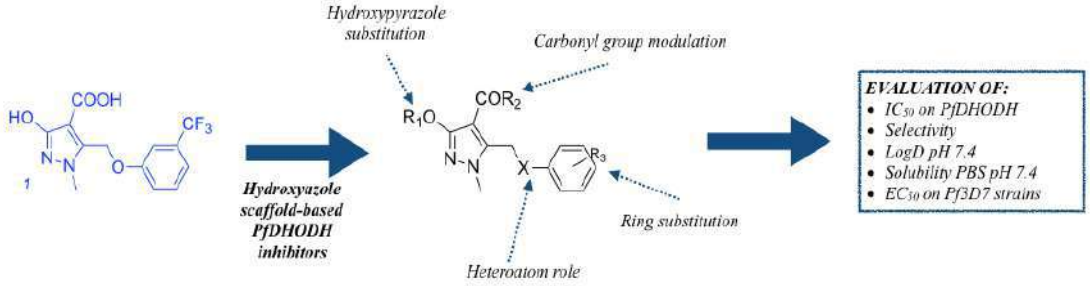
Malaria is an infectious disease caused mainly by *Plasmodium falciparum* that is responsible of millions of deaths every year. Although vaccines for the prevention of malaria have a suboptimal efficacy, chemotherapy approach represents the main treatment. However, drug resistance is very common and new chemoterapic approaches have been identified. One of the most promising discoveries is the targeting of the *Plasmodium falciparum* dihydroorotate dehydrogenase (*Pf*DHODH)[1]. DHODH, a ubiquitous flavin mononucleotide enzyme, acts as the pivotal rate-limiting step in *de novo* pyrimidine synthesis, facilitating the conversion of dihydroorotate (DHO) to orotate (ORO). This pathway is crucial for the survival of the parasite, as Plasmodium species lack the capability to utilize salvage pathway for pyrimidine acquisition, relying exclusively on *de novo* synthesis.

The Medsynth group, an academic research team of Turin University, previously published a work based on hydroxyazole scaffold-based *Pf*DHODH inhibitors[2]. Starting from the lead compound *1*, a new series of hydroxypyrazole inhibitors has been synthetized and investigated. Here we present the characterization of the inhibitor activity on the recombinant *Pf*DHODH of the new hydroxypyrazole inhibitors, their selectivity over the human isoform, their physical-chemical proprieties and their activity on *Plasmodium falciparum*-infected erythrocytes. Finally, co-crystallization studies of the most promising compounds are shown.



References:

[1] A. Singh, M. Maqbool, M. Mobashir, N. Hoda, Eur. J. Med. Chem. 2017, 125, 640-651
[2] Pippione A.C., Sainas S., Goyal P., Fritzson I., Cassiano G.C., Giraudo A., et al., Eur. J. Med. Chem. 2019, 163, 266–280

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FAR-PO-114

Optimization of chemical-biological tools for characterizing the activity of dissociative inhibitor of human thymidylate synthase

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Human thymidylate synthase (hTS) catalyzes the reductive methylation of deoxyuridine monophosphate (dUMP) to deoxythymidine monophosphate (dTMP) which requires methylene tetrahydrofolate (mTHF) as a cofactor [1]. This enzyme has been targeted in cancer treatment because of its crucial role.
Drugs such as 5-fluorouracil (5-FU) and folate analogues like raltitrexed can bind covalently to the active site of hTS. However, this mechanism often leads to an increase in the expression of hTS within the cell, resulting in drug resistance. Over the years, it was shown that the hTS is a homodimer of 76 kDa consisting of two identical subunits, each weighing 37 kDa. Each subunit contributes to the formation of two active sites and can exist in different states. The dimer can switch between an active state and an inactive state, the dimer is in equilibrium with its monomeric form with a Kd around 6-8 nM. All these states can contribute to compose the broad interactome with different biomolecular targets within the cell and trigger eventually different specific mechanism. To overcome drug resistance, our research group has focused on finding new ways to switch the dimer to monomer equilibrium and reduce the enzyme catalytic activity causing its overexpression [2]. We aim to target the interface of the dimer to shift the equilibrium towards the inactive monomeric form of hTS. In order to characterize the dissociative character of these newly synthesized compounds to shift the equilibrium toward the monomeric form of the protein and inactivate it, different chemical-biological tools were set up: fluorescence-resonance energy tarnsfer (FRET) experiments, kinetic assays with dedicate algorithms, site specific mutagenesis and more recently dialysis experiments. The present work present the results from the different assays for some representative inhibitors and focus specifically on the recent results on the dialysis experiments. By conjugating the protein with a fluorescent probe we were able to monitor its movement in the dialysis device and detect some interesting events such as the dissociative effect of the dimer destabilizer. In conclusion, we succed in developing a new chemical biological tools to characterize the dissociative capacity of these newly shythesized inhibitor , which rapresent a promisimg Medicinal Chemistry strategy .

References:

[1] Carreras CW, Santi DV. The catalytic mechanism and structure of thymidylate synthase. Annu Rev Biochem. 1995, 64:721.
[2] Costantino, L. et al. Destabilizers of the Thymidylate Synthase Homodimer Accelerate Its Proteasomal Degradation and Inhibit Cancer Growth. Elife 2022, 11, 1–57.

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FAR-PO-115

New Thiazolidine-4-one Derivatives Capable of Inhibiting SARS-CoV-2 M^{pro}

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Having caused a great socioeconomical impact worldwide since 2019, SARS-CoV-2, is still a major public health issue. Despite benefits obtained with vaccination campaigns, SARS-CoV-2 has been still mutating for potential immune escape pathways. Among viral targets, the main protease (M^{pro}) represents a strong candidate due to various reasons: (1) the pivotal role of M^{pro} in the proteolytic cleveage of viral proteins, (2) the absence of human homolog of this protein,[1] (3) high conservation among Coronaviruses, especially in those domains crucial for its enzymatic activity – a potential for broad-spectrum activity.[2] One SARS-CoV-2 M^{pro} inhibitor has been approved so far by the FDA, namely Nirmatrelvir, but this drug has major issues.[3] Most recently, Petrou *et al*. also reported the antiviral activity of thiazolidine-4-one scaffold against SARS-CoV-2 M^{pro}.[4] All these facts rightfully highlight the pivotal importance of seeking out new M^{pro} inhibitors, more particularly deepening the SAR studies of thiazolidine-4-one class. Herein, we report the synthesis of new thiazolidine-4-one analogues as SARS-CoV-2 M^{pro} inhibitors. They were designed by derivatizing the thiazolidine-4-one scaffold with a 4-nitrophenyl ring and a variously substituted phenethyl moiety. Followingly, we assayed the enzymatic activity of the newly synthesized derivatives in *in vitro* assays against SARS-CoV-2 M^{pro}, showing inhibitory values within the low micromolar range. To deepen our understanding, we have further applied a molecular docking protocol to predict the possible binding mode of the compounds in complex with SARS-CoV-2 M^{pro}, shedding light on the main structural features involved in the enzymatic inhibition. An in-depth discussion of the data coming from the biological assays will be shown and described.

References:

[1] O. Amamuddy, G.M. Verkhivker, O. Tastan Bishop, Journal of chemical information and modelling 2020, 60(10), 5080-5102.
[2] F.A. Ambrosio, G. Costa, I. Romeo, et al, Journal of Chemical Information and Modeling 2023, 63(11), 3601-3613.
[3] Y. Hu, E.M. Lewandowski, H. Tan, et al, ACS central science 2023, 9(8), 1658-1669.
[4] A. Petrou, P. Zagaliotis, N.F. Theodoroula, G.A. Mystridis, I.S. Vizirianakis, T.J. Walsh, A. Geronikaki, Molecules 2022, 27(7), 2180.

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FAR-PO-116

Novel peptides as agonists/antagonists of FPR2 for the treatment of ulcerative colitis

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The inflammatory bowel disease (IBD), Chron's disease and ulcerative colitis are among the idiopathic colorectal inflammatory disorders. As in other inflammatory processes, neutrophils migrate into inflamed tissue in response to chemotactic signals, stimulating various antimicrobial functions including ROS production, phagocytosis, and degranulation. The interruption of this process or the excessive recruitment of neutrophils can cause a dysregulation of the inflammatory process which hinders its resolution.

The Formyl Peptide Receptors (FPRs) are human G protein-coupled receptors located on neutrophils capable of binding specialized pro-resolving mediators and participating in the resolution process. The human FPR family constitutes FPR1, FPR2/ALX and FPR3.

The synthetic hexapeptide WKYMVm, an agonist of the FPR1 and FPR 2 receptors, showed a therapeutic effect against ulcerative colitis by blocking the decrease in body weight, colon shortening and mucosal destruction induced by DSS (in a model mice). In contrast, the FPR2- receptor was inhibited by the WRWWWW peptide, indicating the crucial role of this receptor in inflammatory pathology.

The aim of this study is to design and synthesize WKYMVm agonist/antagonist analogues, testing their binding capacity to the FPR2 receptor and their anti-inflammatory activity at different concentrations in vitro. Future development comprises their encapsulation in different liposomal formulations, investigation of their absorption and possible anti-inflammatory effects in a 2D CaCo2/HT29 and CaCo2/HT29-MTX culture model used in Crohn's disease study.

The novel synthesized peptides may represent useful therapeutic agents against chronic intestinal inflammation.

References:

[1] Wen-sheng Yang, Jing-lin Wang, Wei Wu, Guang-fei Wang, Jun Yan, Qing Liu, Xiao-yan Wu, Qing-tong Zhou, De-hua Yang, Ming-Wei Wang and Zhi-ping Li ; Acta Pharmacologica Sinica (2023) 44:19–31.
[2] Sang Doo Kim, Soonil Kwon, Sung Kyun Lee, Minsoo Kook, Ha Young Lee, Ki-Duk Song, Hak-Kyo Lee, Suk-Hwan Baek, Chan Bae Park and Yoe-Sik Bae ; Experimental & Molecular Medicine (2013) 45, e40.

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FAR-PO-117

cRGD-functionalized liposomes as a theranostic tool for the treatment of triple negative breast cancer

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Triple Negative Breast Cancer (TNBC) poses a significant challenge within oncology due to its aggressive nature and the limited therapeutic option available[1]. To address these challenges, nano-based drug delivery systems have emerged as promising therapeutic tools[2].
In this study, we aimed to develop liposomes designed for targeted doxorubicin (DOX) delivery to TNBC cells overexpressing integrin receptors $\alpha_v\beta_3$ and $\alpha V\beta_5$. The liposomes underwent surface modification with cyclic pentapeptides containing the Arg-Gly-Asp sequence (cRGDs), which selectively bind to $\alpha_v\beta_3$ and $\alpha_v\beta_5$ integrins with nanomolar IC50 values. Lipids modified with a dibenzocyclooctyne moiety were incorporated into the liposome's membrane and exploited for the surface functionalization, while the inclusion of rhodamine-tagged lipids allowed to monitor nanoparticle internalization. The cRGD derivatives, bearing a terminal azide group (N_3-3a-RGD), were linked to the liposome's surface through a strain-promoted azido-alkyne cycloaddition (SPAAC) reaction.
The analysis of the nanosystem's physicochemical properties confirmed the effective functionalization and the high efficiency in encapsulating doxorubicin. *In vitro* studies showed enhanced cellular uptake of cRGD-functionalized liposomes in TNBC cells, leading to increased cytotoxicity compared to free doxorubicin or non-functionalized liposomes. Overall, this study demonstrates that DOX-RGD-liposomes represent a promising theranostic nanocarrier for TNBC treatment.

References:

[1] Bianchini, G., De Angelis, C., Licata, L. *et al.*, *Nat Rev Clin Oncol* (2022), **19**, 91–113
[2] Patra, J.K., Das, G., Fraceto, L.F. *et al.*, *J Nanobiotechnol* (2018), **16**, 71

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FAR-PO-118

Two innovative dried microsampling techniques for the reliable determination of cannabinoids and metabolites in peripheral blood

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The chemistry and possible therapeutic use of cannabinoids are at the forefront of current scientific research. Δ^9-tetrahydrocannabinol (THC) and cannabidiol (CBD) are the most abundant and pharmaceutically significant plant phytocannabinoids. Nonetheless, pre-clinical and clinical studies are still in progress to assess their detailed pharmacokinetic and pharmacodynamic features in new applications and in different formulations, products and conditions. Thus, techniques allowing the performance of studies with minimal invasiveness to humans, and with an acceptable approach to animals, are very welcome. Microsampling is one such approaches, with many supplemental advantages, including increased analyte stability, simplified shipping and storage protocols at room conditions.[1]

In this study we applied and compared two innovative, new-generation dried microsampling technologies, i.e., fabric-phase sorptive extraction (FPSE) and volumetric absorptive microsampling (VAMS). The former is based on cellulose-based, functionalised, calibrated fabric patches, allowing to choose different chemistries and affinity modes, thus providing increased versatility and enhanced selectivity. The latter is based on a calibrated, porous polymeric tip collecting volumetrically accurate samples, thus obviating to the volume variability and haematocrit-dependence of classical dried blood spots. Both microsampling approaches were followed by a feasible solvent extraction procedure and coupled to HPLC-ESI-MS/MS for the determination of THC, CBN and their main metabolites (namely, 11-OH-THC, 11-COOH-THC, 7-OH-CBD and 7-COOH-CBD) in peripheral blood. Deuterated analogues were used as the internal standards.

The results obtained have shown that both FPSE and VAMS are suitable for the purpose, with each one possessing unique strengths and challenges. In particular, both provide satisfactory extraction yields and accuracy, and almost negligible matrix effect. Thus, both dried microsampling approaches appear to be effective alternatives to classical venepuncture for the minimally invasive sampling of blood in pre-clinical and clinical studies involving cannabinoids.

References:

[1] L. Mercolini, M. Protti, *et al.*, Journal of Integrated Omics 2023, 13(1), 1 – 3.

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FAR-PO-119

A new HPLC method with multiple detection systems for impurity analysis and discrimination of natural versus synthetic cannabidiol

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Cannabidiol (CBD) is the main non-psychoactive phytocannabinoid derived from *Cannabis sativa* L. It is now an active pharmaceutical ingredient (API), given its usage in treating some types of paediatric epilepsy. For this reason, this compound requires a deep characterization in terms of purity and origin. Previous research work has shown two impurities, including cannabidivarin (CBDV) and cannabidibutol (CBDB), in CBD samples from hemp inflorescences, while abnormal-cannabidiol (abn-CBD) has been described as the primary by-product that generates in CBD synthesis. Both natural and synthetic CBD samples exhibit the presence of Δ^9-tetrahydrocannabinol (Δ^9-THC) and Δ^8-THC. In the light of all the above, this study is aimed to develop a new analytical method based on high-performance liquid chromatography (HPLC) with different detection systems to study the purity of CBD and define its origin based on the impurity profile. In addition to the above-mentioned cannabinoids, other compounds, such as cannabigerovarin (CBGV), cannabigerol (CBG), cannabichromenvarin (CBCV) and cannabichromene (CBC), were examined as potential discriminating impurities. Qualitative and quantitative analyses were carried out by UHPLC-HRMS and HPLC-UV/Vis, respectively. Principal Component Analysis was finally applied for statistical scrutiny. Natural CBD samples exhibited purity range between 97.5 and 99.7%, while synthetic samples were generally pure, except for three initially labeled as synthetic, revealing natural derived impurities. To further confirm the origin of CBD samples, the presence of other two minor impurities, namely cannabidihexol (CBDH) and cannabidiphorol (CBDP), was assessed as unequivocal for a natural origin. Finally, an enantioselective HPLC analysis was carried out and the results confirmed the exclusive presence of the (–)-*trans* enantiomer in all CBD samples. In conclusion, the HPLC method developed represents a reliable tool for detecting CBD impurities, thus providing a clear discrimination of the compound origin.

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FAR-PO-120

Sustainable Joullié-Ugi and Continuous Flow Implementation Led to Novel Captopril-Inspired Broad-Spectrum Metallo Beta-Lactamase Inhibitors

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Antimicrobial resistance represents one of the major issues for the healthcare system. The β-lactam antibiotics including penicillins, cephalosporins and carbapenems are the cornerstones of antimicrobial chemotherapy.[1] ESKAPE pathogens (Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter spp) have become highly resistant to most available antibacterial drugs by exploiting different mechanism of resistance.[2] The COVID-19 pandemic has increased the antibiotic resistance, since COVID-19 patients were treated with broad-spectrum antibiotics, including extended-spectrum cephalosporins, quinolones, and carbapenems.[3] One of the main mechanism of resistance is due to the presence of metallo beta-lactamases (MBL), that are bacterial enzymes able to cleave the beta-lactam ring of the antibiotics. Since no clinically relevant MBL inhibitors have yet been approved, the quest for novel compound with a broad-spectrum activity against several MBL, represents a necessary although challenging task. Captopril, an angiotensin converting enzyme inhibitor used for the treatment of hypertension showed weak activity against some MBL isoforms. Therefore, our driving idea was to modify the structure of the captopril to improve potency and possibly extend the spectrum of inhibition towards MBL by increasing the hydrophobic features of the molecule generating an indoline system. We employed a Joullié-Ugi multicomponent reaction protocol for the synthesis of two indoline-based subseries generating a novel class of potent MBL inhibitors through a convenient continuous flow protocol for the rapid, efficient and diversity-oriented generation of analogues. Among the compounds tested against different MBL isoforms two derivatives stood out for their broad-spectrum inhibition profile against all the isoforms tested, namely NDM-1, VIM-1, and IMP-7. Furthermore, activity in clinical isolates in synergy with beta-lactam antibiotics was assessed for the best performing compounds, thus paving the way to further optimization for the newly disclosed inhibitors.

References:

[1] H. Li, H. Sun, Nat Chem, 2022, 14, 6-8.
[2] M.F. Mojica, M.A. Rossi, A.J. Vila, R.A. Bonomo, Lancet Infect Dis, 2022, 22(1), 28-34.
[3] T.M. Rawson, L.S.P. Moore, N. Zhu, N. Ranganathan, K. Skolimowska, M. Gilchrist, G. Satta, G. Cooke, A. Holmes, Clin Infect Dis, 2020, 71(9), 2459-2468.

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FAR-PO-121

Modulating 14-3-3 protein interaction network: a challenge for the next generation of cancer therapy

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Lymphoma is a type of cancer that affects the lymphatic system, exist more than 70 cancer subtypes originating from both B- and T-cells. Beside the traditional chemotherapy and radiotherapy treatment options, recently have been developed kinase inhibitors targeting the Bruton's tyrosine kinase (BTK), BCL2 inhibitor Venetoclax and immunotherapeutics anti-PD1, affecting cell cancer growth and progression. However, the development of resistance to these inhibitors poses a significant challenge to successful treatment. Most Lymphomas are in need of new therapeutics and for this reason is constantly growing the interest in identifying alternative small synthetic molecules with targeted therapeutic potential. Starting from the oxindole scaffold widely used for the synthesis of kinase inhibitors[1,2], we synthesized new derivatives of general structure A. Then, following a phenotypic drug discovery (PDD) approach we screened a library of synthesized oxo-indole derivatives against a panel of lymphoma cell lines. Few molecules, across the library tested, showed nanomolar range antiproliferative activities in six lymphoma cell lines. To prioritize the identification of key targets, we set up a kinome profiling, DARTS (Drug Affinity Responsive Target Stability), CETSA (Cellular Theraml Shift Assay) and SPR (Surface Plasmon Resonance) experiments. Collected results led us to the discover of original modulators of 14-3-3 proteins.

This work presents the synthesis of new chemical entities endowed of potent anticancer activity and the campaign of drug target identification that highlighted their role as modulators of 14-3-3 proteins.

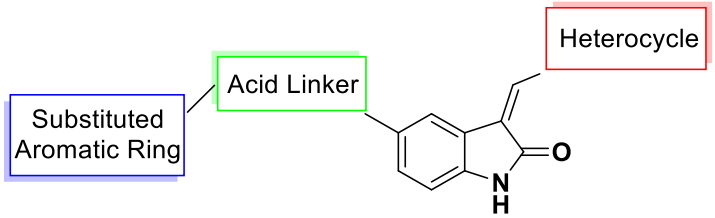

Figure 1: General structure A

References:

[1] S. Sestito, et al. Eur J Med Chem. 2021 Dec 15;226:113895.

[2] S. Sestito, et al. Eur J Med Chem. 2016, 118:47-63

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FAR-PO-122

Can lipidomic alterations of neuroblastoma cells caused by amyloid peptide incubation be reverted by myricetin?

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The investigation of brain lipid composition alterations observed in Alzheimer's disease (AD) can give insights into neurodegenerative mechanisms. Therefore, we wanted to validate and further explore the impact of β-amyloid ($A\beta_{1-42}$) self-aggregates on lipidome alterations, building upon our prior research.[1]
Specifically, differentiated human neuronal cells SH-SY5Y, were treated with $A\beta_{1-42}$ in the absence and in the presence of myricetin (Myr), a well-known $A\beta_{1-42}$ anti-aggregating agent.[2] The evaluation of *in vitro* toxicity confirmed that $A\beta_{1-42}$ (20 µM) significantly affects cell viability compared to control (83± 12 %). Meanwhile, Myr showed to not affect the cell viability at concentrations less than 40 µM. Conversely, it seems that there is an inverse dose-response relationship regarding Myr potential effect in counteracting the amyloid toxicity.
Then differentiated SH-SY5Y were treated in three different conditions.: i) $A\beta_{1-42}$ (20 µM); ii) $A\beta_{1-42}$ (20 µM) in the presence of Myr (40 µM); iii) Myr (40 µM). A protocol based on solvent direct cell scraping using a cold lipid extraction mixture (MeOH/MTBE/IPA (1.3:1:1, v/v/v)) was optimized for samples collection. Then, following a validated protocol lipids were extracted after cell cryo-lysis by homogenizer and the extracts analysed by a RP-UHPLC system coupled with a quadrupole-time-of-flight mass spectrometer in a comprehensive data-independent SWATH acquisition mode.[3] Data processing was achieved by MS-DIAL (version 4.24). After lipid identification we focused on the relative quantification of Glycerophospholipids and Sphingolipids classes and the results were compared with those obtained in our previous study.
By comparing lipid class profile in SH-SY5Y cells treated with $A\beta_{1-42}$ to untreated cells, we confirmed some alterations in PCs, LPCs profiles that might be related to cellular response mechanisms to the toxic stimuli of $A\beta_{1-42}$ aggregation species. According to the antiaggregating properties of Myr, in samples co-treated with this compound, changes in lipid levels seem to be restored, especially in case of O-PCs species that might be increased by the $A\beta_{1-42}$ oxidant effect.

References:

[1] L. Davani, X. Fu, A. De Simone, P.Li, S. Montanari, M. Lämmerhofer, V. Andrisano. J Pharm Biomed Anal 2022, 219, 114876.
[2] J. Fiori, M. Naldi, M. Bartolini, V. Andrisano, ELECTROPHORESIS 2012, 33 3380–3386.
[3] X. Fu, C. Calderón, T. Harm, M. Gawaz, M. Lämmerhofer. Anal Chim Acta 2022, 1221, 340155.

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FAR-PO-123

RNA controlled release from porous silicon nanoparticles coated with hyaluronic acid

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The RNA delivery is emerging in the last century as a new class of therapeutic for a wide range of diseases. Delivering RNA is a very interesting strategy for cancer therapy and rare diseases,[1] but remains a great challenge because of its low cell uptake, instability in blood.

For this reason, the use of lipidic nanoparticles has been recently witness as the solution for COVID 19 and the use of other type of nanocarriers is a promising approach for the RNA delivery and its controlled concentration over time. The problem is: what type of nanoparticles can be biocompatible, degradable and able to load enough RNA for therapeutic efficacy? Porous silicon nanostructures are of particular interest because of they fulfill all the requirements to allow *in vivo* applications, and they are easy to functionalize. The high porosity of these structure also allow a large amount of RNA entrapment and the structures prevent the degradation of the biomolecule and allow the specific drug release in a targeted area.[2] However, due to the fast degradability of the silicon, a coating with a polymeric layer is necessary to increase its stability and control the time of release.

Here, we report a strategy to load a high amount of RNA and, to avoid its early release, the use of hyaluronic acid (HA) wrapped around the particles. The presence of HA also helps to be selective towards the tumor environment due to the presence of overexpressed CD44 receptors specific for the polymer. Also the release of the RNA is achieved by the HA degradation promoted by an enzyme called hyaluronidase.[3]

In this work, is achieved a loading higher than 50% in weight thanks to the use of a calcium silicate reaction and we demonstrate the difference in the time release of RNA between nanoparticles coated and uncoated with HA.

Keywords: nanoparticles, drug delivery, silicon

References:

[1] Huang, X. *et al. Nat. Med.* **28**, 2273–2287 (2022).
[2] Kang, J. *et al. Adv. Mater.* **28**,.
[3] Kim, K. *et al. Pharmaceutics* **11**, (2019).

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FAR-PO-124

Silica nanoparticles functionalized with natural compound derivatives as novel anti-biolfilm agents

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The widespread formation of biofilms plays a significant role in human health, representing an important aspect in the development of infectious processes. To overcome the increasing antimicrobial resistance, the focus is to find new stategies to trigger the dispersal of biofilm or inhibit its initial formation.

To prevent biofilm development, we decided to consider novel antimicrobial-free strategies based on compounds acting at sub-lethal concentration, leading to biofilm inhibition while avoiding bactericidal effects. Starting from our previous studies[1,2], we explored the functionalization of inorganic nanoparticles with natural compound derivatives endowed with antifouling properties. The goal was to achieve novel nanoparticles suitable for surface coating, limiting the drawbacks of current anti-biofilm coverings, particularly the selection of resilient strains. Therefore we designed and synthesized two series of new silica nanoparticles (**1s**,**l** - **2s**,**l** and **3s**,**l** - **4s**,**l**). After their characterization, the sanples exhibiting the higher degree of functionalization (**1l** - **4l**) were used to coat glass coverslips by spin-coating. The coated surfaces (**A**-**D**, respectively) were tested against *P. aeruginosa* biofilm, and the results highlighted that surfaces **B** and **D** (Figure 1) showed promising anti-biofilm properties (percentage reduction of biofilm formation ranging from 59.2 ± 2.2 to 83.7 ± 3.4, respectively).

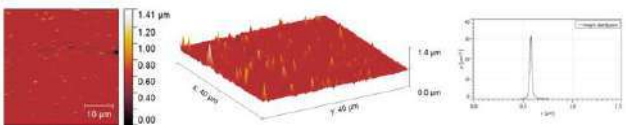

Figure 1: Atomic force microscopy (AFM) topographic image (40 × 40 µm), 3D rendering of the 40 µm image for perspective, and height histogram of surface **D**.

References:

[1] C. Cattò, S. Dell' Orto, F. Villa, S. Villa, A. Gelain, A. Vitali, V. Marzano, S. Baroni, F. Forlani, F. Cappitelli, PLoS ONE, 2015, 10(7), e0131519.
[2] C. Cattò, G. Grazioso, S. Dell'Orto, A. Gelain, S. Villa, V. Marzano, A. Vitali, F. Villa, F. Cappitelli, F. Forlani, Biofouling, 2017, 33, 235-251.

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FAR-PO-125

On the path towards a self-illuminating photodynamic therapy against cancer

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Photodynamic therapy (PDT) emerges as a promising alternative for cancer treatment [1]. However, PDT effectiveness is compromised by the attenuation of external light irradiation within tissues, thus reducing treatment efficacy. To overcome the need of an external light irradiation, an innovative approach involves generating light directly inside the cancer cells through a chemiluminescent reaction [2]. The emitted light can be absorbed by a photosensitizer to produce singlet oxygen or radicals, effectively inducing cell death. However, the proposed solution requires the efficient internalization of the components, ensuring non-toxicity, access to the target cells and close proximity with the photosensitizer. In this context, silica nanoparticles (NPs) emerge as a potential solution due to their ability to encapsulate and release components, offering advantageous properties such as biocompatibility, degradability, and a large surface area.

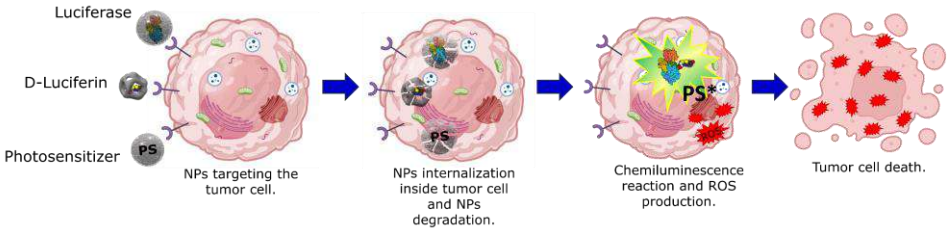

Figure 1: Concept of self-illuminating PDT.

This study explores a self-illuminating PDT approach, based on the encapsulation of chemiluminescent reagents and of a photosensitizer (PS) in silica NPs. Breakable organosilica nanocapsules, (ssNCPs), hollow structures with a unique hydrophilic cavity and breakable nanocages (ssOSCs) (exhibiting a cage-type morphology) were selected for the encapsulation of luciferase (enzyme) and D-luciferin (substrate). The silica network of these NPs contains disulfide bonds, allowing them to break within cells when exposed to a reducing environment like glutathione, abundant in cancer tissue. Figure 1 illustrates the concept of the study, demonstrating that upon the destruction and release of the components, the light generated by the chemiluminescent reaction can be absorbed by a photosensitizer (through energy transfer) to generate reactive species. Herein, preliminary experiments including the synthesis and characterization of organosilica nanoparticles are assessed using various methods (as electron microscopy, DLS, FTIR). Also, evidence of the encapsulation of luciferase and D-luciferin is presented.

References:

[1] G. Gunaydin, M. Emre Gedik, S. Ayan, Frontiers in Chemistry, 2021, 9, 691697.
[2] Y. An, D. Xu, G. Liu et al., Advanced Healthcare Materials, 2024, 13, 2301326.

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FAR-PO-126

Optimizing the antimycobacterial efficacy of MbtI inhibitors: towards a nanoparticle-mediated delivery

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In our efforts to combat the global spread of tuberculosis (TB),[1] we have focused on an innovative target, Salicylate Synthase I (MbtI), by combining traditional medicinal chemistry approaches with nanomedicine strategies. Over the past decades, anti-virulence therapy has emerged as an alternative to traditional antimicrobial treatments. Building on this, the impairment of iron acquisition through enzymatic inhibitors that block the production of siderophores has been identified as a viable strategy. Our group has devoted considerable efforts to developing inhibitors of MbtI, the first enzyme in the biosynthetic cascade, leading to several promising candidates. Among these, 5-(3-cyano-5-isobutoxyphenyl)furan-2-carboxylic acid (1) stands out as the most potent MbtI inhibitor discovered to date.[2] Furthermore, the unique challenges posed by TB, including the need for prolonged treatment regimens, underscore the urgent need for innovative approaches in drug delivery. Nanomedicine presents an unprecedented opportunity to address these challenges, ensuring more targeted, effective, and patient-friendly TB treatment strategies. The core innovation of our project lies in the development of specialized nanoparticles designed to deliver anti-TB drugs more effectively and safely.[3] We successfully loaded poly(2-(methacryloyloxy)ethyl phosphorylcholine)-co-poly(2-(diisopropylamino)ethyl methacrylate) (PMPC-PDPA) polymersomes (POs) with ethyl and propyl ester derivatives of 1, namely 1a and 1b. The POs, synthesized through a bottom-up approach, were fully characterized and MTT assays confirmed the absence of cytotoxicity for both the free drugs and the encapsulated POs. Additionally, we demonstrated that our pro-drugs (1a and 1b) can be converted into the active candidate by hydrolase enzymes once inside the macrophages. In vitro assays are ongoing to investigate the effects of our nanomaterials on innovative murine alveolar-like macrophage infection models of Mtb.

References:

[1] *WHO | Global Tuberculosis Report 2023*; World Health Organization.
[2] M. Mori, A. Griego, G. Stelitano, L. R. Chiarelli, G. Cazzaniga, A. Gelain, E. Pini, M. Camera, P. Canzano, A. Fumagalli, E. Scarpa, C. Cordiglieri, L. Rizzello, S. Villa, F. Meneghetti. Pharmaceuticals 2022, 15, 992-1014.
[3] Acosta-Gutiérrez S., Matias D., Avila-Olias M., Gouveia V., Scarpa E., Forth J., Contini C., Duro-Castano A., Rizzello L., Battaglia G. A Multiscale Study of Phosphorylcholine Driven Cellular Phenotypic Targeting. *ACS Cent. Sci.* 2022, 891–904.

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FAR-PO-127

Nanogel particles for safe and effective RNA-delivery

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The delivery of RNAs remains a challenge due to the fragility of the biomolecule as well as its difficult internalization on the desired cells. Nanostructures, e.g. liposomes, have been employed termed as carriers for different type of RNAs and have the limitation of large size, stability and eventually toxicity[1]. Alternative soft nanostructures are hydrogel particles, composed of polymers and mainly water are interesting carriers for a variety of biomolecules. In my contribution the use of gelatine based hydrogels is described as potential nanovectors for RNA delivery in different cell lines. The choice of the materials is dictated by their biocompatibility, lack of toxicity, ability to entrap large amount of the mRNA and siRNA. The chemical composition of the nanogels influence the charge, size (<100 nm) and degradation of the systems. To this aim, a Gelatin-based nanogels were prepared according to the literature by the two-step desolvation method [2-3] in order to obtain positive charges capable of interacting with RNA molecules for potential drug delivery (Figure 1). The use of nanogels with these characteristics should avoid fast clearance, improve easy cargo release.

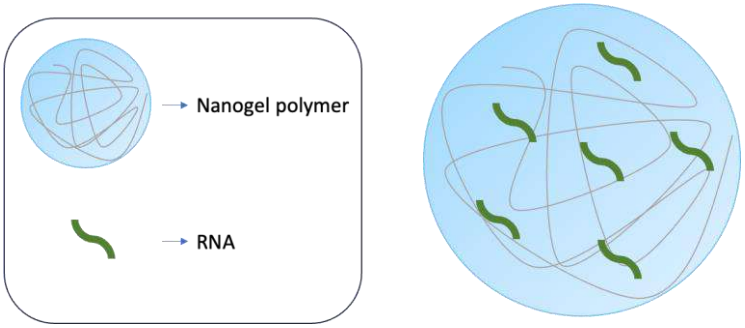

Figure 1: Nanogel-RNA complex

References:

[1] Yi Shu, Fengmei Pi, Ashwani Sharma, Mehdi Rajabi, Farzin Haque, Dan Shu, Markos Leggas, B. Mark Evers, Peixuan Guo, Stable RNA nanoparticles as potential new generation drugs for cancer therapy,
Advanced Drug Delivery Reviews,Volume 66, 2014, Pages 74-89

[2] G. Mugnaini, R. Gelli, L. Mori, and M. Bonini, "How to Cross-Link Gelatin: The Effect of Glutaraldehyde and Glyceraldehyde on the Hydrogel Properties," ACS Appl Polym Mater, vol. 5, no. 11, pp. 9192–9202, Nov. 2023, doi: 10.1021/acsapm.3c01676.

[3] L. Andrée et al., "Gelatin Nanoparticles for Complexation and Enhanced Cellular Delivery of mRNA," Nanomaterials, vol. 12, no. 19, Oct. 2022, p.3423, doi: 10.3390/nano12193423.

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FAR-PO-128

Improved drug delivery strategies to enhance therapeutic outcomes in metastatic melanoma

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Melanoma treatment strategies have significantly improved patient survivability in the last decades, but there are still unresolved issues in current therapies. New drug combinations are gaining ground for the treatment of non-responsive or relapsing patients, and, for the purpose, kinases have been established as promising therapeutic targets in the design of novel drugs against cancer[1]. Recently, an *in vivo* screening performed at the European Institute of Oncology (IEO, Milan) demonstrated that the dual targeting of Aurora kinase A and MEK is highly effective against metastatic melanoma tumours derived from patients[2]. This synergy has already outperformed the standard-of-care therapy in *in vitro* and *in vivo* models.

This work aims to target clinical trials, and we propose to increase the outcome of melanoma treatments improving drug bioavailability, cellular uptake and tumour accumulation. In the nanomedicine field, pharmaceutical co-crystals and drug nanoencapsulation are among the more studied and promising strategies for the purpose.

For these reasons, in a first part of the work, we studied at the molecular level MEK and Aurora kinase A inhibitors, exploiting both protein databases[3] and experimental crystallographic techniques, with the aim of unravelling their internal interaction profile. This information is fundamental to design novel pharmaceutical co-crystals and salts, thus increasing their solubility in physiological conditions.

In parallel, novel dual-loaded nanoformulations of MEK and Aurora kinase A inhibitors have been developed with the aim of reducing toxicity and improving the efficacy of the therapy. First *in vitro* and *in vivo* results show increased cellular internalization and tumour accumulation of the encapsulated drugs with respect to the corresponding free drugs, reflecting in a more effective therapy.

References:

[1] J. Zhang, P. L. Yang, N. S. Gray, Nature Reviews Cancer, 2009, 9, 28 – 39.
[2] F. Marocchi, F. Palluzzi, P. Nicoli, M. Melixetian, G. Lovati, G. Bertalot, S. Pece, P. F. Ferrucci, D. Bossi, L. Lanfrancone, Journal of Investigative Dermatology, 2023, 143, 1993 – 2006.
[3] P. Milesi, F. Baldelli Bombelli, L. Lanfrancone, P. Metrangolo, A. Frontera, R. M. Gomila, G. Terraneo, Chem Asian Journal, 2024, e202301033.

FAR-PO-130

Sustainable Plastic Degradation: A Machine-Learning-Based Enzyme Engineering Approach

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The problem of how to dispose of the enormous amount of plastic waste is a pressing topic worldwide. In particular, new and sustainable approaches to plastic polymer degradation are required since the currently employed techniques are environmentally polluting. In the past few decades, the scientific community has invested considerable efforts to engineer naturally occurring enzymes capable of degrading plastic polymers to increase their catalytic efficiency and applicability on the industrial scale. In this framework, we apply machine learning models to the problem of mutating selected enzymes capable of degrading plastic polymers to increase their catalytic efficiency. In particular, provided the structural data of the enzyme and the polymer to degrade, the machine learning model will aim at predicting the kinetic parameters of the reaction (the binding affinity K_d and the turnover number k_{cat}). Such a pipeline would constitute the basis for a general framework to tackle the problem of enzyme optimization for plastic polymer degradation.

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FIS-KN-01

Astrochemistry & Solar System ancient history

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Astrochemistry is the science that studies the chemistry in the Universe, namely the combination of two fields: astronomy and chemistry. It started about fifty years ago and it has progressed in leaps and bounds, often triggered by the advent of new telescopes. From the collection of new interstellar molecule detections, astrochemistry has evolved more and more in the quest to understand how they are formed and thrive in the harsh conditions of the interstellar space. The more we know the more we can use interstellar molecules as powerful diagnostic tools. In this presentation, I will briefly review some major aspects of astrochemistry connected with the earliest history of our Solar System and that helped to solve some basic puzzles, for example the origin of terrestrial water, or the possible contribution of the interstellar organic chemistry to kickstart life on Earth.

FIS-KN-02

Opportunities and Challenges for the development of solar to fuels technologies: a photochemist's viewpoint

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There is increasing interest in harnessing sunlight to drive the synthesis of molecular fuels and chemicals, including in particular water photolysis to yield molecular oxygen and hydrogen. This can be achieved either through the coupling of photovoltaic cells and electrolysis, or through direct sunlight conversion by photoelectrodes or photocatalysts, the latter being the focus of this talk. In solar conversion, there is often a critical kinetic mismatch between the lifetimes of initially generated photoexcited states and the timescales of charge extraction / catalysis. I will start my talk by introducing solar driven fuel synthesis, and the charge carrier lifetime challenge in photoelectrochemical and photocatalytic systems. I will contrast this with the smaller lifetime challenges for photovoltaic solar energy conversion. I will then go on to discuss some of our recent studies employing transient optical spectroscopies measuring charge carrier dynamics in photoelectrodes and photocatalysts and how these impact upon the efficiency of solar driven water splitting, covering a range of metal oxide and polymer materials. I will consider the importance of d-orbital occupancy in metal oxide photocatalysts in determining charge carrier lifetimes. I will then go on to discuss carbon nitride and organic polymer photocatalysts, and the impact of charge trapping and heterojunctions in extending the lifetime of charge carriers. I will conclude by considering some of the kinetic challenges for photocatalysts and photoelectrodes materials based on conjugated polymers, and the role of materials design in impacting upon these kinetics.

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FIS-OR-001

Unveiling Earth's phosphorus dawn and fate: computational explorations of P-bearing mineral surfaces in the tapestry of prebiotic chemistry

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Phosphorus assumes a paramount role in biology as phosphate (PO_4^{3-}), but its origin and transformation are uncertain. Most theories suggest meteorites brought phosphorus during the Archean, depositing iron-phosphide, like Schreibersite, on Earth. Recent experiments show these materials interact with wetting and corrosion to produce various oxygenated phosphorus compounds.

On the other hand, even if calcium phosphates, *i.e.* apatites, exhibit both low reactivity and insolubility, rendering the phosphate content inaccessible for phosphorylation reactions with specific prebiotic molecules, the role of hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] as a catalyst in prebiotic chemistry for the formation of ribose from formaldehyde and glycolaldehyde has been proposed.

In this contribution, we studied the wetting process of schreibersite (Fe_2NiP) by means of density functional theory calculations.[1] The simulations explored various water coverages on the stable (110) [2] and (001) Fe_2NiP surfaces, providing insights into water binding energy values and predicting vibrational spectra. Furthermore, we examined water reactivity through multiple deprotonation reactions, progressively introducing more water molecules to facilitate the formation of phosphonic and phosphoric acids and their respective deprotonated forms.[3] Finally, we studied by means of very preliminary simulations the steps of the formose reaction on HA surfaces.

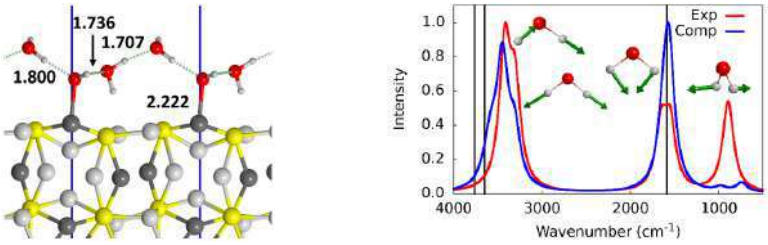

Figure: H_2O on (110) Fe_2NiP surface (left); experimental vs computed IR spectrum at 125 K (right). H in white, O in red, P in yellow, Fe in light grey, Ni in dark grey.

References:

[1] S. Pantaleone, M. Corno, A. Rimola, A.; N. Balucani, P. Ugliengo, ACS Earth Space Chem. 2021, 5, 1741-1751.
[2] S. Pantaleone, M. Corno, A. Rimola, A.; N. Balucani, P. Ugliengo, J. Phys. Chem. C 2022, 26, 2243-2252.
[3] S. Pantaleone, M. Corno, A. Rimola, A.; N. Balucani, P. Ugliengo, ACS Earth Space Chem. 2023, 7, 2050−2061.

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FIS-OR-002

A computation study of binding energies and vibrational spectral features of S_n species on amorphous water ice mantles

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In the denser and colder regions of the interstellar medium (ISM), gas-phase sulphur is depleted by two or three orders of magnitude with respect to its cosmic abundance.[1] Thus, which species are the main carriers of sulphur is an open question. Recent studies have proposed S_n species as potential sulphur reservoirs.[2] Among the various sulphur allotropes, the most stable one is the S_8 ring, detected in asteroid Ryugu and Orgueil meteorite.[3] Shorter species, namely S_3 and S_4, have been found in comet 67P/C-G, but their presence in the ISM remains elusive.[4] In this study, we compute the binding energies (BEs) of S_n (n=1–8) species on an amorphous water ice surface model and analysed their infrared (IR) and Raman spectral features to provide data for their identification in the ISM. Our computations reveal that these species exhibit lower BEs than previously estimated in the literature[2], and their spectral features experience minimal shifts when adsorbed on water ice because of the weak S_n/ice interactions. Furthermore, these species display very weak IR band intensities, suggesting Raman spectroscopy as a promising technique for their identification in terrestrial laboratories.[5] Accurate instruments operating in the mid-infrared range are required for detecting the presence of these species in dense interstellar environments.

References:

[1] A. Fuente, P. Rivière-Marichalar, et al., A&A, 2023, A114, 670 – 692.
[2] S. Cazaux, H. Carrascosa, et al., A&A, 2022, A100, 657 – 668.
[3] J.C. Aponte, J.P. Dworkin, et al., Earth, Planets and Space, 2023, 75, 28 – 41.
[4] U. Calmonte, K. Altwegg, et al., MNRAS, 2016, 462, S253 – S273.
[5] C.N. Shingledecker, T. Lamberts, ApJ, 2020, 888, 52 – 66.

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FIS-OR-003

Crossed molecular beam studies of the reactions between small aromatic compounds and atomic oxygen and atoms and implications in materials science

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The detailed mechanism at the atomistic level of the reactions involving small aromatics has remained mostly unexplored because of the difficulty in studying multichannel reactions with the typical experimental methods available in the field of reaction dynamics. We have recently succeeded in doing that thanks to the versatility of the crossed molecular beam technique with mass spectrometric detection and time-of-flight analysis empowered by the soft ionization approach developed in our laboratory. We have investigated the reactions of atomic oxygen and atomic nitrogen with benzene, toluene and pyridine. The results have been surprising and interesting at the same time. Briefly, in the case of the atomic oxygen reactions, notable differences have been observed when comparing the reactions with benzene and pyridine (even though they are isoelectronic species for which a similar reaction mechanism was expected) or when comparing the reactions of benzene and toluene (even though the methyl substitution was not expected to affect the reaction mechanism).[1-3] A comparison with the predictions of state-of-the-art quantum calculations proved that those differences are due to the different extent of intersystem crossing to the underlying singlet potential energy surface (PES).[1] That, in turn, depends only on the coupling terms between the triplet and singlet PESs. In the case of the atomic nitrogen reactions, the reaction mechanisms for the three systems proceed via the insertion of N into the aromatic rings with the formation of 7-membered rings.[4,5] Ring contraction mechanisms are important in all cases, challenging the common notion that aromatic rings are resistant to chemical attack.

Our results help in clarifying the mechanism of chemical erosion of space-technology polymers in the Low Earth Orbit and the mechanism for the formation of N-doped graphene in N_2 plasmas.

We acknowledge financial support under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.1, Call for tender No. 1409 published on 14.09.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU– Project Title P20223H8CK Degradation of space technology polymers by thermospheric oxygen atoms and ions: an exploration of the reaction mechanisms at an atomistic level (ThermOPoly) – CUP J53D23014440001- Grant Assignment Decree No. 1386 adopted on 01.09.2023 by MUR.

References:

[1] C. Cavallotti, C. De Falco, et al., J. Phys. Chem. Lett. 2020, 11, 9621–9628.
[2] P. Recio, S. Alessandrini, et al., Nature Chemistry 2022, 14, 1405–1412.
[3] N. Balucani, G. Vanuzzo, et al., Faraday Discuss. 2024, in press; doi: 10.1039/D3FD00181D
[4] N. Balucani, A. Caracciolo, et al., Faraday Discuss. 2023, 245, 327-351.
[5] P. Recio, D. Marchione, et al., Chem. Phys. Lett. 2021, 779, 138852.

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Multiscale Frozen Density Embedding/Molecular Mechanics Approach for Simulating Response Properties of Solvated Systems

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The reliable simulation of molecular properties of complex systems requires an accurate description of all its components, including the interactions between the target molecule and its chemical environment. Multiscale modeling approaches have emerged as the most successful methodologies in this context, especially for computing spectroscopic properties of systems in solution.[1,2]

We have recently proposed a multilayer embedding approach, which divides the system into three portions. The first two portions are treated using density functional theory (DFT) and the frozen density embedding (FDE) approach.[3] The third part is described by using a classical atomistic polarizable embedding, based on the fluctuating charges (FQ) force field. The resulting QM/FDE/FQ method was challenged to calculate excitation energies of molecules in aqueous solution.[4]

In this contribution,[5] we extend the method to the calculation of NMR spectra of solvated systems, refining the outer FQ shell in terms of the fluctuating charges/fluctuating dipoles force field (FQFμ).[6] We demonstrate the effectiveness of the model by applying it to the simulation of NMR spectra of Brooker's merocyanine in aqueous and non-aqueous solutions, showing a good agreement with available experimental results and providing insight into solvent effects on NMR signals.

References:

[1] T. Giovannini, C. Cappelli, Chem. Commun. 2023, 59, 5644 – 5660.
[2] T. Giovannini, F. Egidi, C. Cappelli, Chem. Soc. Rev. 2020, 49, 5664 – 5677.
[3] T. A. Wesolowski, S. Shedge, X. Zhou, Chem. Rev. 2015, 115, 5891 – 5928.
[4] F. Egidi, S. Angelico, P. Lafiosca, T. Giovannini, C. Cappelli, J. Chem. Phys. 2021, 154, 164107.
[5] P. Lafiosca, F. Rossi, F. Egidi, T. Giovannini, C. Cappelli, J. Chem. Theory Comput. 2024, 20, 266 – 279.
[6] T. Giovannini, A. Puglisi, M. Ambrosetti, C. Cappelli, J. Chem. Theory Comput. 2019, 15, 2233 – 2245.

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Adsorption and decomposition of ammonia on Fe surfaces: a molecular dynamics study

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Ammonia is considered a potential hydrogen vector due to its high hydrogen content and ease of transportation and storage. However, on-site carbon-free hydrogen production requires the development of efficient methods of hydrogen extraction from ammonia. To this end, iron-based catalysts are widely employed in ammonia cracking. Despite more than one century of studies, a microscopic characterization of the reaction is still lacking, hindered by extreme reaction conditions (700-800 K).[1] So far, studies based on density functional theory (DFT) calculations often neglect dynamic behaviours, which play a critical role in heterogenous catalysis, explaining the activity and long-term stability.[2-4] Leveraging state-of-the-art molecular dynamics, machine learning potentials, and enhanced sampling methods, we offer an atomistic view of the adsorption, diffusion, and dehydrogenation processes of NH_x (x=1,3) on two representative surfaces at *operando* temperature of 700 K. Dynamics pervasively affects all steps of decomposition, including on the stable (110) surface where the high mobility of reaction intermediates influences the reactivity. The role is even more dramatic on the (111) surface, where the mobility of Fe surface atoms introduces new adsorption sites and alters the dehydrogenation barriers. Our study establishes a correlation between diffusion and dehydrogenation free energy barriers, highlighting the intricate interplay between surface dynamics and catalytic activity. A detailed analysis of reactive events shows that there is never a single transition state, but it is always an ensemble composed of at least two pathways (Fig.1 left). Notwithstanding, a unified mechanism can be identified by following the charge transfer along the different reaction pathways (Fig.1 right).[5] The framework used is general and can be employed to study other heterogeneous catalysis processes with quantum mechanical-like accuracy.

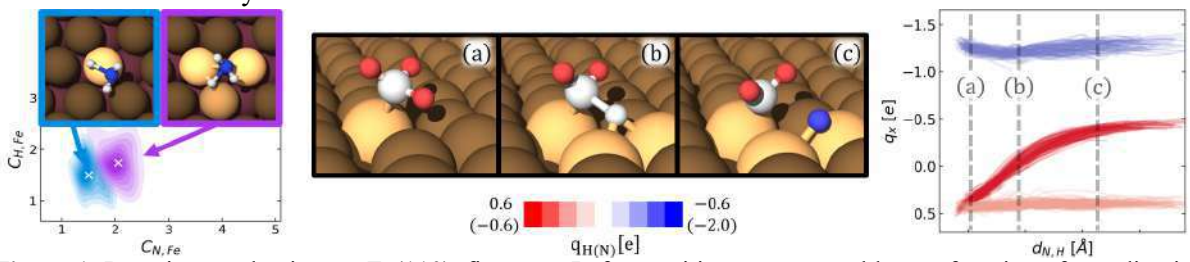

Figure 1: Reaction mechanism on Fe(110), first step. Left: transition state ensemble as a function of coordination numbers $C_{X,Fe}$. Two different channels are highlighted for each reaction. Right: charge evolution during reaction across 100 reactive events. Insets (a-c) show a reactive event with atoms coloured according to their net charges.

References

1. I. Lucentini, et al., *Ind. Eng. Chem. Res.*, **2021**, *60(51)*, 18560-18611.
2. M. S. Spencer, *Nature* **1986**, *323,* 685-687
3. L. Bonati, et al., *Proceedings of the National Academy of Sciences* **2023**, 120, e2313023120.
4. S. Tripathi, L. Bonati, S. Perego, M. Parrinello, *ACS Catal.* **2024**, 14, XXX, 4944–4950
5. S. Perego, L. Bonati, S. Tripathi, M. Parrinello, *ChemRxiv.*, **202**4

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FIS-OR-006

Exploring PET dissolution in monoterpenoid-based eutectic solvents: experimental insights and Molecular Dynamics simulations

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Poly(ethylene terephthalate) (PET) is a widely used polyester plastic, accounting for 8% of global plastic production. Despite its versatility across industries, PET poses environmental challenges due to its non-biodegradable nature, raising concerns about its long-term persistence in landfills and potential harm to marine and human life. Chemical recycling methods facilitated by ionic liquids and eutectic solvents (ES), offer promising avenues for efficient PET breakdown. Notably, a natural ES comprised of carvacrol and thymol, two structural isomers, in a 1:1 molar ratio demonstrated effective PET solubilization, achieving a remarkable 10 wt% solubilization at 150°C without inducing plastic degradation.[1] This study presents a thorough characterization of various ES-PET mixtures at different plastic contents (ranging between 0 and 10 wt%). We investigated the temperature-dependent behavior of density (ρ) and dynamic viscosity (η) between 293.15 K and 333.15 K. Additionally, the aggregation of PET in these mixtures was examined through Dynamic Light Scattering and Small Angle X-ray Scattering experiments, elucidating the polymer status in solution. Furthermore, Molecular Dynamics simulations delve into PET oligomer solvation mechanisms, revealing the interplay between carvacrol and thymol in efficiently solvating the chain. This approach suggests that PET's high solubility is driven by thymol's hydrogen bonding interactions with PET oxygens and carvacrol's π-π interactions with the PET aromatic rings, underscoring its ring's propensity for such interactions [2]. This work represents a significant advancement in the comprehension of PET dissolution utilizing a natural ES based on monoterpenoids.

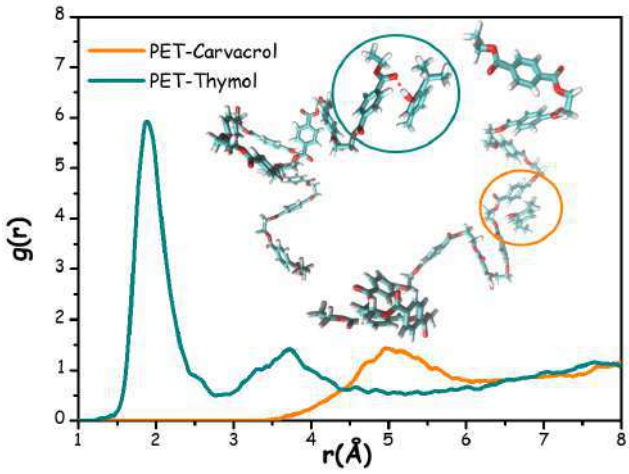

Figure 1: Radial Distribution Functions (RDFs) of the correlations between carbonyl oxygens of PET and thymol hydroxyl hydrogen (in green) and those between the centers of PET and carvacrol rings (in orange).

References:
[1] S. C. Pestana, J. N. Machado, R. D. Pinto, B. D. Ribeiro, I. M. Marrucho, Green Chemistry 2021, 23, 9460–9464.
[2] E. Mangiacapre, A. Triolo, F. Ramondo, F. Lo Celso, O. Russina, Journal of Molecular Liquids 2024, 394, 123778.

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FIS-OR-007

Thermodynamic study of urea/choline chloride deep eutectic solvent by vapor pressure measurements under effusion conditions

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Deep eutectic mixtures have received an ever-increasing attention in the last two decades as a novel class of eco-friendly solvents for a number of uses, thanks to their appealing and tunable properties such as low volatility, good thermal stability, low toxicity, and the possibility of being synthesized by safe, readily accessible and inexpensive precursors. Among the most useful applications proposed for deep eutectic solvents (DESs) there are batteries and other energy-related fields, catalysis and organic synthesis, separation processes, drug delivery and other aspects of pharmaceutical and biomedical research.

Starting from the work by Abbott et al.,[1] reporting unexpectedly low freezing points and interesting solvent properties for 2:1 mixtures of urea/choline chloride (reline) and other quaternary ammonium salts, the number of eutectic mixtures claimed as DESs has grown exponentially in the last years. Nevertheless, a rigorous methodology for the investigation of some of their fundamental physico-chemical properties has not been established yet, even for the most studied systems. In particular, it is frequently reported that DESs are characterized by low vapor pressures, in comparison with conventional solvents, although not as low as those of ionic liquids, which share with these mixtures several characteristics and prospective applications.

Despite their importance in deriving the mixing thermodynamic properties, studies reporting vapor pressure measurements of DESs are surprisingly scarce: as regards reline, only two thermogravimetric determinations, carried out under free evaporation conditions, are reported,[2,3] resulting in one order-of-magnitude disagreement. Apparently, no vapor pressure data based on effusion close-to-equilibrium conditions are available in the literature. In the effort to give a contribution to elucidate these contradictory results and to fill the gap on thermodynamic description of DESs, we have undertaken the measurement of equilibrium vapor pressures of reline using Knudsen effusion mass spectrometry. The vapor phase was proven to contain exclusively urea and, by integrating the mass spectrometric signal as a function of time, the change in the composition of the liquid mixture during the experiments was monitored. Urea vapor pressures were measured in the temperature range 320 – 360 K around the eutectic composition, aiming at determining the activity as a function of temperature and composition and the mixing properties.

References:

[1] A. P. Abbott, G. Capper, D. L. Davies, R. K. Rasheed, V. Tambyrajrajah, Chem. Commun. 2003, 70-71.
[2] K. Shahbaz, F. S. Mjalli, G. Vakili-Nezhaad, I. M. AlNashef, A. Asadov, M. M. Farid, J. Mol. Liq. 2016, 222, 61-66.
[3] S. Ravula, N. E. Larm, M. A. Mottaleb, M. P. Heitz, G. A. Baker, ChemEngineering 2019, 3, 42.

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FIS-OR-008

CO-induced dynamic behavior of Al_2O_3-supported Pd nanoparticles at room temperature

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Supported metal nanoparticles (NPs) may undergo adsorbate-induced phenomena, with evident consequences on their performance in catalytic applications. CO-induced surface phenomena involving Pd NPs have been documented mostly at high temperatures.[1,2] In this work, we report an unusual step-shaped CO adsorption isotherm at 30°C on Pd/Al_2O_3, associated with an unexpected increase in the heat of adsorption and with a modification in the relative abundance of the different Pd-carbonyl species. These three independent observations can be reconciled by considering a partially reversible CO-induced roughening of the Pd(100) facets entailing the creation of novel defective sites. The detailed knowledge of the interaction of CO with Pd NPs at mild temperature in terms of strength, coverage and adsorption mode/sites is a key to control reactivity and has analytical relevance for the correct interpretation of CO chemisorption measurements. Our experimental strategy has the potential to become a benchmark in the investigation of the adsorbate-induced dynamic behaviour of supported metal NPs.

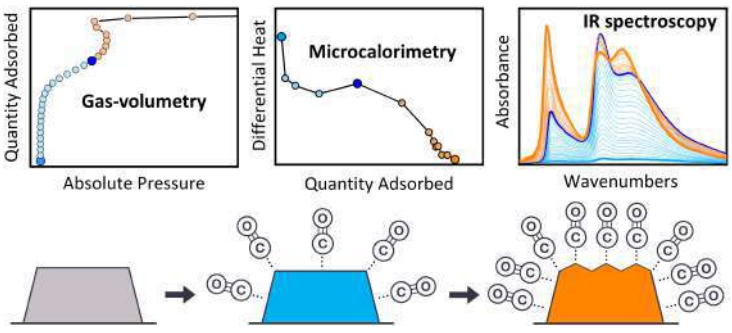

Figure 1: Combination of gas-volumetry, adsorption microcalorimetry and IR spectroscopy provided an unprecedent insight into a CO-induced surface reconstruction of Al_2O_3-supported Pd NPs involving the (100) surface and entailing the creation of new, defective, adsorption sites.

References:

[1] I. Jbir, J. Couble, S. Khaddar-Zine, Z. Ksibi, F. Meunier, D. Bianchi, ACS Catal. 2016, 6, 2545–2558.
[2] M. A. Newton, C. Belver-Coldeira, A. Martínez-Arias, M. Fernández-García, Nat. Mater. 2007, 6, 528–532.

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Insights into the activity of the different phases of Bi_2O_3 for the photocatalytic production of ammonia

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Ammonia (NH_3) has gained widespread use as a potent fertilizer in agricultural practices,[1] and has recently gained attention as a promising source of clean energy and fuel.[2,3] Although natural processes such as lightning and biological nitrogen fixation by nitrogenase contribute to nitrogen fixation, they are insufficient to satisfy the increasing demand driven by population growth. The introduction of the Haber–Bosch method in 1909 revolutionized ammonia industrial process. Due to the exceptional stability of nitrogen molecule (N_2) with a bond energy of 941.3 kJ mol^{-1}, the process of nitrogen fixation via the Haber-Bosch method requires the utilization of an Fe-based catalyst at elevated temperatures (400-450 °C) and pressures (150-200 atm).[4] This results in substantial energy consumption and elevated production costs for NH_3, along with significant environmental impacts.[1] Consequently, there is an urgent need for the advancement of novel nitrogen fixation technologies that are cost-effective, efficient, and environmentally sustainable.[5-7] In these last years, thanks to their unique and suitable energy band structure, high separation rate of photogenerated electrons-holes and response to visible light,[8] bismuth-based materials have emerged as a new kind of effective photocatalysts for nitrogen photofixation. We have then opted to direct our focus towards a more straightforward material such as Bismuth Oxide (Bi_2O_3). This material indeed has interesting properties,[8] notably its various phases (α, β, γ, δ, and ω), each with different property such as the band-gap, leading to distinct optical behaviours. Despite these intriguing properties, the literature regarding this material, particularly in nitrogen fixation, is rather limited. Therefore, we have synthesized various phases, including a mixture of these, to explore and elucidate their efficacy for the ammonia photoproduction. Additionally, we have focused on studying the luminescence properties of the obtained materials, in order to elucidate the dynamics of charge carriers and thus attempting to relate photocatalytic efficiencies to structural and electronic properties of the prepared materials.

References:

[1] P. H. Pfromm, Journal of Renewable and Sustainable Energy 2017, 9, 034702.
[2] A. Valera-Medina, H. Xiao, M. Owen-Jones, W. I. F. David, P. J. Bowen, Progress in Energy and Combustion Science 2018, 69, 63.
[3] A. Valera-Medina et al., Costa, Energy Fuels 2021, 35, 6964.
[4] S. Chen, D. Liu, T. Peng, Solar RRL 2021, 5, 2000487.
[5] M. Li, H. Huang, J. Low, C. Gao, R. Long, Y. Xiong, Small Methods 2019, 3, 1800388.
[6] L. Hollevoet, M. De Ras, M. Roeffaers, J. Hofkens, J. A. Martens, ACS Energy Letters 2020 5 (4), 1124-1127.
[7] F. Valentini, A.M. Grigoras, L. Vaccaro, L. Latterini, Carbon Energy. 2024; Accepted.
[8] P. Xia, Y.-J. Song, Y.-Z. Liu, M.-X. Long, C. Yang, X.-Y. Zhang, T. Zhang, J. Mater. Chem. C 2024, 12, 1609.

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FIS-OR-010

Effects of Au Nanoparticles Deposition on the Photoactivity of Differently Shaped Anatase TiO_2

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Titanium dioxide nanosheets enthralled photocatalysis scientists worldwide due to their peculiar properties, such as the higher reactivity of the {001} facets compared to the {101} facets and an optimized charge separation resulting from the preferential migration of electrons and holes towards the {101} and {001} facets, respectively.[1] Nevertheless, the effects induced by the deposition of noble metal nanoparticles (NPs) on the photoactivity of differently shaped TiO_2 are still incompletely grasped. In this scenario, the present work aims at elucidating the interplay on TiO_2 photoactivity between particle morphology[2] and gold NPs deposition by evaluating the photoactivity of Au modified anatase nanocrystals with either a pseudo-spherical shape or a nanosheet structure.

We found that only in the case of pseudo-spherically shaped TiO_2 photocatalysts, mainly exposing {101} facets the deposition of noble metal NPs produces a significant photoactivity increase in both Rhodamine B photocatalytic oxidation under *in-situ* surface fluorination conditions and formic acid photocatalytic degradation.

Differently, we found that the deposition of Au NPs on the anatase surface only slightly affects its photocatalytic performance in Cr(VI) reduction, which is kinetically limited by the anodic half-reaction,[3] whereas a larger exposure of highly oxidant {001} facets result to be intrinsically beneficial for overcoming the rate-determining step of this photodegradation process. The obtained results are rationalized in the light of a novel mechanism based on the preferential migration of oppositely charged carriers towards different crystal facets. In fact, Au NPs deposited on {101} facets may cooperate with the preferential migration of electrons towards such facets by efficiently capturing them and improving charge separation. Instead, when Au NPs are mainly deposited on the more oxidant {001} facets, the electron capture ability of gold NPs and the preferential migration of the holes towards the same {001} facets may favour the extremely undesired recombination of photoproduced charge carriers.

References:

[1] Z. Li, S. Wang, J. Wu, W. Zhou, Renew. Sustain. Energy Rev. 2022, 156, 111980.
[2] M.V. Dozzi, M. Montalbano, G. Marra, L. Mino, E. Selli, Mater. Today Chem. 2021, 22, 100624.
[3] M. V. Dozzi, A. Saccomanni, E. Selli, J. Hazard. Mater. 2012, 211-212, 188 – 195.

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Reduction of Ru/Al_2O_3 followed by temperature programmed operando methods.

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Catalysts based on supported ruthenium (Ru) nanoparticles (NP) are widely employed for oxidation and hydrogenation reactions, owing to their performance and competitive price. Here we study the reducibility and the H_2-induced restructuring of a 5 wt% Ru/Al_2O_3 catalyst synthesized by deposition-precipitation from $RuCl_3$. Supported RuO_x species obtained with this method are easily reducible, at the expense of a higher complexity of the systems. Understanding the nature and the reducibility of supported RuO_x species is essential to optimize the catalyst activation step and/or obtain the best reaction conditions in hydrogenation reactions. By means of H_2-TPR, *operando* IR-MS spectroscopy and *operando* XRD/PDF-MS, we obtained deeper insights on thermodynamics and kinetics of Ru reduction, focusing on both surface and bulk phenomena. All measurements were carried out with the same protocol to allow direct comparison of complementary techniques. In H_2-TPR, two H_2 consumption events are assigned to the reduction of surface RuO_x and bulk RuO_2 (Fig.1A). Reduction occurs at notably lower temperature compared to similar catalysts previously reported[1,2] and a fraction of RuO_x reduces already at 25°C, as determined with quantitative analysis of H_2-TPR runs starting from -120 °C. In the *Operando* IR-MS experiment (Fig.1B), surface reduction is pinpointed by the decrease of the 2ν(Ru=O) band and the appearance of signals due to Ru hydrides concomitant to water evolution. *Operando* XRD/PDF-MS allowed to follow the kinetics of reduction of bulk rutile RuO_2 and the emergence of the *hcp* Ru phase (Fig.1C)[3,4]. The multi-technique approach undertaken allows to obtain a better definition of the reduction process of a complex catalyst composed of various Ru oxide entities and of the structural and chemical features of metal NP in their active state.

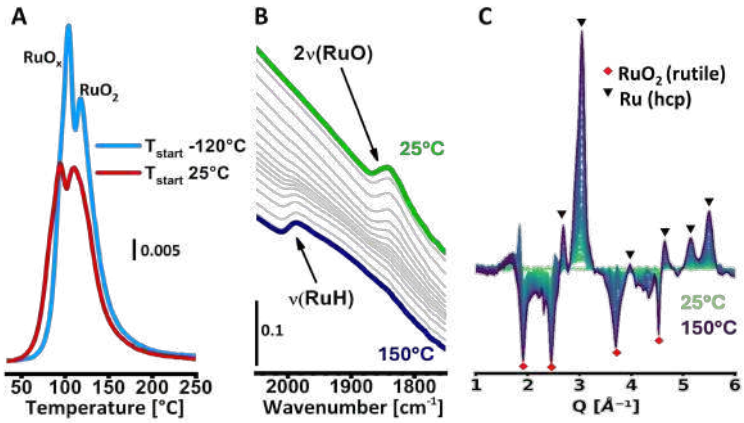

Figure 1(A) H_2-TPR performed starting, (B) IR spectra and (C) differential XRD patterns during reduction from 25°C.

References:

[1] Balaraju, M., Rekha, V., Devi, B. P., Prasad, R. B. N., Prasad, P. S., Lingaiah, N. *Appl. Catal. A* 384 (2010) 107.
[2] Pavan Kumar V., Priya S. S., Harikrishna Y., Kumar A., Chary K. V. (2016). *J. Nanos. and Nanot. 16*, 1952-1960.
[3] Zhang, B., Zhang, C., He, H., Yu, Y., Wang, L., & Zhang, J. *Chem. Mater.* 22 (2010) 4056.
[4] *Operando* total scattering experiment: DOI 10.15151/ESRF-ES-1430230544.

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Insight on Ti Sites in MWW Zeolite in presence of Hydrogen Peroxide

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Titanium (Ti) doped zeolites are used as shape selective catalysts for partial oxidation reactions (e.g. epoxidations or hydroxylations), using hydrogen peroxide (H_2O_2) as oxidizing agent.[1] Titanium Silicalite-1 (TS-1)[2] with MFI framework is the most renowned among all Ti-zeolites. The Ti-zeolite with MWW framework and high TiO_2 loading (Ti-MWW, graphical representation of the framework shown in Figure 1, Ti atoms in cyan) recently showed very promising catalytic outcomes.[3-4] The Ti insertion in the purely siliceous MWW framework was discovered to occur mainly during the post treatment washing with HNO_3, when the double structure directing agent synthetic method is used.[5] When the framework is modified, the behaviour of the Ti-peroxo (Ti-OO^-) and Ti-hydroperoxo (Ti-OOH) active species[6] can be different. Here, a combination of infrared (IR) and ultraviolet-visible (UV-Vis) spectroscopies was adopted to unveil the reason of the catalytic behaviour of TS-1 and to provide direct means of comparison with TS-1.[5]

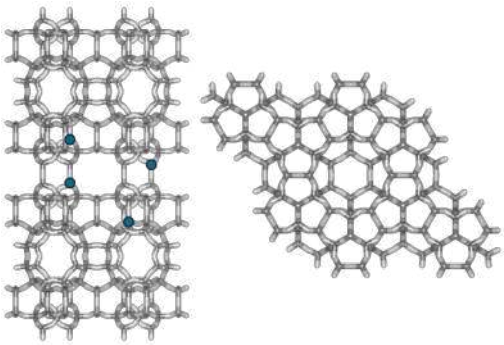

Figure 1: structure of MWW framework.

The acidic behaviour of the Ti sites and the interaction of the Ti sites with H_2O_2 were revealed by exploiting carbon monoxide, acetonitrile, pyridine and ammonia as probe molecules in infrared spectroscopy and diffuse reflectance ultraviolet spectroscopy. The Ti centres that behave as Lewis acid sites showed stronger acidity than those observed in TS-1. This is coherent with previously reported results,[4] suggesting that a significative fraction of the Ti sites in Ti-MWW are $TiOH(SiO)_3$ instead of $Ti(OSi)_4$. The Ti-peroxo and -hydroperoxo complexes formed with H_2O_2 were shown to be more labile than in TS-1 case and preliminary studies suggest that the formation of the active complexes is completely reversible.

References:

[1] J. Přech, Catal. Rev, 2017, 60:1, 71-131.
[2] M. Taramasso, G. Perego, B. Notari, US Patent no. 4410501, 1983.
[3] P. Wu, T. Tatsumi, T. Komatsu, T. Yashima, J. Phys. Chem. B, 2001, 105, 2897-2905.
[4] H. Xu, Y. Guan, X. Lu, J. Yin, X. Lin, D. Zhou, P. Wu, ACS Catal. 2020, 10, 4813-4819.
[5] F. Bonino, A. Damin, G. Ricchiardi, M. Ricci, G. Spanò, R. D'Aloisio, A. Zecchina, C. Lamberti, C. Prestipino, S. Bordiga, J. Phys. Chem. B, 2004, 108, 3573-3583.
[6] F. Rosso, A. Airi, M. Signorile, S. Bordiga, V. Crocellà, F. Bonino, submitted to ChemCatChem.

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The double life of kesterite nanoparticles: photovoltaics and photocatalysis

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In the last decade, kesterite (Cu_2ZnSnS_4 – CZTS) thin films have been widely studied for photovoltaics (PV), due to their similarity to the well-known and well-performing $Cu(In,Ga)Se_2$ (CIGS). Its high absorption coefficient (> 10^4 cm^{-1}), its high stability and a tuneable direct band gap of 1.45 - 1.50 eV, promote kesterite as an ideal candidate for non-toxic, cheap, earth-abundant photovoltaic thin-film absorber.

Here we present our study on the properties and the possible use of CZTS in the form of nanoparticles (NPs) based on a straightforward hot-injection synthesis in an oxygen-free environment, starting from metal acetates and elemental sulphur in oleylamine. The impact of different injection temperatures on the crystalline size, crystal structure and formation of undesired secondary phases was investigated, along with a procedure to get rid of them. The resulting NPs were fully characterised by Raman spectroscopy, X-ray diffraction, energy-dispersive X-ray spectroscopy, transmission electron microscopy, and scanning electron microscopy. Additionally, the presence and removal of both organic traces and detrimental phases were confirmed by thermogravimetric analysis and FTIR-ATR analysis.

Our CZTS NPs were tested as potential inorganic hole transport material (HTM) to achieve cost-effectiveness, long-term operational stability and sustainability goals in perovskite solar cells (PSCs), especially if compared to the organic, expensive, not-sustainable but conventionally-used HTMs in PSCs (i.e. PTAA, 2PACz, PEDOT:PSS). The hole mobility and charge transport properties were investigated in plane and out of plane, to ensure the feasibility of the material to act as HTM. The resulting HTM film was used in p-i-n architecture with $[CH_3NH_3]PbI_3$ and compared to an organic-HTM-containing reference device. Under optimised conditions, the PSCs with CZTS NPs HTM remained stable, with PV performance improving by up to 80% of the initial value over time.

Parallelly, the photocatalytic activity of our CZTS NPs was tested, to address the environmental impact of industrial wastewater. To this purpose, the CZTS NPs were employed to degrade diclofenac (DCF) in water, being one of the most persistent and hazardous emerging micropollutants. Notably, the CZTS NPs show promising efficiency of 80-90% DCF degradation over 120 minutes in both UV-vis and Visible-light-only conditions, demonstrating its potential employment also in this field of application.

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CO oxidation on $LaFe_{1-X}Co_XO_3$ perovskite: transient species analysis *via* Modulation Excitation DRIFT Spectroscopy with Phase Sensitive Detection (ME-DRIFTS-PSD)

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DRIFT Spectroscopy, under gas-phase and *operando* conditions, in combination with Modulation Excitation Spectroscopy (MES) could help provide new insights in heterogeneous catalysis and surface science to increase the signal-to-noise ratio and differentiate between the active vs. spectator species. Under a periodic modulation of the reaction environment, the catalyst's active species give different responses. By transforming the data into the phase domain and performing in-phase analysis, the Phase Sensitive Detection (PSD) can identify the sequence of the occurrence of these species in the phase domain and therefore, provide information about the reaction mechanism (Figure 1a).[1] A square wave stimulation was used.[1] To extract kinetic information from the system, the PSD analysis was applied at different *k* indices.

This work shows a transient species analysis regarding two LaFe-based perovskite catalysts with 0% and 25% of Co loading involved in CO oxidation. The focus is to clarify the role of Co in CO_2 formation. In this case, we performed the analysis after CO oxidation at both 100 and 200 °C (based on catalytic results). The analysis shows that carbonates are formed before any other species on the surface upon exposure to a mixture of $CO+O_2$. In the presence of Co, the catalyst shows a slower (more negative phase delays) saturation of the surface due to carbonates and faster (less negative phase delays) formation of CO_2, suggesting the active role of Co, compared to the 0%Co sample. On the other hand, the comparison of different *k* indices highlights that CO_2 formation is faster at k=1, suggesting the presence of two competing mechanisms: one carbonate-mediated route and one non-carbonate-mediated route. Our study unveils the potential of ME-DRIFTS as a powerful tool to unravel kinetic information from catalytic reactions by shedding light on the reaction mechanism. This study not only widens understanding but also influences future research and application of spectroscopy in the field of heterogeneous catalysis.

$$A_k\left(\phi_k^{psd}\right) = \frac{2}{T}\int_0^T A(t)\sin\left(k\omega t + \phi_k^{psd}\right)dt$$

a)

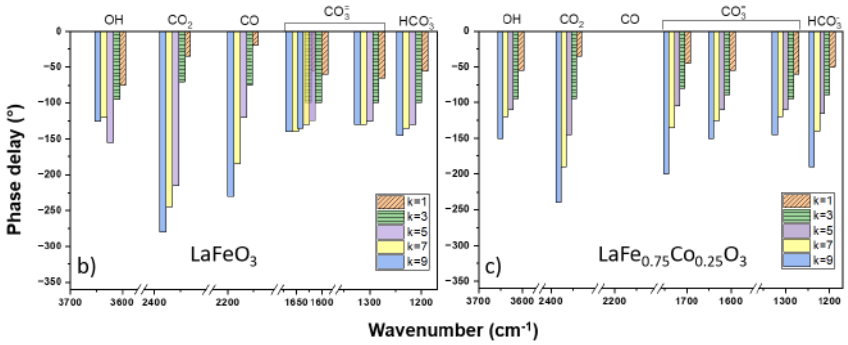

Figure 1: a) MES-PSD equation; b) and c) ME-DRIFTS-PSD comparison of phase delays of 0% and 25% Co-samples, respectively.

References:

[1] A. Urakawa, T. Bürgi, A. Baiker, Chem Eng Sci 2008, 63, 4902–4909.

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Role of the nature, strength, and density of the acid sites in mesostructured aluminosilicate catalysts for CO_2 conversion to dimethyl ether

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Due to the increasing concern regarding global warming, research is currently focusing on green fuels obtained by the reduction of captured CO_2 (e-fuels). One of the most promising e-fuels is dimethyl ether (DME), a replacement for diesel fuel. DME is obtained from CO_2 through two subsequent reactions. The first one, promoted by Cu-based redox catalysts, is the reduction of CO_2 to methanol; the second one, promoted by solid acidic catalysts, is the dehydration of methanol to DME[1,2].

Three different mesostructured aluminosilicates (Al-MCM-41, Al-SBA-16, and Al-SBA-15) and a mesostructured alumina (γ-Al_2O_3) are here proposed as methanol dehydration catalysts to be used in physical mixture with a Cu-based redox catalyst (CZA) for the one-step DME synthesis from CO_2. All the systems were synthesized by different sol-gel approaches. All mesostructured catalysts were characterized with XRD, TEM and nitrogen physisorption to determine their structural, morphological, and textural properties. Some systems were characterized by ^{27}Al- and ^{29}Si-SS-NMR. A particular focus was put on the characterization of the acid sites with NH_3-microcalorimetry and pyridine-FTIR. The catalysts were finally tested for the CO_2-to-DME conversion in a bench-scale plant with a fixed-bed reactor, correlating their performances with their acidic properties. The structural, morphological, and textural characterization evidences a hexagonal (P6mm) mesopore arrangement for all samples with the exception of Al-SBA-16, that shows a cubic (Im3m) arrangement. The characterization of the acid sites indicates that γ-Al_2O_3 only features Lewis sites, while all the aluminosilicates show both Lewis and Brønsted sites; it also points out that Lewis sites are stronger than Brønsted sites. Another important observation is that γ-Al_2O_3 shows the highest surface density of acid sites (number of sites as a function of the surface area); among the three aluminosilicates, the one with higher surface density of sites is Al-SBA-16. The catalytic tests show that Al-SBA-16 is, among all catalysts, the one with the highest dehydration activity, followed by the other aluminosilicates and, last, by γ-Al_2O_3. These results evidence that Brønsted sites are more active towards methanol dehydration than Lewis sites, due to their nature and their moderate strength, and that the proximity of such sites (high surface density) promotes methanol dehydration.

References:

[1] N. Mota, E.M. Ordonez, B. Pawelek, J.L.G. Fierro, R.M. Navarro, Catalysts 2021, 11(4), 411.
[2] E. Catizzone, C. Freda, G. Braccio, F. Frusteri, G. Bonura, Journal of Energy Chemistry 2021, 58, 55 – 57.

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Influence of Halloysite from different deposits on organic molecules degradation

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In this work, a catalytic system was investigated using halloysite nanotubes (HNTs) sourced from different deposits. Halloysite nanotubes find application in different fields including drug delivery, enzyme immobilization, polymer technology, catalysts design, removal of pollutants and cultural heritage.[1] HNTs are characterized by mineral impurities that influence the physical and chemical properties of this material.[2] Despite the possibility of using HNTs as support for catalytic purposes, HNTs could have an intrinsic catalytic activity that alter the final experimental results. The purpose of this research is to highlight this aspect through the degradation of ascorbic acid and the photocatalysis of ibuprofen employing four different types of halloysite, as shown in Figure 1. In particular, we observed a correlation between the presence of impurities in the chemical composition and the efficiency of a catalyst. Specifically, we examined how the presence of zinc and manganese in the composition could influence the degradation.

This investigation opens up new perspectives of research for accurately selecting halloysite over other nanoclays options.

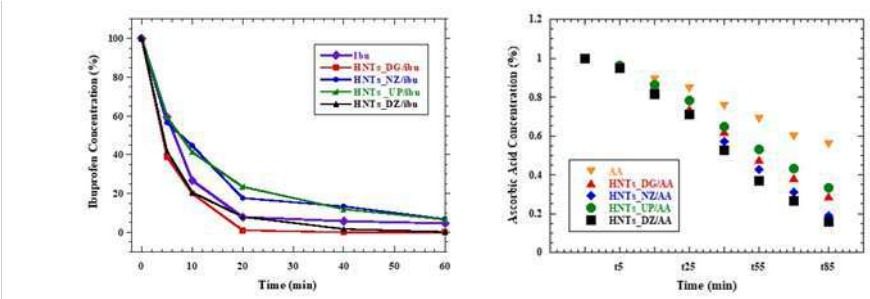

Figure 1: Photodegradation of ibuprofen (on the left), degradation of ascorbic acid (on the right).

References:

(1) Ferrante, F.; Bertini, M.; Ferlito, C.; Lisuzzo, L.; Lazzara, G.; Duca, D. A Computational and Experimental Investigation of Halloysite Silicic Surface Modifications after Alkaline Treatment. *Applied Clay Science* **2023**, *232*, 106813. https://doi.org/10.1016/j.clay.2022.106813.
(2) Cavallaro, G.; Chiappisi, L.; Pasbakhsh, P.; Gradzielski, M.; Lazzara, G. A Structural Comparison of Halloysite Nanotubes of Different Origin by Small-Angle Neutron Scattering (SANS) and Electric Birefringence. *Applied Clay Science* **2018**, *160*, 71–80. https://doi.org/10.1016/j.clay.2017.12.044.

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$BiVO_4$-based Photoanodes for Solar Energy Conversion

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Solar water splitting in a photoelectrochemical (PEC) tandem cell is a leading candidate reaction to convert and store solar energy in high-value chemicals, such as green hydrogen, that could replace fossil sources.[1] Identifying light-absorbing materials that satisfy the requirements of stability and performance is a major challenge, especially when employing them as photoanodes in the demanding water oxidation reaction.

Bismuth vanadate, having a 2.4 eV band gap energy and thus being able to absorb ca. 8% of the solar spectrum, has emerged as a good transition metal semiconductor oxide to be employed as photoanode, though it has intrinsic limitations, i.e., poor charge transport, slow water oxidation kinetics and high rate of surface recombination.

Two main strategies have been pursued to increase the solar energy to fuel conversion efficiency of $BiVO_4$, consisting in either i) coupling it with another suitable semiconductor oxide in a heterojunction, in order to increase the separation of the photoproduced charges, or ii) doping it with higher valent metal ions, with respect to both Bi^{3+} and V^{5+}, such as Mo^{6+}, trying to alleviate its intrinsic poor electron transport properties.

Indeed, significantly higher values of Incident Photon to Current Efficiency (IPCE) have been attained at wavelengths shorter than 500 nm when $BiVO_4$ was coupled with WO_3 in a $WO_3/BiVO_4$ heterojunction, by exploiting the excellent visible light harvesting properties of $BiVO_4$ combined with the superior conductivity of photoexcited electrons, typical of WO_3. Due to the favourable band alignment between the two oxides, photopromoted electrons in $BiVO_4$ are expected to migrate into WO_3 and then rapidly to the external circuit, while photoproduced holes may accumulate in $BiVO_4$. Selected case studies dealing with the performances exhibited under different irradiation configurations by home-made thin coupled electrodes, prepared through variable deposition techniques, will be presented.[2-4] At the same time, the multifaceted role of Mo^{6+} doping onto both bulk and surface properties of $BiVO_4$ will be clarified by means of a unique combination of morphological and PEC analyses.[5-6]

References:

[1] M. Grätzel, Nature 2001, 414, 338.
[2] I. Grigioni, M. Abdellah, A. Corti, M.V. Dozzi, L. Hammarström, E. Selli, J. Am. Chem. Soc. 2018, 140, 14042.
[3] I. Grigioni, M. V. Dozzi, E. Selli, J. Phys. Condens. Matter 2020, 32, 014001.
[4] C. Nomellini, A. Polo, C. A. Mesa, E. Pastor, G. Marra, I. Grigioni, M. V. Dozzi, S. Giménez, E. Selli, ACS Appl. Mater. Interfaces 2023, 15, 52436.
[5] A. Polo, I. Grigioni, M. Magni, A. Facibeni, M.V. Dozzi, E. Selli, Appl. Surf. Sci. 2021, 556, 149759.
[6] A. Polo, M.V. Dozzi, I. Grigioni, C. Lhermitte, N. Plainpan, L. Moretti, G. Cerullo, K. Sivula, E. Selli, Sol. RRL 2022, 6, 2200349.

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Semi-Transparent Perovskite Solar Cells with Dielectric/Metal/Dielectric Electrodes

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Semi-transparent perovskite solar cells (ST-PSCs) are promising devices for applications including building-integrated photovoltaics and multi-junction tandem cells.[1,2] The performances of ST-PSCs are influenced by the electrical and optical characteristics of each cell component. In this context, dielectric/metal/dielectric (D/M/D) multilayers have emerged as one of the current preferred choices for semi-transparent electrodes, achieving an ideal balance between conductivity and transparency.[3,4] This study proposes a novel D/M/D multilayer with nickel as a thin metallic film in between MoO_x dielectric layers as the top anode electrode in ST-PSCs. The MoO_x/Ni/MoO_x multilayers were deposited by thermal evaporation and their optical and electrical properties were characterized by using UV-visible absorption spectroscopy and sheet resistance measurements. Also, the electrodes were studied using depth-profiling X-ray Photoelectron Spectroscopy (XPS) to investigate possible atom migration or interface physicochemical processes. The systems proposed can represent a more economical alternative to the common noble metal layer used as electrodes, thus improving the cost-effectiveness and commercial viability of ST-PSCs.

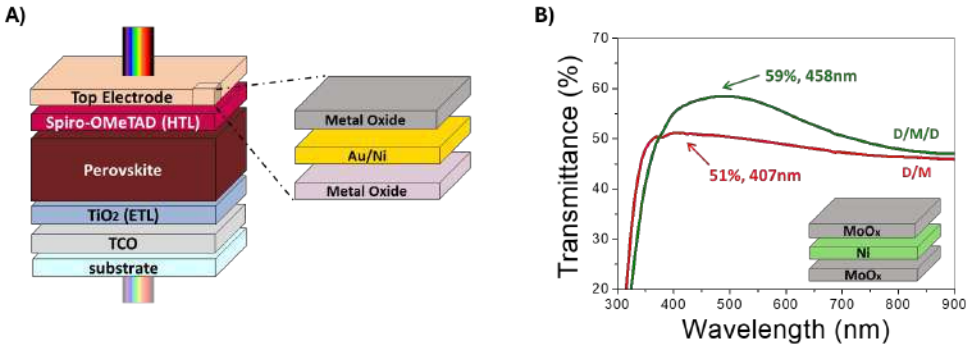

Figure 1: A) scheme of ST-PSC with a semi-transparent D/M/D electrode; B) transmittance changes at 300-900 nm.

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References:

[1] M. Batmunkh, Y. L. Zhong, H. Zhao, Adv. Mater. 2020, 32, 2000631.
[2] T. M. Koh, H. Wang, Y. F. Ng, A. Bruno, S. Mhaisalkar, N. Mathews, Adv. Mater. 2022, 34, 2104661.
[3] S. Kim, J.-L. Lee, J. Photonics Energy 2012, 2, 21215.
[4] G. Giuliano, S. Cataldo, M. Scopelliti, F. Principato, D. Chillura Martino, T. Fiore, B. Pignataro, Adv. Mater. Technol. 2019, 4, 1.

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The C treasure in agrifood wastes for solid state hydrogen storage

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In recent years, exploring sustainable energy sources has led to growing interest in hydrogen (H_2) as an energy carrier; in particular, many studies have been dedicated to H_2 storage, aiming to overcome its application limits [1]. Solid-state systems are considered the safest option to store H_2 and various classes of materials have been thoroughly investigated to assess their gravimetric capacity, distinguishing them according to the sorption mechanism that takes place. By the physical adsorption approach, porous carbon materials are the most suitable candidates because of their lightweight, high surface area, and microporous structure [2].

To enhance cost-effectiveness, activated carbon materials (ACs) derived from various renewable feedstock wastes have gained importance, owing to their abundance and the potential for tailoring their properties through simple chemical processing [3].

Our work is based on activated carbons (ACs) derived from pyrolysis and activation of agrifood wastes, ranging from the most common biomasses as cereals to more local wastes typical of the Lombardy region as asparagus stems and pumpkin peels, aiming to use them as solid-state H_2 storage systems. Biomass residues undergo a two-step synthesis: an initial pyrolysis process at moderate temperatures (450°C-650°C), yielding a carbonaceous material referred to as biochar, followed by a thermochemical activation with KOH leading to alterations in structural morphology, specifically in microporosity development, and giving as final product ACs. Analyses of specific surface area, pore characteristics, and H_2 adsorption/desorption behaviours provide insights into the impact of the thermochemical treatments on the H_2 storage efficiency of the various ACs. The results demonstrated a significant improvement in H_2 storage capacity through activation in all the analysed biochar, going from initial values on pyrolyzed biochar of less than 1 wt% to values of 5 wt% at 77K and 20 bar, substantially higher than the performance of graphitic based materials (up to 3 wt%). The forthcoming comparative analysis of various biochar materials derived from different agricultural wastes enables the identification of the most optimal biochar for enhanced H_2 storage and advancing clean energy technologies.

References:

[1] C. Pistidda, Hydrogen 2021, 2, 428-443
[2] K. Xia, et al. Applied Surface Science 2014, 315, 261-267
[3] N. Bader, et al. J Porous Mater 2018, 25, 221-234.

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Fast microwave-assisted syntheses for layered oxides as positive electrodes in conventional and solid-state batteries

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Even though $LiCrO_2$ and $NaCrO_2$ belong to the same family of O3-type layer oxides and share the same transition metal, they have significantly different electrochemical properties. The latter is one of the most popular active materials as positive electrodes in Na-based all-solid-state batteries, since its working voltage matches fairly well with the stability window of a series of solid electrolytes.[1,2] The former, however, has proven to be electrochemically inactive *vs.* Li. When Li is de-intercalated, the oxidized, relatively small Cr(VI) moves towards tetrahedral sites in the Van der Waals gap. [3] Such a migration is preferred in $LiCrO_2$, in which the O-O distance is shorter, allowing the Cr(VI) to sit in a more stable configuration. To prevent the Cr migration, it could be synthesized a mixed phase possessing both Li and Na as interslabs cations, with the Na increasing the O-O distance (*i.e.* less stable tetrahedral sites for Cr). Nonetheless, the large chemical stability of both $LiCrO_2$ and $NaCrO_2$ hampers the synthesis of such mixed phase following conventional, quasi equilibrium processes. Indeed, the synthesis of both $LiCrO_2$ and $NaCrO_2$ requires 5 hours of heat treatment at 900 °C in an inert atmosphere.[3] Conversely, solid-state microwave-assisted syntheses, provide a high heat transfer rate to the reacting powders, forming metastable phases.[4] This dramatically reduces the reaction time, making these processes more attractive from both economic and environmental point of view. In the present work, $LiCrO_2$ and $NaCrO_2$ have been obtained from fast microwave-assisted reactions, after 120 s of treatment at 500°C, in an open crucible. Moreover, a new mixed $Li_xNa_{1-x}CrO_2$ phase has been successfully synthesized, with different Li/Na ratios. P-XRD highlighted that the quaternary phase crystallizes in the *R*-3*m* space group, as the ternary oxides do, with an intermediate cell parameter along *c*-axis. No peaks owing to a superstructure demonstrate that Li and Na are mixed in each WdV gap and they do not form alternate layers. The formation reaction of $Li_{0.58}$-$Na_{0.42}CrO_2$ has been followed by *in situ* synchrotron P-XRD simulating the fast-heating rate with a tuned hot blower, revealing an intermediate formation of a eutectic between the two carbonates. Galvanostatic cycling tests show that microwave-assisted $NaCrO_2$ has the same electrochemical behaviour in both liquid- and solid-state cells of the same compound obtained via conventional synthesis, while the $Li_xNa_{1-x}CrO_2$ still shows poor to no activity *vs.* Li.

References:

[1] M. Brighi, F. Murgia *et al.* Journal of Power Sources 2018, 404, 7 – 12.
[2] L. Duchêne *et al.* Chemistry Communications 2017, 53, 4195 – 4198.
[2] S.-I. Komaba N. *et al.* Electrochemistry Communications, 2009, 12, 355 – 358.
[2] R.V. Batienkov *et al.* Metallurgist 2022 65 1163 – 1173.

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Metal-organic frameworks as solid state conductor for energy storage

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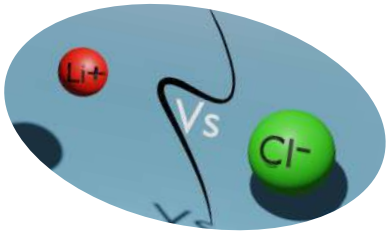
In the last decades in the field of energy storage, many research efforts have been devoted to the development of solid-state electrolytes (SSE), in order to eliminate the flammability issues related to the organic solvents and allow the manufacturing of compact, more durable and with higher energy density secondary batteries.[1]
In this context, we recently explored the development of novel SSE based on metal-organic frameworks (MOFs), to be employed as stand-alone or auxiliary electrolytes, taking advantage of the single-ion conducting features of these materials.
This can be either obtained by anchoring anionic pendants to the MOF structure in a post-synthetic fashion, leaving only the cations (e.g. Li^+, Na^+, Mg^{2+},) free to flow, or by synthetizing MOFs that feature themselves an anionic (or cationic) structure.[2]
An example of the first approach might involve MOF structures modified to conduct further reactions on them (e.g. couplings, click chemistry, condensations). We implemented this idea to develop a composite electrolyte in which a UiO-66 series MOF has been embedded into a polymeric membrane to improve mechanical properties while also participating in the ionic conduction.
The second approach mentioned above involves anionic or cationic MOFs. These structures have counter ions to stabilize the charge. Respectively, anionic MOFs are targeted to develop SSE for conventional batteries, while cationic ones aim to investigate SSE for halide-ion (e.g. F^-, Cl^-) batteries.
The latter are an emerging field in which the lack of solid-state electrolytes for ambient temperature applications is an issue to tackle. In fact, several of the cells developed so far suffer from degradation due to the liquid electrolytes which dissolve the metal halide electrodes.[3]
In this context, a cationic MOF is being studied as anion-conductor to assess the electrochemical properties of the material while changing the anions in the bulk.
In summary, our studies aim to explore the possibility of applying different MOFs as SSE, comparing the two different routes of post-synthetic modification and ion-exchange approach.



References:

[1] L. Fan, S. Wei, S. Li, Q. Li, Y. Lu, Adv. Energy Mater. 2018, 8, 1702657.
[2] R. A. Kharod, J. L. Andrewsm, M. Dincă, Annu. Rev. Mater. Res. 2022, 52, 103–28.
[3] X. Zhao, Z. Zhao-Karger, M. Fichtner, X. Shen, Angew. Chem. Int. Ed. 2020, 59, 5902 – 5949.

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Green consolidants for cultural heritage: physico-chemical aspects of the new materials developed within GREENART

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Cultural Heritage (CH) is a pivotal socioeconomic resource, yet its preservation confronts persistent threats from recurring degradation processes. Conservation methodologies nowadays available lack sustainability and cost-effectiveness, and are typically based on non-environmentally friendly materials. This contribution will report on the main results so-far achieved in the EU-funded project GREen ENdeavor in Art ResToration (GREENART). Coping with the imperatives of EU Green Deal, the project proposes new solutions based on green and sustainable materials and methods, to preserve, conserve and restore CH. Here we will tackle consolidants based on natural polymers from renewable sources, to mechanically strengthen weak artifacts. In the restoration practice, consolidation is typically carried out to re-introduce adhesion and cohesion of color binders with pigments, of surface layers in murals and stone, or of fibers in canvas paintings, textile, collagen-based and cellulose-based substrates. In this context, colloids and soft matter can provide invaluable contributions. For instance, we have recently demonstrated that the consolidation of decohesive pictorial layers can be achieved using amorphous starch nanoparticles (SNPs), which can be obtained by starch dissolution followed by nanoprecipitation in green non-solvents, that allows controlling the physicochemical properties of SNPs, by tuning the local ordering of polymeric chains[1]. In addition to that, we recently proposed the use of dispersions of self-regenerated silk fibroin (SRSF) for the consolidation of fragile silk, alone or in combination with cellulose nanocrystals (CNC). We have studied the response of gels formed by pure SRSF dispersions and by SRSF/CNC mixtures to shed light on the effect of nanocellulose on the physico-chemical behavior of hybrid systems. For instance, our findings show that the addition of CNC alters the gelation kinetics, leads to stronger gels and qualitatively modifies the yielding behavior[2]. Nanocellulose have been also used to strengthen degraded cellulosic fibers, by preparing hybrid systems with calcium hydroxide and calcium carbonate nanoparticles. In particular, we explored the impact of composition on the macro- and nano-scale properties of CNC-based systems through rheological analysis and small-angle X-ray scattering (SAXS), highlighting that the interactions between cellulose nanocrystals are the driving force behind the gelation of the systems[3]. Overall, the GREENART project is re-writing the current landscape of restoration tools by incorporating green metrics into the best state-of-the-art practices. It not only introduces innovative systems but also anticipates the establishment of novel green and sustainable standards in the preservation of CH.

References:

[1] A. Casini et al, ACS AMI 2024, *accepted*.
[2] G. Poggi et al, Coll. Surf. A 2022, 636, 128121-12130.
[3] G. Poggi et al, PCCP 2024, *under revision*.

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A sustainable approach for corrosion protection of concrete heritage

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Nowadays, the corrosion of steel rebars represents one of the main degradation causes in concrete heritage. It is well known that the formation of corrosion products can induce mechanical stress into the concrete structure and those are typically responsible for cracks formation, spalling and detachment of the surface cover.

To preserve concrete monuments that are part of our heritage for their artistic, cultural or social value, it is necessary to develop novel solutions that are more effective than state-of-art materials and that are purposely designed for cultural heritage applications. It means that the conservation treatments should be not invasive and maintain the original aesthetical properties.

In the last decades, the search on new materials for the effective and long-term protection of steel rebars has received increasing interest. It is worth noting that new solutions should be safe for humans and the environment, preserving the surface appearance and ensuring protection from corrosion.

To face these issues, we have developed active protective materials based on stimuli responsive nanocarriers that can release a corrosion inhibitor only in a degrading environment. This approach, previously used for the protection of copper alloys,[1] was optimized for the conservation of concrete monuments within the EU H2020 InnovaConcrete project (G.A. n. 760858). Different corrosion inhibitors for steel rebars were validated in simulated concrete pore solutions and the most promising one was loaded into nanocarriers, as silica and layered double hydroxides, for a tailored release. The results showed that, by selecting an appropriate nanocarrier, it is possible to control the inhibitor release based on external stimuli and time of treatment.[3-4]

Efforts are now addressed to make these protective materials greener and to increase their protective efficacy. Specifically, safe and sustainable corrosion inhibitors have been selected and validated by comparing their protective properties with those of a benchmark. This activity is carried out within the "Smart and eco-sustainable materials for the long-term and safe protection of concrete heritage – ECOforCONCRETE" project (MUR PRIN2022 2022M4KCKP) which is kindly acknowledged for financial support.

References:

[1] M. Salzano de Luna, G.G. Buonocore, C. Giuliani, E. Messina, G. Di Carlo, M. Lavorgna, L. Ambrosio, G.M. Ingo, Angewandte Chemie Int. Ed. 2018, 57(25), 7380-7384.
[2] C. Giuliani, E. Messina, M.P. Staccioli, M. Pascucci, C. Riccucci, L.F. Liotta, G.M. Ingo, G. Di Carlo, Frontiers in Chemistry 2020, 8, 304.
[3] E. Messina, M. Pascucci, C. Riccucci, G.M. Ingo, G. Di Carlo, Molecules 2023, 28, 5863.

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"Twin-Chain" gels with tailored tortuosity and cleaning abilities

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Twin-Chain Networks (TCNs) are a class of hydrogels featuring enhanced cleaning ability on rough, delicate artistic surfaces.[1]

TCNs are obtained by mixing two poly-vinyl alcohols, with higher (H-PVA) and lower (L-PVA) hydrolysis degree.[1] H-PVA/L-PVA aqueous mixtures undergo a spontaneous liquid-liquid phase separation before gelation, that templates the final gel structure. After a freeze-thaw process, sponge-like gels are obtained.

We recently focused on the cleaning mechanism occurring at the gel-artwork interface: a multiplicity of factors influences the cleaning process, making its full understanding extremely complex. Nonetheless, gels cleaning abilities can be related to the networks apparent tortuosity at the nanoscale (i.e. to gels transport properties and the removal of soluble components) and gel surface roughness at the microscale (enabling the embedding of particulate matter)[2,3]. Counterintuitively, highly tortuous gels, i.e. gels in which diffusion is slower, show higher cleaning performances. Tortuosity affects the cleaning fluid residence time at the interface: a higher tortuosity results in longer residence times, improving dirt removal.

In this contribution, TCNs tortuosity was modulated by varying L-PVA molecular weight, degree of hydrolysis and hydrophilicity. As L-PVA acts as porogen during gels cryostructuration, the variation of L-PVA properties affects the polymers phase-behaviour in water, leading to different sponge-like networks (Confocal Microscopy and SEM data). The different pores morphology at the micron-scale affects both gels roughness and transport at the nanoscale: gels are characterized by a different apparent tortuosity, measured through Fluorescence Correlation Spectroscopy (FCS). Nanoscale features (crystallinity and mesh-size, from SAXS) are also affected. In general, gels featuring the largest pores at the micron-scale are the most tortuous and those showing the highest cleaning ability. The systems were tested on both model artistic surfaces and paintings from Pollock, Hélion and Tancredi Parmeggiani (Peggy Guggenheim Collection, Venice).

References:

[1] R. Mastrangelo, D. Chelazzi, G. Poggi, E. Fratini, L. Pensabene Buemi, M.L. Petruzzellis, P. Baglioni, Proceedings of the National Academy of Sciences 2020, 117(13), 7011-7020.
[2] R. Mastrangelo, C. Resta, E. Carretti, E. Fratini, P. Baglioni, ACS Applied Materials & Interfaces 2023, 15(39), 46428-46439.
[3] R. Mastrangelo, D. Chelazzi, P. Baglioni, Nanoscale Horizons 2024, 9, 566-579.

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New Flexible Metal-Organic Frameworks for carbon dioxide capture

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Carbon Capture and Storage (CCS) strategies play a central role in mitigating carbon dioxide (CO_2) emissions. Solid adsorbents for post-combustion carbon capture appear to be a promising solution due to their easier application into existing facilities.[1] Among the materials potentially able to overcome the state-of-the-art technology based on aqueous amines, Metal-Organic Frameworks (MOFs) attract an increasing attention due to the ease in tuning their structure toward a more selective CO_2 binding and a lower energy consumption process. Of special interest are the so-called "phase-change" MOFs that display steep CO_2 uptake when a threshold partial pressure is reached, because they can afford superior separation performance with a reduced energy penalty. In this work, new recently discovered flexible perfluorinated MOFs were synthesized and deeply studied: an ultramicroporous MOF based on Ce(IV) and tetrafluoroterephthalate (F_4BDC),[2] and a MOF based on Al(III) and F_4BDC.[3] The fluorinated linkers were chosen to possibly increase the hydrophobicity of the materials and the affinity towards CO_2.

An advanced multi-technique characterization approach was adopted to unveil the origin of their peculiar CO_2 adsorption mechanism, disclosing phase-change behaviours and breathing effects. To this purpose, we combined gas sorption analysis, in situ infrared spectroscopy, in situ powder X-ray diffraction, multinuclear solid state nuclear magnetic resonance spectroscopy and adsorption microcalorimetry with periodic density functional theory simulations. This fine experimental approach allowed us understanding the "phase-change" behaviour of these MOFs, associated with very specific interactions of the adsorbate with the surface of the sorbent that trigger a structural rearrangement.

References:

[1] A. Samanta et al., Ind. Eng. Chem. Res., 2012, 51, 1438–1463.
[2] R. D'Amato et al, ACS Sustain. Chem. Eng., 2019, 7, 394–402.
[2] D. Morelli Venturi, V. Guiotto et al., Mol. Syst. Des. Eng., 2023, 8, 586–590.
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Extraction and valorization of natural bioactive compounds from agri-food matrices

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Agri-food matrices are known for their excellent nutritional value. They are rich in vitamins, carbohydrates, macro- and trace elements, secondary metabolites, and other bioactive compounds, both in the edible part and in the waste. By virtue of their anti-inflammatory, antioxidant and anti-cancer properties, natural products are increasingly included in food supplements and their use has been suggested for the treatment of various types of diseases. The major class of secondary metabolites is represented by polyphenols, occurring in fruits, cereals, spices, nuts, legumes, tea, coffee, olive oil, and herbaceous plants (e.g., Brassicaceae, Asteraceae)[1].

Thus, numerous studies have been carried out on the extraction of bioactive molecules from natural products for applications in a wide variety of fields. Traditional extraction processes include maceration, pressing, decoction, infusion, percolation and Soxhlet extraction[2]. However, these processes involve the use of huge amounts of organic solvents and/or energy-intensive conditions. In line with the "six principles of green extraction of natural products", efforts are currently directed towards environmentally friendly extraction processes. Examples of green extraction techniques are supercritical fluid or pressurized liquid extraction, microwave, ultrasound, enzyme, or cold plasma assisted techniques, or combined technologies[3].

In this work, we proposed the use of ultrasounds and bio-based surfactants in water-based solvents for the extraction of antioxidant compounds from Zingiberaceae and Brassicaceae derivatives. First, the effects of solvent composition, temperature, time, and ultrasound power on the extraction process have been investigated. Thus, obtained extracts were characterized in terms of antioxidant activity and biological properties. However, extracted compounds often show limited bioactive efficacy due to their poor absorption and low bioavailability. To improve their efficacy, hydrophobic and hydrophilic natural compound models were encapsulated in colloidal delivery systems and their activity was further investigated.

This study was carried out within the project AGRITECH National Research Centre for Agricultural Technologies – Spoke 8 and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1032 17/06/2022, CN00000022). This abstract reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

References:

[1] N. Sreenivasulu, A. R Fernie, Current Opinion in Biotechnology, 2022, 74, 164-170.
[2] F. Chemat, M.A. Vian, G. Cravotto, International Journal of Molecular Sciences. 2012; 13(7), 8615-8627.
[3] C. Picot-Allain, M. F. Mahomoodally, G. Ak, G. Zengin, Current Opinion in Food Science, 2021, 40, 144-156.

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Hybrid swellable silicas as adsorbent for the removal of organic dyes from water media

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Organic dyes are a class of compounds largely used for industrial applications, but they can have adverse effects for the environment and humans; for this reason, there is the needing to find convenient processes to remove these compounds from wastewaters. Due to its efficiency, low cost and versatility, adsorption on porous materials is considered a valuable solution for the decontamination of water from organic dyes[1]. Nevertheless, commercial adsorbents (i.e. carbons, clays) lack of affinity towards certain dyes or are characterised by low removal efficiency and/or are difficult to be regenerated and then reused. For these reasons, the research work devoted to the study of new and more performant solids deserved increasing interest[2].

Swellable Organically Modified Silicas (SOMS) are a class of hybrid silicas with peculiar adsorption properties for PFAS[3] and VOCs[4] species. SOMS are hybrid materials formed by polycondensation of a bis-silane that contains an aromatic ring linked to an ethyl group as binding unit between Si atoms. These materials possess the peculiar ability to swell when in contact with organic solvents thus resulting in an improvement of SOMS adsorption capacity[4].

In this work, SOMS silicas have been prepared by an optimised sol-gel approach and characterized from the physico-chemical point of view through a multi-technique approach. SOMS possess an irregular shape and distribution of particle dimensions, with a surface area of ca. 420 m^2/g and an irregular distribution of pores dimensions. SOMS have been functionalised using a quaternary amino group, thus conferring a positive surface charge to the material (QA-SOMS).

The adsorption performances have been tested against different dye molecules (i.e. Rhodamine B, Methyl Orange, Crystal Violet). In particular, the kinetics, and effect of pH have been studied. The materials can be regenerated with a simple sonication in ethanol and reused for 6 adsorption cycles, showing no losses in adsorption performances, which remain very rapid and high in terms of quantity removed for every cycle. Finally, mixtures of dyes have been also tested for the first time.

References:

[1] J. Guo, et al., Separation and Purification Tech., 2024, Vol. 330 Part C, 125480.
[2] W. Xiang, et al., Separation and Purification Tech., 2024, Vol. 330 Part A, 125268.
[3] V. Miglio, et al., J. Phys. Chem. C, 2024, Vol. 128, 5, 2179-2189.
[4] P. L. Edmiston, et al., Ind. Eng. Chem. Res., 2016, Vol. 55, 12068−12079.

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FIS-OR-028

Mechanistic insights into C mineralization over Si-based materials driven by mechanical energy

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Among CCUS, Carbon Capture Utilisation and Storage, strategies, the C mineralisation represents a potentially versatile and downhill pathway for achieving safe and efficient reduction of CO_2 levels in the atmosphere.[1] In particular, the utilisation of poor or waste materials as substrates and the implementation of sustainable activation routes for those processes, may represent the key for unravelling the potential of C mineralization for large scale applications. Along this line, the use of various Si-based materials, arising from largely available minerals or from scraps of established industrial processes, as well as the exploitation of mechanical energy for triggering the process, fulfil the above-mentioned requirements. This latter is worth of interest since it can be, at least partially, recovered from the industrial process itself. In this framework our attention has been addressed to set up efficient mechanochemical pathways for CO_2 valorisation over different Si-based systems, including olivine, basalt, black steel slags and granites, continuously feeding moist CO_2 into the reactor, so mimicking industrial processes.[2] Elevated CO_2 conversion values with fast reaction kinetics characterise those processes, although ruled by complex mechanisms, including specific features typical of mechanochemically activated processes and gas-solid interactions. In this work our efforts are addressed to tentatively shed light on mechanistic inferences of such processes: to this, ex situ structural investigation through X Ray Diffraction and semi-quantitative phases analyses by Rietveld were paralleled by fitting the kinetics profiles of CO_2 conversion according to different reaction path models. Survey results suggest that mineral carbonation, and eventual CO_2 reduction to hydrocarbons, occur through a multi-step process with specific features depending on the chemical characteristics of the solid substrates and on the adopted mechanochemical experimental conditions.

References:

[1] S.Chen et al. Renewable and Sustainable Energy Reviews 2022, 167, 112537 – 112554.
[2] Università degli Studi di Sassari, Process for the conversion of carbon dioxide into value-added products by means of a process of mechanochemical activation of industrial processing scraps, MD Simula, A Taras, L Pinna, S Piu, S Enzo, S Garroni, G Mulas, WO2023199254A9 WIPO (PCT) Appl: 15/4/2023.

FIS-OR-030

Geographical origin characterization of agrifood products from olive oil and wine production chains via ^{1}H NMR and fluorescence spectroscopy combined with multivariate analysis

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Geographic origin assessment of food products involved in olive oil and wine production plays a crucial role in protecting the top-quality standards of these traditional excellences and in raising consumers and stakeholders awareness of product authenticity. Moreover, it represents an open challenge in the framework of the EU and international regulations, that require a precise labelling for products traceability.[1] In this work a set of extra virgin olive oils and *Sangiovese* monovarietal wines from the 2022 harvest in the Tuscany area, along with their corresponding vegetable matrices (*i.e.* drupes, grapes and plant leaves), were analyzed via ^{1}H NMR and Excitation-Emission Matrix (EEM) fluorescence spectroscopy. The spectral features were processed using different chemometric methods: Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Partial Least Squares Discriminant Analysis (PLS-DA) for NMR data, and Parallel Factor Analysis (PARAFAC) for EEM maps.[2] The results show that the two combined spectroscopic-chemometrics approaches provide a sub-regional classification of the oil and wine samples according to their geographic origin. The performance of the classification procedure is confirmed by the results obtained for the drupes, grapes and leaves samples. In addition, a novel multi-block analysis strategy integrating the data from NMR and fluorescence spectroscopy is proposed.

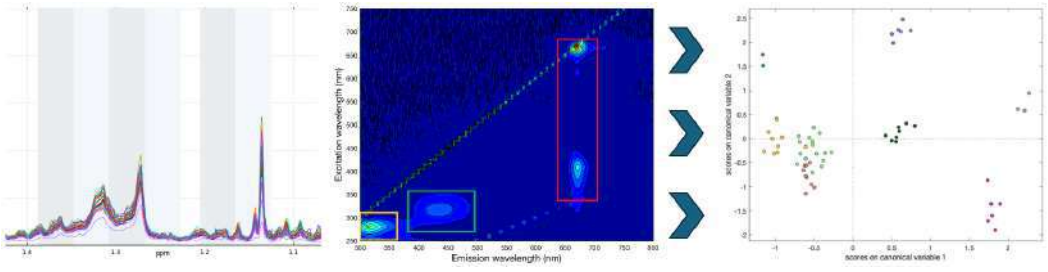

Figure 1: Scheme of combined spectroscopic-chemometric approaches for geographic origin discrimination.

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References:

[1] F. Calò, C.R. Girelli, S.C. Wang, F.P. Fanizzi, Foods 2022, 11, 113 – 149.
[2] A. Biancolillo, F. Marini, C. Ruckebusch, R. Vitale, Applied Sciences 2020, 10, 6544 – 6578.

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FIS-OR-031

Soft composites based on liquid crystalline elastomers: chemical-physical and shape-memory properties of 3D reprogrammable systems

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Liquid crystalline elastomers are well known smart materials with interesting actuation properties. In the recent years, these partially ordered materials were used to prepare soft-soft composites called 'Polymer Dispersed Liquid Crystalline Elastomers' (PDLCEs).[1] 3D shape reprogrammable objects (see **Figure 1**) showing highly reproducible actuation properties and different geometries[2] have been prepared based on PDLCEs made of main-chain liquid crystalline elastomers.[3]

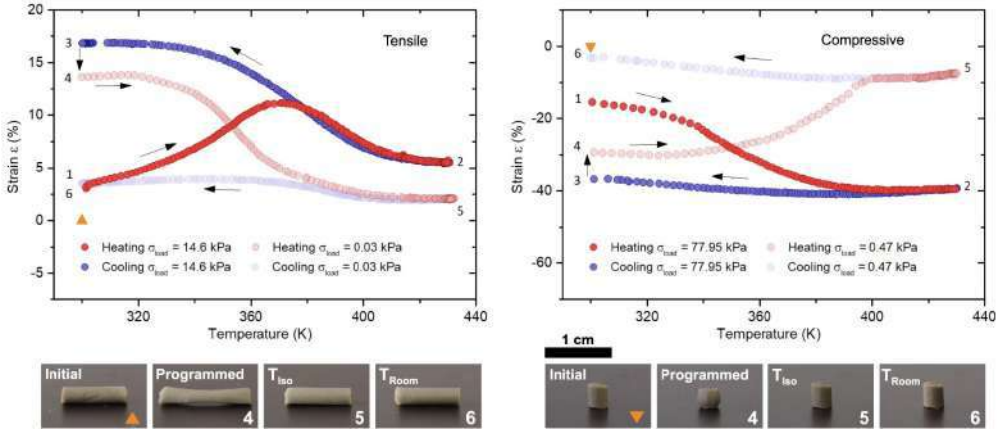

Figure 1: Tensile (left) and (compressive) strain behaviour versus temperature of PDLCEs during actuation and reprogrammed shape steps are shown.

Several key parameters concerning the preparation of PDLCEs aimed to tune several chemical-physical and physical properties, such as the mesomorphic behaviour, the thermo-mechanical and thermo-elastic response, were object of investigation and the main results will be presented and discussed.

References:

[1] A. Rešetič, J. Milavec, B. Zupancic, V. Domenici, B. Zalar Nature Communications, 2016, 7, 13140.
[2] M. Bobnar, N. Derets, S. Umerova, V. Domenici, N. Novak, M. Lavrič, G. Cordoyiannis, B. Zalar, A. Rešetič Nature Communications, 2023, 14, 764.
[3] N. Derets, V. Domenici, A. Resetic, B. Zalar. Mater. Res. Express 2024, 11, 025701.

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FIS-OR-032

Tailoring Magnetic Properties in Superexchange-Coupled Nanocomposites: Insights from Monte Carlo Simulations and Spark Plasma Sintering

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Permanent magnets (PM) play a pivotal role in energy-related applications[1], and the quest for sustainable materials has refocused attention on ferrites, with $SrFe_{12}O_{19}$ (SFO) standing out. This study explores synthetic strategies, including cation substitution and superexchange-coupling of magnetic phases, to enhance ferrite magnetic properties[2]. Employing a scalable bottom-up sol-gel self-combustion process, we designed superexchange-coupled nanocomposites ($SrFe_{12-x}Al_xO_{19}/CoFe_{2-y}Al_yO_4$ 90/10 wt%).

Monte Carlo simulations unveiled insights into the magnetic behavior, aligning with experimental findings. Structural analysis, including synchrotron X-ray powder diffraction and electron microscopy, highlighted controlled size, morphology, and composition of the nanocomposites. This integrated approach showcased the success of the sol-gel process in tailoring properties. Spark plasma sintering (SPS) was employed to fabricate highly dense bulk magnets (SPS_NC and SPS_NC_SM). The SPS process, known for its efficiency[3], demonstrated the preservation of desired properties and improved alignment. Hysteresis loops, studied for randomly and parallel-oriented anisotropy axes, unravelled the intricate interplay of factors influencing magnetic properties. Importantly, the interface differences in NC and NC_SM nanocomposites were explored, shedding light on their unique characteristics. Calculations of $(BH)_{max}$, the energy product, were conducted, further emphasizing the tailored magnetic properties achieved in this study. The exploration of interface variations, alongside the calculated $(BH)_{max}$ values, provides comprehensive insights into the design, synthesis, and processing of advanced permanent magnets, offering potential for sustainable energy applications.

References:

[1] J. Cui, M. Kramer, L. Zhou, F. Liu, A. Gabay, G. Hadjipanayis, B. Balasubramanian, and D. Sellmyer, *Acta Mater.*,2018, **158**, 118

[2] P. Maltoni, G. Barucca, B. Rutkowski, M. C. Spadaro, P. E. Jönsson, G. Varvaro, N. Yaacoub, J. A. De Toro, D. Peddis, R. Mathieu *Small*, 2024, **20**, 2304152

[3] M. Saura-Múzquiz, C. Granados-Miralles, H. L. Andersen, M. Stingaciu, M. Avdeev, and M. Christensen, *ACS Appl. Nano Mater.*, 2018, **1**, 6938

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FIS-OR-033

Optimization of F-ZnO NPs as a transducer for an optical biosensor

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Bacterial infections cause numerous risks to human health. Gram (-) is a major source of infection, due to the inside of their outer membrane of endotoxins, such as lipopolysaccharides (LPS) [1]. For this reason, it is important to develop a biosensor that can specifically detect and quantify Gram (-) pathogens [2]. Biosensors combine a biological recognition mechanism with physical transduction, leading to selective and sensitive recognition of analytes. The aim of this project is to develop a biosensor by optimizing the matrix, consisting of F-doped zinc oxide nanoparticles (F-ZnO NPs) [3,4], and choosing the appropriate biomolecule (the aptamer LA-27). In this way, the aptamer labeled with a fluorescence probe (i.e., FAM or ROX) should act as the energy donor and the NPs as the energy acceptor, analyzing the optical response of the aptasensor will be able to detect the presence of LPS and their quantification. Therefore, we have synthesized and characterized F-ZnO at different F-concentration NPs in solution to choose the best sample, in terms of size, morphology, and optical properties, to create the matrix. On the NPs matrix surface was linked an LPS sensible aptamer for the detection and quantification of LPS of Gram (-) pathogens. Here the development of the system and the preliminary results will be discussed.

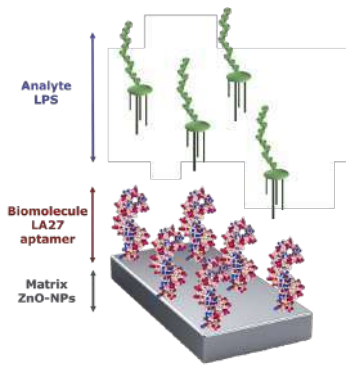

Figure 1: Schematic representation of the aptasensor.

References:
[1] G. Ramachandran, Virulence 2014, 5, 213 – 218. [2] X. Guo, F. Wen, N. Zheng, M. Saive, M-L Fauconnier, J. Wang, Front. Chem. 2020, 8.[3] G. P. Papari, B. Silvestri, G. Vitiello, L. De Stefano, I. Rea, G. Luciani, A. Aronne, A. Andreone, J. Phys. Chem. C 2017, 121, 16012-16020. [4] C. Feng, S. Dai, L. Wang, Biosens Bioelectron 2014, 59, 64-74.

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FIS-OR-034

Guiding the packing, morphology and optical properties of metal-organic frameworks

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Concurrent control over packing, morphology and spectroscopic response of crystals is desirable for designing materials with targeted functionalities. Yet, achieving such combination of properties via direct synthetic approaches is extremely challenging.

We show that an initial metal–organic framework (Mn-AdDB) can be used as crystallographic and morphological template to generate a series of isomorphic and isostructural crystals having different bivalent metal ions of the first row of the transition elements (Fe, Co, Ni, Cu or Zn) by post-synthetic metal cation exchange.[1-3] The crystal-to-crystal conversion has been shown to be quantitative both at the single-crystal and ensemble level. We detail on the mechanistic aspects of the exchange process, and demonstrate how the metal cation controls the optical (absorption, fluorescence, cathodoluminescence) and magnetic properties. Our work is an intriguing example of crystal engineering spanning different hierarchical orders, from molecular packing, composition to morphology and properties thereof.

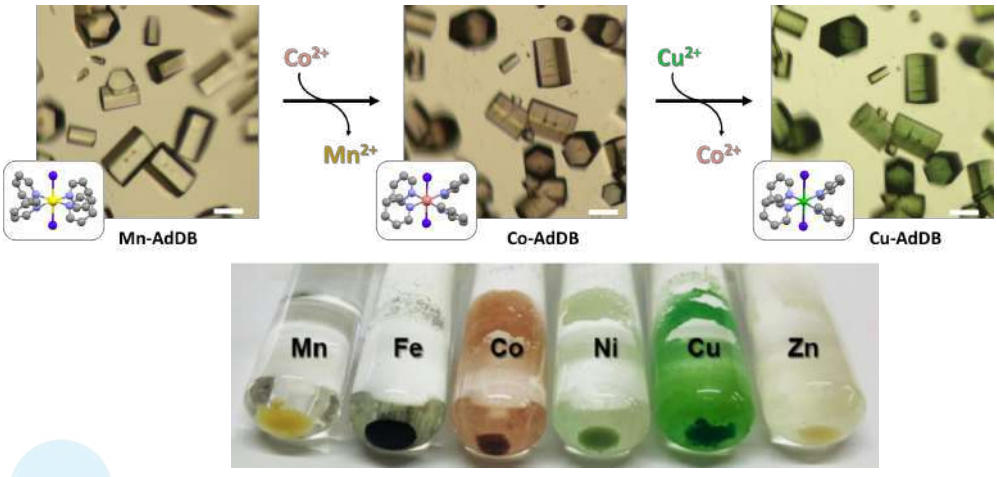

Figure 1: Optical microscopy images demonstrating the consecutive metal cation exchange. Bulk appearance of the sample before (tube Mn) and after metal cation exchange (from tubes Fe to Zn)

References:

[1] H. Nasi, M. C. di Gregorio, Q. Wen et al. Angew. Chem. Int. Ed. 2022, 61, e202205238
[2] M. C. di Gregorio, L. J. W. Shimon, V. Brumfeld et al. Nat. Commun. 2020,11, 380
[3] M. C. di Gregorio, V. Singh, L. J. W. Shimon et al. J. Am. Chem. Soc., 2022,144, 22838–22843

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FIS-OR-035

Strontium Aluminate Phosphors: a photochemical and environmental journey insight the most famous persistent luminescent materials

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Thanks to the capability to produce light for seconds or even minutes after the excitation ceases, in recent times persistent luminescence (PersL) materials have become very popular with their application that spreads from civil uses (decoration, safety displays) to scientific application fields (energy and environmental engineering, biomedicine)[1,2]. The stunning properties of persistent luminescence materials mainly come from the emitter and the trap centers. While the emitter emit radiation after excitation, the trap centers, formed due to impurities or various co-dopants, store the excitation energy for some time and then gradually release it to the emitters by thermal or other physical activation. Their incredible success started from the 1996 breakthrough discovery of $SrAl_2O_4:Eu^{2+},Dy^{3+}$ by Mitsuzawa et al., which showed extremely bright and long phosphorescence. In this work, the strontium aluminate phosphor is synthesized by combustion method[4]. Then, different rare-earth (Tb^{3+}, Yb^{3+},Er^{3+}) or transition metals (Co^{3+}) elements are introduced as co-dopants to investigate the effect on the emission intensity and persistent luminescence time. Emission spectra, excitation spectra, PL Quantum Yield and persistent luminescence decay measurements will be recorded.

Figure 1: Persistent luminescence of $SrAl_2O_4:Eu^{2+},Dy^{3+}$ collected 1,10,20,30,40 and 50s (from left to right) after excitation at 390 nm. The excitation time was 30 s.

After having found the right balance between persistent luminescence time, emission intensity and PLQY, the sample with the optimized co-dopant will be dispersed into different polymer matrices (PMMA, PVA, PVP…) and later tested as possible indoor and outdoor environmental solutions thanks to a climatic chamber.

References:

[1] C.Chiatti, C.Fabiani, R.Bondi, G.Zampini, L.Latterini, A.L. Pisello, Energy 2023, 275, 127333
[2] C.Fabiani, M.Gambucci, C.Chiatti, G.Zampini, L.Latterini, A.L. Pisello, Applied Energy 2022,324
[3] T. Matsuzawa, Y. Aoki, N. Takeuchi, Y. Murayama, J. Electrochem. Soc. 1996,143(8), 2670–2673
[4] P.Gao, J.Wang, J.Wu, Q.Xu, L.Yang, Q.Liu,Y. Qi and Zhenjun Li, Coatings 2023, 13, 808,119687

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FIS-OR-036

Investigation of the CO_2 interaction with a polymeric membrane containing triptycene groups using Solid-State NMR spectroscopy

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Membrane-based gas separation technology has attracted considerable interest as an energy-efficient alternative to most common techniques. Swager et al. introduced the concept of including rigid molecular structures in polymers, leading to materials with intrinsic microporosity and high gas separation performances [1,2,3,4]. In this scenario, triptycene groups are rigid three-dimensional structures generating free volume and preventing the efficient packing of molecular chains [5]. In this work, we present a Solid-State NMR (SSNMR) study of a triptycene-containing fluorinated aryl ether (FLARE) polymer [1].

A polymer film prepared starting from a high molecular weight polymer was studied both before and after adsorption of $^{13}CO_2$. Indeed, SSNMR can provide information about host@guest interactions exploiting many different nuclear properties combined with the possibility to probe different nuclei [6].

The dynamics of the host was here investigated by measuring ^{1}H and ^{19}F spin-lattice relaxation times (T_1) and utilizing ^{19}F-^{13}C and ^{1}H-^{13}C DIPolar chemical SHIFT correlation experiments (DIPSHIFT).

CO_2 dynamics of the $^{13}CO_2$-loaded sample was studied by recording variable temperature ^{13}C Direct Excitation (DE) spectra both in static and high-resolution (*i.e.*, under Magic Angle Spinning (MAS)) conditions. A deeper understanding of CO_2 motions inside the porous structure of the membrane was also gained through the analysis of ^{19}F-^{13}C and ^{1}H-^{13}C Cross-Polarization/MAS (CP/MAS) spectra and ^{13}C spin-lattice relaxation times (T_1) of $^{13}CO_2$.

References:

[1] T. Long, T. Swager, Journal of the American Chemical Society 2003, 125, 14113-14119.
[2] J. Yang, T. Swager, Journal of the American Chemical Society 1998, 120, 5321-5322.
[3] J.R. Weidman, S. Luo, J.M. Breier, P. Buckley, P. Gao, R. Guo, Polymer 2017, 126, 314-323
[4] B. Comesaña-Gándara, J. Chen, C.G. Bezzu, M. Carta, I. Rose, M.C. Ferrari, E. Esposito, A. Fuoco, J. C. Jansen, N.B. McKeown, Energy and Environmental Science 2019, 12 (9), 2733-2740
[5] T. Swager, Accounts of Chemical Research 2008, 41, 1181-1189
[6] A. Sutrisno, Y. Huang, Solid State Nuclear Magnetic Resonance 2013, 49-50, 1-11

FIS-OR-037

Temporal Progression of Glycation in Collagen Type 1 Bovine Pericardium BioTissues

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Small Angle X-ray Scattering (SAXS), when coupled with Wide X-ray Angle scattering (WAXS), offers a comprehensive understanding of a material's structure, ranging from supra-molecular (SAXS) to sub-molecular scales (WAXS)[1]. Here, we utilize SAXS/WAXS scanning microscopies to investigate the glycation process of type 1 collagen in bio-tissues derived from bovine pericardium, following incubation in glucose and ribose[2]. By identifying arginine and lysine/hydroxylysine amino acids as primary glycation sites and assuming that the topological polar surface area of sugar molecules influences glycation rates, we modelled glycation over time. This modelling allowed us to determine glycation rates, track the progression of glycation, and observe resulting volume increases. Research was supported by the PRIN2017 project entitled "A system approach for identifying connective tissue degeneration in diabetic analogues (SAPIENT)".

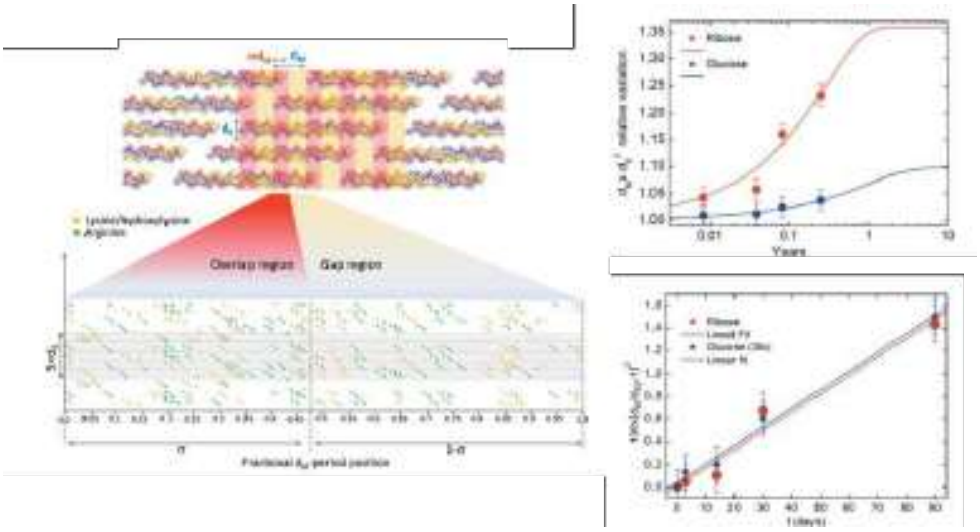

Figure 1: Top Left: Schematic rappresentation of the staggered repetition unit of the triple-helix collagen structure alternating σdM-wide overlapping regions and (1-σ)dM-wide gap regions. Bottom Left: linearized projection of the 3D triple-helix collagen residues, with the lysine/hydroxylysine (orange bullets) and arginine (green bullets) amino acid positions shown as a function of the fractional d_M-period coordinate. Top Right: Time variation of the volume occupied by glycated collagen with respect to the native molecule for a sugar concentration of 40 mg/ml. Bottom Right: measure for the variation of the equatorial in-plane areal density of collagen molecules as a function of the incubation time. Note that the glucose data have been multiplied by a constant factor of 38.

References:

[1] Watching nanomaterials with X-Ray eyes: probing different length scales by combining scattering with spectroscopy, C. Giannini, V. Holy , L. De Caro, L. Mino & C. Lamberti, PROG. MAT. SC. 112 – 100667 (2020)

[2] Time scale of glycation in collagen in bovine pericardium derived bio-tissues, L. De Caro, A. Terzi, L. Fusaro, D. Altamura, F. Boccafoschi, O. Bunk & C. Giannini, IUCRJ 8(6), 1024-1034 (2021)

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FIS-OR-038

Spectroscopy and microscopy methods to unravel the interactions between protein and 2D nanostructured materials.

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Phosphorene and graphene with their derivatives are novel supports that present a dimension in the nanoscale, and have attracted the attention of the scientific community in the last years owing to their unique physicochemical, optical, mechanical, thermal and conductive properties.[1] Two-dimensional sheets have been employed for the physical and chemical adsorption of molecules in a diverse range of applications such as drug delivery, catalysis, composites for electronics, nanophotonics and optoelectronics fields, sensors and energy related systems and their combination have been used for the preparation of gels.[2] But, to exploit these promising materials, it is critical to understand the molecular mechanisms that govern the adsorption of molecules onto its surface. To reach the goal, in this work,[4] many spectroscopic and microscopic methods have been utilized going to investigate the effects on proteins conformation after the interaction between Lysozyme and the 2D-nanomaterials, i.e. phosphorene, graphene and graphene oxide at different molar ratio and environmental conditions. In particular, UV-Vis absorption, reflectance and emission spectroscopy have proven to be fast, non-invasive and sensitive tools that represent a molecular fingerprint enclosing chemical, structural and conformational information on the biomolecules in contact with the nanosurface.[3] We have followed the changes of the profiles band of Amide I and Amide II signals through IR measurements to monitor the protein adsorption and denaturation processes. The size and the surface charge of the binary systems have been determined by Dynamic Light Scattering and Z-Potential measurements. Images of the different nanocomposites have been obtained through Transmission Electron and Confocal Microscopy to detect the modification of the protein structures after the absorption and the gelling processes. Through Raman spectra, we have evaluated the interactions at the interfaces, monitoring the conformation changes of Lysozyme.

The work represents a starting point for the development of controlled interfaces materials with different chemical-physical properties respect to the native proteins.

References:

[1] W. Zhang, T. Huynh, P. Xiu, B. Zhou, C. Ye, B. Luan, R. Zhou, Carbon, 2015, 94, 895-902.
[2] S. Mondal, R. Thirupathi, L. P. Rao, H. S. Atreya, RSC advances, 2016, 6(58), 52539-52548.
[3] A. Giugliarelli, L. Tarpani, L. Latterini, A. Morresi, M. Paolantoni, P. Sassi, J. Phys. Chem. B, 2015, 13009-13017.
[4] S. Rinaldi, A. M. Grigoras, M. Caporali, M. Serrano Ruiz, M. Peruzzini, A. Ienco, L. Latterini, SUBMITTED

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SERS Nanostructures with *ad hoc* designed oligopeptides targeting the programmed death ligand 1 (PD-L1) for applications in cancer therapy.

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The discovery of immune checkpoint inhibitors made a huge contribution to the research for cancer treatments. Particularly, programmed death ligand-1 (PD-L1) is a protein placed on the surface of some (regulatory) cells that, by binding to the PD-1, an immune checkpoint receptor expressed on the surface of killer T-cells, forms the PD-1/PD-L1 complex, which suppresses the immune response. The over-expression of PD-L1 is exploited by tumor cells as a strategy to escape the immune system. To inhibit this interaction, small molecules, such as peptide therapeutics, have been developed. Peptides have, particularly, numerous advantages such as low toxicity, absence of immunogenicity, high fidelity of synthesis, and low manufacturing costs. Moreover, to improve targeting affinity for the ligand and to avoid the degradation of the peptides due to enzymes present in a biological environment, peptides can be linked to AuNP plasmonic nanostructures (AuNP-NS), which are inert in a biological environment[1]. By addition of reporters, AuNP-NS also show strong surface-enhanced Raman scattering (SERS) signals, which are narrow and very intense signals, which represent a novel approach for imaging and diagnosis.[2]

In this work, a new generation of oligopeptides (Table 1) showing a high affinity for the PD-L1 region which interacts with PD-1, will be presented. They have been designed through Molecular dynamics (MD) simulation, synthesized, and bonded to the AuNS, through the S-Au covalent bond. The prepared nanostructures were incubated, at several concentrations, with tumoral cells which overexpress PD-L1. SERS measurements quantified the great affinity of the oligopeptides for PD-L1. MD simulations of NPs functionalized with peptides, interacting with PDL1, allow to explain, at molecular level, the different activity of the peptides under study.

Compound	Sequence
MG16A	Ace-C-KKKGG-**IQIREGILYNTHWVLH**-NH_2
MG16PEG	HS-PEG3000-KKKGG-**IQIREGILYNTHWVLH**-NH_2
MG16C	Ace-**IQIREGILYNTHWVLH**-O_2Oc-C-NH_2
sMG16C	Ace-**HLYEIVQHIGNLRWTI**-O_2Oc-C-NH_2

Table 1: Sequences of oligopeptides with modifications on the region of linking to the Au nanoparticles

[1] C. Mazzuca, *et al.*, Nanoscale Adv., 2019, 1, 1970–1979.
[2] M. Gobbo, *et al.,* Nanoscale, 2024, 16, 5206–5214.

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Unfolding and refolding of Albumin induced by a time-programmable dissipative pH-jump

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Simple reagents can be employed to control the pH of a water solution as a function of time, generating dissipative pH jumps whose amplitude and duration can be tuned. This represents a strategy to control pH-dependent properties as a function of time without additional intervention. Nitroacetic acid (NAA), an activated carboxylic acid able to undergo base catalysed decarboxylation, can be used as a chemical fuel to achieve pH_{high} - pHl_{ow} - pH_{high} sequences, exploited to drive the operation of host-guest systems and DNA based molecular devices.[1,2] We show how this strategy works to induce and monitor with fluorescence and synchrotron small-angle X-ray scattering (SAXS) the pH-dependent conformational variations of Human Serum Albumin (HSA), in a complementary way to the time-dependent acidification obtained by slow hydrolysis of glucono-d-lactone.[3,4] Starting from the protein in its native form, we employed NAA to achieve a fast acidification of the solution with consequent denaturation of the protein, followed by a time-tunable slow raising of the pH without additional intervention, which enables a full protein refolding. This method allows a whole conformational cycle (from native form to acid partially unfolded forms, and then to native again) and a verification of the extent and reversibility of the protein structural transition in different conditions. It could be applied to formulate pH-dependent drug encapsulation and release protocols using albumin as a safe and versatile macromolecular carrier.

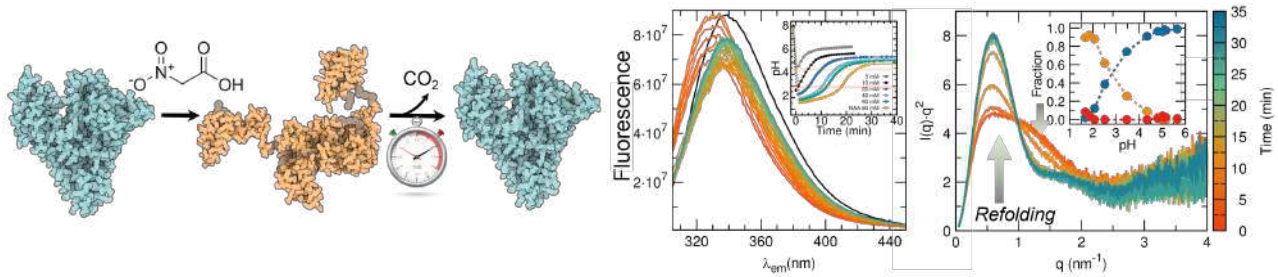

Figure 1: Pictorial view of an unfolding-refolding experiment triggered by NAA decarboxylation. Intrinsic fluorescence of HSA and SAXS data in the form of Kratky plot show time-dependent refolding to native state.

References:

[1] D. Del Giudice, E.Spatola, M.Valentini, C.Bombelli, G. Ercolani, S. Di Stefano, Chem. Sci. 2021, 12, 7460-7466.
[2] D. Del Giudice, S. Di Stefano, Acc. Chem. Res. 2023, 56(7), 889–899.
[3] A. Del Giudice, C. Dicko, L. Galantini, N. V. Pavel, J. Phys. Chem. B 2017, 121(17), 4388–4399.
[4] A. Del Giudice, L. Galantini, C. Dicko, N. V. Pavel, Colloids Surfaces B Biointerfaces 2018, 168, 109–116.

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High-throughput screening and optimization of microfluidic-synthetized lipid-based nanocarriers

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In the past decade lipid-based nanocarriers have gained increasing popularity as the emergent technology for drug delivery, owing to the capability to protect the bioactive cargo and improve intracellular transport and release[1]. Since their approval for clinical usage both as vectors for anticancer drugs and gene therapy, several lipid nanocarrier formulations were investigated to obtain optimal physicochemical properties and enhanced therapeutic efficacy. Among the factors influencing structure, stability and intracellular uptake, the choice of lipid components plays a major role[2].

Generally, the main constituents are helper/structural lipids (i.e. phospholipids and cholesterol), that provide stability and membrane fusogenicity. Then, either ionizable lipids for lipid nanoparticles (LNPs) or solid lipids for solid LNPs (SLNs) respectively, are employed to improve cargo encapsulation and protection from leakage. Finally, surfactant or polyethylene glycol-lipids coatings are used to enhance *in vivo* circulation time. Thus, careful manipulation of composition and relative abundance results in dramatic modification of physicochemical properties and functionality. Microfluidic-assisted preparation of lipid-based nanocarriers allows to obtain monodisperse and stable formulations with high reproducibility, boosting screening and optimization potential for rapid clinical translation.[3]

In this work, high-throughput screening and optimization of three types of lipid nanocarriers, i.e. LNPs, SLNs and transethosomes as candidates for drug delivery is proposed. Microfluidic synthesis allowed to screen a large set of lipid components, surface coatings and relative compositions following an experimental design approach. Supramolecular characterization by means of Dynamic Light Scattering, Zeta potential, Small Angle X-ray Scattering, Nuclear Magnetic Resonance, and quantification of encapsulation efficiency of model drugs by High Performance Liquid Chromatography allowed to select the optimal carrier candidates.

References:

[1] JA Kulkarni, PR Cullis, R. van der Meel Nucleic Acid Ther. 2018,28,146-157.
[2] C Hald Albertsen, JA Kulkarni, D Witzigmann, M Lind, K Petersson, JB Simonsen. Adv Drug Deliv Rev. 2022,188,114416.
[3] E Kastner, R Kaur, D Lowry, B Moghaddam, A Wilkinson, Y. Perrie Int J Pharm. 2014, 477,361-8.

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Effect of proteins and stabilizing agents on the formation and stability of colloidal hybrid calciprotein-like particles

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Calciprotein particles (CPPs) consist of hybrid protein-mineral nanoparticles made of calcium phosphate stabilized by a glycoprotein called Fetuin-A (Fet-A). CPPs circulate in serum and contribute to maintain calcium and phosphate homeostasis and prevent the formation of unwanted calcium phosphate deposits in soft tissues[1]. In pathological situations, the initially formed amorphous spherical nanoparticles (CPPI) may mature into crystalline hydroxyapatite (CPPII), eventually resulting in ectopic calcifications. In this context, the role of albumin is also important, given the abundance of this protein in serum and its ability to complex Ca^{2+} ions. Understanding from a physico-chemical perspective the ripening from CPPI to CPPII and the factors affecting the process is fundamental to prevent the surge of ectopic calcifications by developing strategies to delay the crystallization and precipitation of CaP in serum.

In this contribution we describe the effect of proteins (Fet-A and Albumin) and ions (Mg^{2+}, pyrophosphate and citrate) on the formation and crystallization of CPPs[2-3]. Synthetic CPPs were prepared at different concentrations of Fet-A and their formation and ripening were followed in situ by means of turbidimetry and scattering techniques. The morphology of the nanoparticles was analyzed by means of scanning and cryo-transmission electron microscopy whereas FT-IR spectroscopy and X-Rays diffraction allowed for the study of their crystallinity. Experiments were also conducted with different concentrations of albumin and Mg^{2+}, pyrophosphate and citrate. This multi-technique approach allowed us to identify the most effective conditions for preventing the crystallization of CPPI, suggesting novel strategies to inhibit and treat cardiovascular calcifications.

References:

[1] W. Jahnen-Dechent, A. Büscher, S. Köppert, A. Heiss, M. Kuro-o, E.R. Smith, Journal of Structural Biology 2020, 212, 107577.
[2] R. Gelli, V. Pucci, F. Ridi, P. Baglioni, Journal of Colloid and Interface Science 2022, 620, 431-441.
[3] R. Gelli, F. Ridi, Colloids and Surfaces B: Biointerfaces 2023, 227, 113372.

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Physicochemical studies of new G-quadruplex-forming aptamers against mutant huntingtin

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Huntington's Disease (HD) is a rare, progressive, autosomal dominant neurodegenerative disorder. HD hinges on the CAG triplet expansion within the first exon of the HTT gene, which then encodes for a mutant, polyglutamine-expanded (polyQ) protein (mHTT). Unfortunately, no effective therapy exists to date. Molecular approaches, as antibodies or intrabodies failed because of inadequate selectivity, toxicity, poor delivery, and system complexity[1]. Aptamers promise to override these limits thanks to their unmatched specificity, easy selection, very low immunogenicity, and broad stability. Four guanine-rich DNA aptamers able to selectively bind the mHTT protein have been recently identified, showing high efficacy in modulating the functions of the mutated protein in a variety of cell experiments[2]. Interestingly, these aptamers were proved to fold into G-quadruplex structures but no conclusive data on their conformation and/or structure-activity relationship were provided.

Here, we demonstrated that the best aptamer in the series and some of its derivatives adopt a very stable parallel G-quadruplex structure and show high resistance to nuclease digestion in pseudo-physiological solutions. Moreover, experiments on SH-SY5Y cells, as model of neuronal cells, have been also carried out, to verify the aptamers cell uptake and cytotoxicity. Finally, the *in vivo* activity of the aptamers has been studied using a well-established *Drosophila melanogaster* model for HD, which expresses the human mutated huntingtin[3,4].

References:

[1] M. Caterino, T. Squillaro, D. Montesarchio, A. Giordano, C. Giancola, M.A.B. Melone, Neuropharmacology 2018, 135, 126 – 138.
[2] B. Shin, R. Jung, H. Oh, G.E. Owens, H. Lee, S. Kwak, R .Lee, S.L. Cotman, J.M. Lee, M.E. MacDonald, J. J. Song, R. Vijayvargia, S. Seong, Mol. Ther. - Nucleic Acids 2018, 11, 416 – 428.
[3] C. Riccardi, F. D'Aria, F.A. Digilio, M.R. Carillo, J. Amato, D. Fasano, L. De Rosa, S. Paladino, M.A.B. Melone, D. Montesarchio, C. Giancola Int. J. Mol. Sci. 2022, 23, 4804 – 4821.
[4] C. Riccardi, F. D'Aria, F.A. Digilio, M.R. Carillo, J. Amato, D. Fasano, L. De Rosa, S. Paladino, M.A.B. Melone, D. Montesarchio, C. Giancola Int. J. Mol. Sci. 2022, 23, 12412 – 12434.

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Liposomes for enhanced intracellular delivery of therapeutics through inhalation: design and physicochemical characterization

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With their ability to encapsulate therapeutics and release their content at the desired time, liposomes provide a valuable platform for the treatment of a variety of diseases. Notwithstanding their impressive advantages, the administration modality plays a not less important role in targeting efficiency and side effect reduction, as well as patient comfort. In this regard, a promising alternative to intravenous administration is represented by pulmonary administration by inhalation.[1,2] We developed liposomes using the main component of pulmonary surfactant (DPPC) as a major substituent to improve the biocompatibility of the entire system and ensure better interaction with the lung surfactant membrane, which is the main barrier that liposomes need to overcome while being pulmonary administrated. Liposomes with different compositions have been designed to understand how each lipid (DPPC, DOTAP, and cholesterol) affects the physicochemical properties of the system itself. This was done by combining several techniques, such as DSC, DLS and SAXS. The results obtained revealed that DOTAP and cholesterol addition affect liposome size, as well as lipid system transition temperature. Preliminary tests have been performed to encapsulate a CSC-targeting DNA aptamer (AP-9R) that suppresses tumorigenesis, cancer progression and angiogenesis in lung cancer.[3] Understanding how the different lipids affected the physicochemical properties of lipid nanocarriers, can benefit the development of new strategies for the delivery of oligonucleotide therapeutics, providing a scientific platform for future clinical approaches.

References:

[1] N. Gallucci, I. Russo Krauss, G. D'Errico, L. Paduano, *Curr Opin Colloid Interface Sci.* 67, 101727 (2023).
[2] R. Tenchov, R. Bird, A. E. Curtze, Q. Zhou, *ACS Nano* 15, 16982 (2021).
[3] Y. Wu, I. Hsieh, C. Tung, C. Weng, J. Wu, J. Yu, T. Hong, Y. Chen, *Mol Ther Nucleic Acids*, 27, 956 (2022).

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Exploring the Cellular Antioxidant Mechanism Against Cytotoxic Silver Nanoparticles: A Raman Spectroscopic Analysis

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Silver nanoparticles (AgNPs) hold great promise for several different applications, from colorimetric sensors to antimicrobial agents. Despite their widespread incorporation in consumer products, limited understanding of the detrimental effects and cellular antioxidant responses associated with AgNPs at sublethal concentrations persists, raising concerns for human and ecological well-being.[1] To address this gap, we synthesized AgNPs of varying sizes and evaluated their cytotoxicity against human dermal fibroblasts (HDF). Our study revealed that AgNPs-toxicity is a time- and size-dependent process, even at low exposure levels. AgNPs exhibited low short-term cytotoxicity but high long-term impact, particularly for the smallest NPs tested. Raman microspectroscopy was employed for in-time investigations in the intracellular molecular variations, during the first 24 h of exposure to AgNPs of 35 nm. Subtle protein and lipid degradation were detected, but no discernable damage to DNA was observed. Signals associated with antioxidant proteins, such as superoxide dismutase (SOD), catalase (CAT) and metallothioneins (MTs), increased over time, reflecting heightened production of these defense agents.[2,3] Fluorescence microscopy further confirmed the efficacy of overexpressed antioxidant proteins in mitigating ROS formation during short-term AgNPs exposure. This work provides valuable insights into the molecular changes and remedial strategies within the cellular environment, utilizing Raman microspectroscopy as advanced analytical technique. These findings offer a novel perspective on the cytotoxicity mechanism of AgNPs, contributing to the development of safer materials and advising regulatory guidelines for their biomedical applications.

References:

[1] B. Nowack, H. F. Krug and M. Height, *Environ Sci Technol*, 2011, **45**, 1177–1183
[2] L. Wang, T. Zhang, P. Li, W. Huang, J. Tang, P. Wang, J. Liu, Q. Yuan, R. Bai, B. Li, K. Zhang, Y. Zhao and C. Chen, *ACS Nano*, 2015, **9**, 6532–6547
[3] Y. Hayashi, P. Engelmann, R. Foldbjerg, M. Szabó, I. Somogyi, E. Pollák, L. Molnár, H. Autrup, D. S. Sutherland, J. Scott-Fordsmand and L. H. Heckmann, *Environ Sci Technol*, 2012, **46**, 4166–4173

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Large Pore Mesoporous Silica-Based Nanostructures and Nanostructured Lipid Carriers as New Platforms of Gene Transfection Immunotherapy of Cancer

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Cancer immunotherapy exploits the body's own immune system to fight against cancer. T cells play central roles in cell-mediated adaptive immunity. Crucial to advancing gene-modified cell therapies, especially T cell therapies, are lenti- or retroviral vectors. While effective, these approaches are costly and carry residual risks such as germline transmission, immunogenicity, and insertional mutagenesis. Therefore, there is a quest for efficient strategies for non-viral transduction of synthetic receptors into primary T cells[1]. Synthetic nanovectors, loaded with a specific plasmid (pSLCAR-CD19-28z), have been engineered to bypass chromosomal integration and reduce risks. Nanostructured lipid carriers (NLCs) and two kinds of mesoporous silica nanoparticles (MSNs), namely core@shell nanostructures (SiO_2@MSNs), with a non-porous silica core and dendritic mesoporous silica shell, and hollow MSNs (H-MSNs) were synthesized for their advantageous properties, including biocompatibility and efficient loading capacity. NLCs were produced through hot homogenization and loaded with the plasmid using a hydrophobic ion pairing approach. SiO_2@MSNs and H-MSNs were synthesized *via* dynamic soft-templating and single-step sol-gel processes, respectively[3] and were surface-functionalized with a cationic polymer polyethyleneimine (PEI) as initial step for plasmid loading. Physical-chemical characterization and *in vitro* studies were conducted on both types of nanostructures, that resulted characterized by an average hydrodynamic diameter lower than 200 nm, featuring all a considerable colloidal stability in physiological media, a high capacity of releasing the plasmid without degradation and a good biocompatibility. These conclusive results affirm the successful development of these nanoplatforms positioning them as promising candidates for potential applications the field of oncology.

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References:

[1] De Angelis B., Depalo N., Petronella F., Quintarelli C., Curri M.L., Pani R., Calogero A., Locatelli F. and De Sio L., J. Mater. Chem. B, 2020,8, 1823-1840

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Microbial-based biocathodes for green hydrogen production.

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Microbial electrochemical systems combine biological catalysts to abiotic electrodes to achieve sustainable devices (i.e. biosensing, electrochemical wastewater remediation, energy generation, and the production of chemical commodities)[1]. While considerable research has been directed towards the identification of suitable microorganisms, less studies have focused on the rational development of electrode materials for interaction with these biocomponents. Specifically, an efficient electrode would combine both desired surface and structural properties, with conductive and biodegradable materials being of interest to achieve high biocompatibility and electrochemical performance. In this context, the use of biobased polymers coupled with conductive material ensure efficient bacterial colonization and enhanced catalytic activity.[2] Our group previously reported the use of polydopamine (PDA) on polyhydroxybutyrate (PHB)-based electrodes for obtaining microbial electrodes.[3] PHB is a biopolymer produced by purple non sulphur bacteria (PNSB) as energy feedstock under specific environmental condition.

Herein, we report the possibility to employ the reported system to develop a biohybrid photocathode with anoxygenic photosynthetic bacteria. Specifically, we utilized a blend of PHB and carbon nanofibers (CF) with metabolically active cells of *Rhodobacter capsulatus* embedded in a biohybrid PDA matrix. The biohybrid photocathode was characterized by means of scanning electron microscopy, cyclic voltammetry, and chronoamperometry, revealing the role of PNSB in the obtained cathodic photocurrent. The system achieved enhanced catalytic activity under illumination, with a 30-35-fold increase in photocurrent production compared to biophotoelectrodes based on glassy carbon, and 10-fold increase compared to abiotic control electrodes. These results pave the way towards possible applications of such bio-based photocathode in water remediation and chemical energy conversion into a green energy vector, *i.e.* hydrogen.

[1] G. Bedendi, L.D. De Moura Torquato, S. Webb, C. Cadoux, A. Kulkarni, S. Sahin, P. Maroni, R.D. Milton, Grattieri, M. ACS Measuremente Science Au 2022, 2 (6), 517-541.
[2] H.R. Luckarift, S.R. Sizemore, K.E. Farrington, J. Roy, C. Lau, P.B. Atanassov, G.R. Johnson, ACS Applied Materials Interfaces 2012, 4 (4), 2082-2087.
[3] G. Buscemi, D. Vona, P. Stufano, R. Labarile, P. Cosma, A. Agostiano, M. Trotta, G.M. Farinola, M. Grattieri, ACS Applied Materials Interfaces 2022, 14 (23), 26631-26641.

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Synergistic effects of inorganic nanoparticles for microbial electrochemical systems

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Bio-electrochemical systems (BES) offer a promising avenue for sustainable energy production. Among the various biological catalysts reported in literature (i.e., enzymes, organelles, bacteria), intact photosynthetic bacteria are of particular interest as they allow developing biohybrid photoelectrochemical systems for the conversion of solar energy into electrical energy.[1] The combination of nanomaterials with bacterial cells has the potential to overcome some of the intrinsic limitations associated with living organisms-based electrochemical systems, such as limited solar light absorption, hindered extracellular electron transfer (EET), and low stability.[2,3,4] Accordingly, herein we explore the potential synergistic effects of gold (Au) and ceria oxide (CeO_2) nanoparticles on enhancing electron transfer kinetics and stability in purple photosynthetic bacterium *Rhodobacter capsulatus* (*R. capsulatus*)-based electrodes. This bacterium exhibits remarkable metabolic versatility, making it suitable for application in BES.[5,6] With the aim to facilitate the ET and solar light absorption, our group proposed the modification of *R. capsulatus* with cysteine-functionalized gold nanoparticles, which resulted in increased current generation. To tackle the stability limitations, CeO_2 nanoparticles have been proposed based on their reactive oxygen species scavenging capabilities to mitigate oxidative stress-induced degradation, thereby improving the overall performance and longevity of microbial-electrode interfaces. This work will discuss the potential of nanoparticle-mediated strategies for improving microbial-electrode interactions in BES and advancing the development of sustainable bioenergy technologies.

References:

[1] M. Grattieri, Photochemical & Photobiolical Sciences, 2020, 19, 424-435.
[2] L. D. de Moura Torquato, M. Grattieri, Current Opinion in Electrochemistry, 2022, 34, 101018.
[3] X. Deng, D. Luo, A. Okamoto, Bioresource Technology, 2022, 350, 126844.
[4] M. Mouhib, A. Antonucci, M. Reggente, A. Amirjani, A.J. Gillen, A.A. Boghossian, Nano Research, 2019, 12, 2184–2199.
[5] G. Drews, J. F. Imhoff, in Variations in Autotrophic Life, 1991, 51–97.
[6] M. Grattieri, R. Labarile, G. Buscemi, M. Trotta, Photochemical & Photobiolical Sciences, 2022, 21, 101-111.

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Beyond configurational entropy: understanding the phase stability of high entropy oxide $Mg_{0.2}Co_{0.2}Ni_{0.2}Cu_{0.2}Zn_{0.2}O$ by a chemometric approach

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High entropy oxides (HEOs) are a recently discovered class of materials where a particular crystal structure, which in general is different from that of the parent compounds, is stabilized in a multicomponent system, characterized by a large amount of configurational entropy[1]. In recent years, these materials are gathering increasing attention for many technologically relevant applications. In particular, they have been employed as electrodes for Li and Na-ion batteries, for catalysis, and they present interesting properties such as colossal dieletric constant and enhanced mechanical properties[2,3].

The main driver for the growing interest in HEOs is the potential to obtain novel properties by exploiting the enormous number of possible elemental combinations. However, most investigations on HEOs assume that these systems present their optimal characteristics in the proximity of an equimolar composition, where the configuration entropy is highest. Overall, the study of phase stability and of the optimization of the functional properties in HEOs present significant challenges. In fact, conducting a study using the traditional approach of uniformly sampling the compositional space is not feasible due to the high number of compositional parameters involved.

Here we present a chemometric approach based on the Design of Experiment (DoE), that we employed as a simple and time-saving strategy to predict the phase stability of the prototypical high entropy oxide (Cu,Zn,Mg,Ni,Co)O with a rock salt structure[4]. This approach allowed to extract a polynomial function able to predict, for every combination of the 5 elements, the fraction of the single rocksalt phase that could be obtained, allowing therefore to draw an isothermal phase diagram at 1000 °C for this multicomponent system. It was observed that the stability region of this HEO extends well beyond the equimolar composition $Cu_{0.2}Zn_{0.2}Mg_{0.2}Ni_{0.2}Co_{0.2}O$. In particular, significantly lower and higher fractions of Cu^{2+} and Zn^{2+} can be inserted and still lead to a single phase. By combining these thereotical findings with X-ray diffraction, we observed that a high content of Cu^{2+} induces a tetragonal distortion, associated to the strong Jahn-Teller effect of this cation. Moreover, it was clearly observed that the overall quantity of single-phase RS that can be formed is not strictly dependent on the configurational entropy of the resulting compositions, but rather on the type and content of the cations involved[5]. This points towards the fact that configurational entropy does not have a central role in the phase stability of this HEO.

We also note that this chemometric approach can be exploited for all multicomponent systems, allowing to draw isothermal phase diagram with a limited exprimental effort.

References:

[1] C. Rost, E. Sachet, T. Borman, A. Moballegh, E. C. Dickey, D. Hou, J. L- Lones, S. Curtarolo, J. Maria, *Nat. Commun.* 2015, *6* 8485.
[2] P. Ghigna, L. Airoldi, M. Fracchia, D. Callegari, U. Anselmi Tamburini, P. D'Angelo, N. Pianta, R. Ruffo, G. Cibin, D. Oliveira de Souza, E. Quartarone, *ACS Appl. Mater. Interfaces* 2020, 12, 50344-50354.
[3] M. Fracchia, P. Ghigna, T. Pozzi, U. Anselmi-Tamburini, V. Colombo, L. Braglia, P. Torelli, *J. Phys. Chem. Lett.* 2020, *11*, 9, 3589-3593.
[4] M. Coduri, L. R. Magnaghi, M. Fracchia, R. Biesuz, U. Anselmi-Tamburini, "Assessing Phase Stability in High Entropy Materials by Design of Experiments: the Case of the System (Mg,Ni,Co,Cu,Zn)O", *Chem. Mater.* 2024, 36, 2, 720-729
[5] M. Fracchia, M. Coduri, M. Manzoli, P. Ghigna, U. Anselmi Tamburini, *Nat. Commun.* 2022, 13, 2977.

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FIS-OR-051

Deciphering the Structural Rearrangement in the Activation Cycles of a Cobalt-Free, Lithium-Rich Layered Oxide Cathode

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Besides pure performance, the development of new materials for electrochemical devices must satisfy mandatory requirements addressing costs and sustainability, issues that become increasingly more important day by day. In particular, the large use of cobalt poses ethical and political concerns, since cobalt commodities have reached limited availability, are expensive, and are harmful to human health and the environment.[1]

In this work, we analyzed the structural rearrangement occurring in the formation cycles of a cobalt-free lithium-rich layered oxide (LRLO) positive electrode with $Li_{1.28}Ni_{0.15}Mn_{0.57}O_2$ stoichiometry in a lithium cell.[2] After applying a tailored activation procedure, this LRLO formulation shows a remarkable reversible capacity of 240 mAh g^{-1} at a C/10 rate. The absence of this electrochemical formation protocol results in much worse performance in terms of specific capacity or reversibility. Our analysis of the compositional and structural rearrangements in the lattice of the LRLO phase provided a rationale for these phenomena. We combine electrochemical tests, on-line electrochemical mass spectrometry, *operando* X-ray diffraction and dual-edge X-ray absorption spectroscopy, and density functional theory modeling. The large capacity originates from the Ni^{2+}/Ni^{4+} as well as the O^{2-}/O^{-} redox couples. However, at potentials above 4.2 *vs*. Li^{+}/Li, the electron exchange is smeared over the entire anionic sublattice, rather than being localized on a specific oxygen atomic site. This redox mechanism is nicely reversible and takes place without detrimental evolution of molecular oxygen, thus avoiding the onset of the degradation of the LRLO crystal structure. However, in the activation cycles, the sequential nickel and oxygen redox trigger irreversible structural distortions in the coordination of the redox-inactive Mn^{4+} centers. We can ascribe this local structural evolution, mainly involving the MnO_6 octahedra, as the enabler for superior electrochemical performance in this LRLO phase.

References:

[1] L. Simonelli, A. Sorrentino, C. Marini, N. Ramanan, D. Heinis, W. Olszewski, A. Mullaliu, A. Birrozzi, N. Laszczynski, M. Giorgetti, S. Passerini, D. Tonti, J. Phys. Chem. Lett. 2019, 10, 3359–3368.
[2] A. Celeste, M. Tuccillo, A. Santoni, P. Reale, S. Brutti, L. Silvestri, ACS Appl. Energy Mater. 2021, 4, 11290–11297.

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Cerium Oxide-based catalysts for direct synthesis of dimethyl carbonate from methanol and CO_2

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Dimethyl carbonate (DMC) is a valuable eco-friendly compound, and its increasing demand is due to its various applications (polycarbonates, fuel and the lithium-ion battery industries). There are several synthetic pathways that are used for the production of DMC, but most of them involve toxic and dangerous substances, as reagents, catalysts, and by-products. For example, most of the industrial production of DMC still uses phosgene, a highly toxic chemical that can cause several health issues. In recent decades, research has been focused on developing more sustainable synthetic approaches that can replace the phosgene method. Currently the attention has been paid on the direct synthesis from methanol and CO_2, converting the latter from waste into fuel. However, this strategy still remains at laboratory level because of poor conversions and low yields of DMC, due to thermodynamic stability and kinetic inertness of CO_2. In order to overcome these drawbacks, new and efficient catalysts have been developed. Among all, Ce-based catalysts are particularly promising for their chemical stability, redox properties, and high catalytic activity. In this work, low porosity CeO_2 and Fe-doped CeO_2 were prepared through hydrothermal (nanorods) and sol-gel self-combustion (SC) synthesis, mesoporous CeO_2 was obtained with a surfactant-assisted precipitation method, and impregnation methods were used to obtain mesostructured nanocomposites (10%wt CeO_2@SBA-15). The as-obtained catalysts were characterized using PXRD, TEM, FTIR, Raman and N_2-physisorption. In some cases, XPS measurements were performed. The direct formation of DMC from methanol and CO_2 was carried out in a batch reactor by studying different parameters such as temperature, pressure, amount of catalyst, and volume of methanol. GC-FID was used to evaluate the DMC formation. The various synthetic strategies led to the obtainment of ceria-based systems with different microstructures and textures. CeO_2 and particularly Fe-doped CeO_2 nanorods are the most promising ones from the catalytic point of view, mainly due to the peculiar morphology. The superior performance of the Fe-doped nanorods could be ascribed to the co-presence of the hematite phase and the creation of the ceria/hematite interface. The worse catalytic performance is observed for the SC sample doped with iron where a complete insertion of iron into the ceria structure was achieved. Mesoporous CeO_2 shows intermediate performances. The homogeneous dispersion of ceria on SBA-15 through proper impregnation strategies (CeO_2@SBA-15) resulted to be a promising approach to design efficient catalysts. The effect of dehydrating agents is under study.

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FIS-PO-002

Harnessing Silver Nanoparticles for Environmental Remediation and Disinfection

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In recent years, nanotechnology has garnered significant attention as a pivotal tool for addressing critical challenges such as environmental remediation and clean energy production, aligning with initiatives like the European Agenda 2030 and the Green Deal program.[1] In this context, suitably engineered nanoparticles (NPs) have been found advantageous in the disinfection from pathogenic microorganisms, thus overcoming the antibiotic resistance problem.[2] In particular, Silver (Ag) NPs are promising for their disinfectant function in various sectors, including biomedical disinfection, water and air disinfection, the textile industry and food packaging. Ag has served as a disinfectant for centuries, utilized in various forms including salts and colloidal nanosystems.[3] However, only since 2004 extensive studies on the antibacterial activity of Ag NPs have emerged, and research in this field has grown considerably in recent years. Particularly, it has been demonstrated that Ag NPs have a high capacity to inhibit the growth of a wide range of pathogens, even at low doses.[4] The toxicity of Ag NPs depends on their physicochemical characteristics e.g., size, shape, chemical nature, reactivity, surface area and surface charge, the nature of surface coatings, the exposure concentration and release of Ag^+ ions.[5] The antimicrobial efficacy of Ag NPs is ascribed to several phenomena and reactions occurring both on the bacteria membrane and within the cytoplasm, altering cellular metabolism and leading to bacterial death.[6] NPs surface composition influence the kinetics of Ag^+ release as well as their interaction with the bacteria. Moreover, NPs size plays a crucial role, as smaller NPs exhibit a higher release rate of Ag^+ ions in various media, thereby significantly enhancing their antibacterial activity. On the other hand, small Ag NPs easily tend to aggregate and form larger particles, thus turning in a decreased antibacterial activity.

This study addresses this challenge by synthesizing heterostructures utilizing mesoporous silica nanoparticles (MSNs) as templates and/or supports for the in situ reduction of silver precursor salts, facilitating the formation of physically separated, anchored Ag NPs. Different growth mechanisms and final size of the metal domain result by using mild reducing agents as tetrakis(hydroxymethyl)phosphonium chloride (THPC) in water or, alternatively, butyl amine in ethanol. The two selected heterostructures are tested for inhibiting Escherichia coli in aqueous medium and their activity is compared with that of bare Ag NPs and MSN. The results reveal a reduction of the dose of heterostructures required for the inhibition process, that, remarkably, demonstrates to be structure-dependent.

References:

[1.] L. Pokrajac et al.*ACS Nano* **2021,** 15, (12), 18608-18623.
[2.] L. Wang et al. *International journal of nanomedicine* **2017,** 12, 1227-1249.
[3.] S. P. Deshmukh et al. *Mater Sci Eng C Mater Biol Appl* **2019,** 97, 954-965.
[4.] D. Bamal et al. *Nanomaterials (Basel)* **2021,** 11, (8).
[5.] L. P. Padhye et al. *Science of The Total Environment* **2023,** 871, 161926.
[6.] P. R. More et al. *Microorganisms* **2023,** 11, (2), 369.

FIS-PO-003

Effect of Anchored Phosphonium Cations on Cu nanoparticles in the electrochemical CO_2 reduction

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In the field of CO_2 reduction reaction (CO_2RR), there are multiple strategies to increase the process selectivity towards desired C-containing products. In particular, the use of additives with anchored ionic liquids, binding ionomers and N-based cationic species (i.e. ammonium, pyridinium, imidazolium) on metal electrocatalysts has been successfully exploited in order to limit the competitive and undesired hydrogen evolution reaction and modify the product selectivity.[1-3] Less attention has been devoted to the use of P-based cations, though these species positively affect the stabilization of reaction intermediates of CO_2RR and chemical fixation of CO_2 in solution.[4,5]

In this work, we prepared and characterized styrene-based copolymers containing phosphonium groups to be employed as functionalized binding additives mixed with Cu nanoparticles (NPs) to assemble gas diffusion electrodes (GDEs) for electrochemical CO_2RR in flow cells (**Figure 1**). We carefully compared the CO_2RR results attained by using commercial Cu NPs and Nafion® as binding agent with those achieved with our home-made GDEs with different substituents and amounts of phosphonium groups, seeking for selectivity changes. Preliminary results show the GDE's high hydrophobicity and higher selectivity towards C_1 gas products.

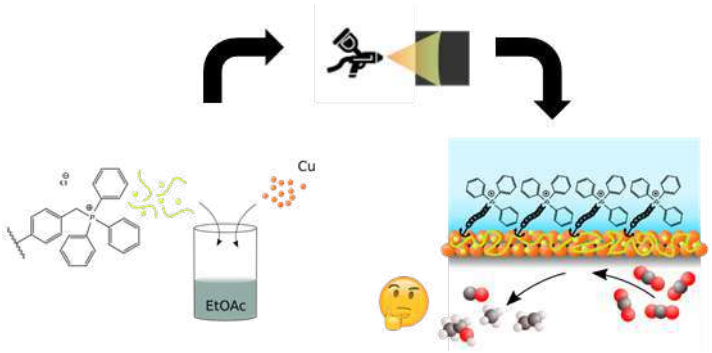

Figure 1: Home-made functionalization of Cu NPs with phosphonium loaded styrene-based copolymer to be used in electrochemical flow cells for CO_2RR.

References:

[1] M. Zhuansun, Y. Liu, R. Lu, F. Zeng, Z. Xu, Y. Wang, Y. Yang, Z. Wang, G. Zheng, Y. Wang, Angew. Chem. Int. Ed., 2023, 62, e202309875.
[2] Z. Gao, L. Xue, X. Hu, J. Yin, L. Xiao, G. Wao, J. Lu, L. Zhuang, Electrochim. Acta, 2023, 458, 142509.
[3] O. Coskun, S. Dongare, B. Doherty, A. Klemm, M. Tuckerman, B. Gurkan, Angew. Chem. Int. Ed., 2024, 63, e202312163.
[4] Y. Li, X. Yao, Y. Liu, M. Li, Q. Su, Y. Liu, Y. Li, Z. Yang, ChemistrySelect, 2023, 8, e202301449.
[5] C. Jiang, S. Zeng, X. Ma, J. Feng, G. Li, L. Bai, F. Li, X. Ji, X. Zhang, AIChE J., 2023, 69, e17859.

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Unveiling the competitive diffusion of binary gas mixtures in polymers: the case of carbon dioxide and alkanes in nanoporous-crystalline polyphenylene oxide

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Natural gas and petroleum gas (ethane, propane, buthane) are energy carriers more sustainable than coal. Moreover, natural gases like propane are seen as green refrigerants which will soon replace highly polluting hydrofluorocarbons (HFCs). Purification of fossil fuel gases may be accomplished with polymeric membranes. In this work, we investigated the sorption of binary gas mixtures constituted of carbon dioxide and either methane, ethane or propane in Poly(2,6-dimethyl-1,4-phenylene)oxide (PPO) endowed with nanoporous crystalline domains[1]. This material is a good candidate for fuel gas sweetening due to its peculiar pore morphology and distribution. The experiments were conducted at sub-atmospheric pressures and in the range [24, 35] °C to prevent any structural modification induced by the sorbates.

We resorted to a hyphenated technique coupling *in situ* FTIR Spectroscopy and Barometry[2]. First, we conducted pure gas sorption tests. At thermodynamic equilibrium, the IR signal of each low molecular weight species was isolated in the polymer phase and its absorptivity was calibrated with Barometry[1]. Then, binary sorption tests were conducted and the solubility of each species in PPO was measured at thermodynamic equilibrium and during diffusion with vibrational spectroscopy. Competitive sorption with ethane or propane produces a depletion of the solubility of carbon dioxide with respect to pure gas sorption at the same partial pressure. Moreover, at short times during co-diffusion, carbon dioxide reaches *supraequilibrium* loading. Such a phenomenon is described by an *overshoot* in the kinetics and is attributed to the solubility competition between the two penetrants. We effectively interpreted it with the Maxwell – Stefan theory of multicomponent diffusion coupled with the classical Langmuir's adsorption model and showed that the *overshoot* is a proof of *uphill* diffusion in PPO[3].

At the thermodynamic conditions investigated, the separation performances of PPO are analogous to DDR type zeolites despite the different chemical nature of the two adsorbents[4]. For the first time, the competitive diffusion of two gases in a polymer film is unveiled.

References:

[1] V. Loianno, G. Guerra, B. Nagendra, G. Mensitieri, P. Musto, Sep. Pur. Tech. 2024, 341, 126953 – 126968
[2] V. Loianno, G. Mensitieri, A. Baldanza, G. Scherillo, P. Musto, J. Mem. Sci. 2022, 652, 120445 – 120455
[3] R. Krishna, Phys. Chem. Chem. Phys. 2016, 18, 15482 – 15495
[4] A. Lauerer, T. Binder, C. Chmelik, E. Miersemann, J. Haase, D. M. Ruthven, J. Kärger Nature Comm. 2015, 6, 7697

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Enhanced Photocatalytic Methylene Blue Degradation by Mn_3O_4/HNT-based composite material

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Manganese oxide-based materials are extensively explored for their application in catalysis, photocatalysis, environmental cleanup, water splitting, and energy storage, owing to their polymorphism and composite formation capability[1]. It notably features the use of halloysite (HNT), with its distinct tubular structure and variably charged surfaces, to improve photocatalytic performance by increasing the active surface area.

In this work, the influence of excess ammonium ions (NH_4^+) on the phase composition of a composite material based on manganese oxides and halloysite nanotubes was studied. The composites' photocatalytic performance was evaluated based on their efficiency in degrading the model dye methylene blue. Their phase composition was determined by the Rietveld refinement procedure using Powder Cell for Windows software.

Analysis of the phase composition shows that the presence of NH_4^+ ions stabilises the hausmannite phase during chemical synthesis under relatively high pH = 10 with a stoichiometric amount of $MnSO_4$ and H_2O_2 as an oxidising agent. The observed phenomena could potentially arise from the stabilisation of manganese's anionic sulfate complexes and the preferential formation of a spinel phase, which exhibits a mixed oxidation state of manganese (II, III) compared to Mn_2O_3. Samples synthesised at the pH range 5–7 contain predominately $MnOOH/MnO_2$ components at other equal conditions. Therefore, higher pH and the presence of NH_4^+ ions change the phase composition and reduce the average oxidation state of manganese in the product.

Concerning photocatalytic activity, samples containing 28% of halloysite showed higher dye removal efficiency compared to those synthesized under similar conditions but without the addition of halloysite; 95% and 24% were removed in 60 minutes under UV light, respectively. Despite their insulating properties, HNTs enhance photocatalytic activity, probably due to the decoration effect of Mn_xO_y NPs onto HNTs. Moreover, similar behaviour of HNTs was described elsewhere[2,3].

References:

[1] G.V. Sokolsky, Y.I. Boldyrev, N.D. Ivanova, S.V. Ivanov, G.Y. Kolbasov, G. Lazzara, L.V. Zudina, N.V. Gayuk, S.V. Chivikov, Surface and Coatings Technology, 2020, Volume 400, p. 126211.
[2] B. Szczepanik, P. Słomkiewicz, D. Wideł, M. Czaplicka, L. Frydel, Catalysts, 2021, Volume 11, p. 1548.
[3] M. Abid, A. B. H. Amara, M. Bechelany, Nanomaterials, 2023, Volume 13, p. 1578.

FIS-PO-006

Eco-conscious innovations in black pigments manufacturing: a path to sustainability

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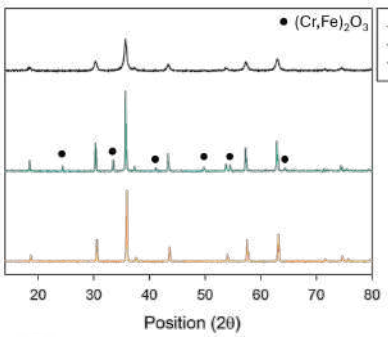
In our study, we optimized a commercial black pigment containing Cr, Mn, Fe, Ni, and high amounts of Co, targeting the environmentally demanding steps required for its industrial production. This includes the use of metals classified as critical raw materials by the EU Commission[1], solid state synthesis at 1300°C[2], and lengthy milling to decrease the pigment's particle size for better dispersion in the ink solvent. By employing the Design of Experiments[3], we obtained a composition containing only Cr, Fe and low Co content, eliminating the other critical metals while maintaining the desired black hue of original 5-metals formulation. Further improvements included reducing both calcination temperature to 1100°C, and milling time.

The life cycle assessment is underway to evaluate the environmental impact of our pigment.

Additionally, the optimized composition was prepared via spray pyrolysis, a more sustainable procedure that ensures product formation in nanometre dimensions, potentially eliminating the need for milling.

Assessment of colorimetric performance is currently under investigation.

Our research marks a significant stride towards designing ecological pigments, aiming to reduce the overall carbon footprint.



Optimized composition:
$Cr_{1.2}Fe_{1.05}Co_{0.75}O_4$

Synthesis	T(°C)	Spinel (%)	$(Cr,Fe)_2O_3$ (%)	ΔE
Solid State	1300°C	100		2.7 ± 0.2
	1100°C	79.3(3)	20.7(3)	0.69 ± 0.04
Spray Pyrolysis	1000°C	100		Expected <1

Figure 1: X-ray diffraction patterns of the synthesized black pigments; quantification of secondary phases via Rietveld Refinement and colorimetric performance of the pigments (evaluated via chromatic factor ΔE)

References:

[1] European Union Commission, Critical Raw Materials: https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en.
[2] L. Matovic, R. Vujasin, J. Environ. Chem. Eng. (2021), 9, 105038.
[3] R. Leardi, Analytica Chimica Acta (2009), 652, 161-172.

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FIS-PO-007

Novel Strategy in Anchoring Amine Functionalities to MOFs for applications in Direct CO_2 Capture from Air.

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Direct air capture (DAC) of has been recognized as a fundamental strategy to drastically reduce CO_2 levels in the atmosphere and mitigate the greenhouse effect.
However, CO_2 removal from ambient air is a difficult task, since its atmospheric concentration is only 420 ppm, which is roughly 350 times lower than its concentration in other sources of air, like coal-based flue gas (≈15% CO_2). In these conditions, sorbents that capture CO_2 through chemisorption exhibit stronger and more selective interaction sites than physisorbent materials.
Amine functionalities contribute to the chemical sorption of CO_2 by virtue of the reversible formation of carbamate moiety. The development of amino-functionalized solids sorbents (e.g., Metal-Organic Frameworks - MOFs) represents a benchmark strategy to create new possible DAC technologies.[1]
Many amino-based Ionic Liquids (ILs) possess high efficiency in CO_2 capture, in particular a class of ILs containing azoles and amines has shown interesting performances. For this reason, the IL composed of pyrazole and diethylenetriamine has been chosen as main target to design a novel amino-functionalized MOF for DAC.[2]
The synthetic procedure involves the anchoring of diamine molecules to the MOF by virtue of an acid-base interaction, rather similar to that involved in the formation of the ionic liquids previously mentioned ILs. The novel MOF-303 structure[3] appeared to be suitable for this scope thanks to the pyrazolic nature of the linkers and the presence of a strong H-bonding adsorption site which makes anchoring of the amine moieties possible. The employment of spectroscopic techniques (such as in *situ* IR and Solid State-NMR) and computational methods could elucidate the structure of the adsorption sites and the nature of the still unclear CO_2 capture mechanism involved. In the next future, further experiments will include the use of breakthrough set up, the evaluation of water effect on adsorption performances and how the presence of water in the gas streams could affect the performances of the adsorbent.

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References:

[1] S. Bose, D. Sengupta, T. M. Rayder, X. Wang, K. O. Kirlikovali, A. K. Sekizkardes, T. Islamoglu, O. K. Farha, Adv Funct Mater, 2023.
[2] J. Wu, B. Lv, X. Wu, Z. Zhou, G. Jing, ACS Sustain Chem Eng, 2019, 7, 7312–7323.
[3] Z. Zheng, H. L. Nguyen, N. Hanikel, K. K. Y. Li, Z. Zhou, T. Ma, O. M. Yaghi, Nat Protoc, 2023, 18, 136–156.

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FIS-PO-008

Investigating Cu speciation in histidine-modified Cu-UiO-66 MOFs a XAS-MCR study

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Successfully achieving methane-to-methanol selective oxidation present a significant catalytic challenge, one that nature efficiently masters through specific copper-histidine sites in lytic polysaccharide monooxygenases (LPMOs) enzymes[1]. Compared to enzymatic systems, Metal Organic Frameworks (MOFs) represent promising candidates because of their stability, high surface area and selectivity[2]. Inspired by LPMOs, two **Cu-UiO-66-his** MOFs samples with different Cu/his ratios (high and low histidine loading) were synthesized and characterized at the ESRF beamline BM23 by *in situ* X-Ray Absorption Spectroscopy (XAS). The experimental protocol consisted of an activation step in He up to 150 °C, isothermal reduction in H_2 and re-oxidation in O_2. Multivariate Curve Resolution (MCR) and Wavelet Transform (WT) EXAFS advanced analysis methods were applied, securing a thorough understanding of the experimental data in complex multi-component cases. MCR analysis was performed following a *Waterfall* systematic approach, guiding the method to yield chemically and physically meaningful outcomes. The results are reported in **Errore. L'origine riferimento non è stata trovata.**.

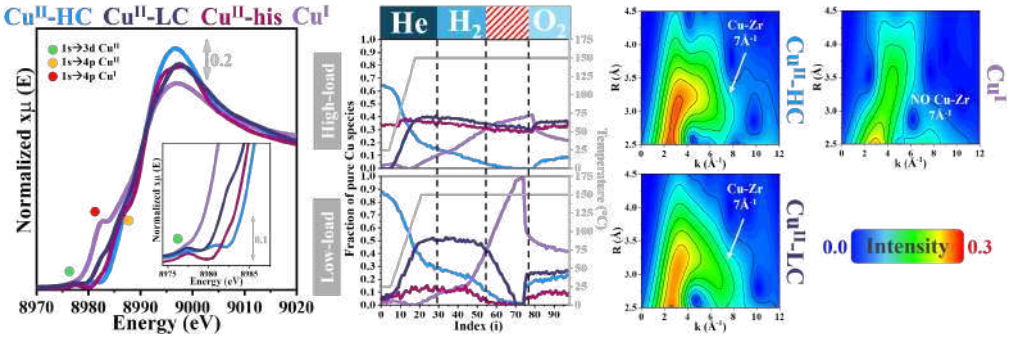

Figure 1 : (Left) MCR reconstruction, including XANES, FT-EXAFS spectra and concentration profiles of pure Cu species. (Right) Representation of WT maps magnified in the 2.5-4.5 Å range.

According to XANES fingerprints, four distinct pure Cu species were identified in both samples. Notably, the **Cu^{II}-his** pure species displayed partial inertness to the overall chemistry, while the **Cu^{II}-LC** species underwent preferential evolution at the expenses of the more-coordinated **Cu^{II}-HC**. The presence of pure **Cu^{I}** species suggests that both samples exhibit redox properties, albeit with preferential Cu^{II} reduction in the low-loading sample. This is attributed to the ca. 40% of **Cu^{II}-his** species present in the high-loading sample. WT analysis indicated that in **Cu^{II}-HC** and **Cu^{II}-LC** species, Cu-Zr contributions were detectable, leading us to describe these species as cluster-derived sites. Importantly, this Cu-Zr scattering contribution was completely lost for the identified Cu^{I} species. We're currently working on EXAFS fitting analysis using DFT-derived structures, obtaining promising results aimed at validating our structural hypothesis.

References:

[1] C. D. Blanchette, et al., Nature Comm., 2016, 7, 11900.
[2] L. Braglia, et al., Catal. Today, 2017, 283, 89-103.

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FIS-PO-009

Agri-food wastes as new resource: Kiwi Peels as adsorbent material for water remediation

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In recent years, population growth has caused the increase in supply demands, like water and food 1. That represents the source of the different global issues, particularly the management of water resources, including pollution, treatment, and protection concerns, and handling of agri-food wastes end-life 2. In contrast with linear economy approach, which enhances these problems, by following the principles of Circular Economy, the same agri-food wastes can represent a solution for water treatment 3,4. In this context, the use of Kiwi Peels, an agri-food waste, was proposed as an adsorbent material to remove various Concern Emerging Contaminants and textile dyes from water. The adsorbent substrate was characterized by adopting FTIR-ATR, TG and SEM analyses, before and after its use, proposing it as a recyclable material. UV-VIS spectroscopy analyses were performed for the purpose. Ciprofloxacin and Direct Blue 78 were selected model contaminants to infer information about the behaviour of Kiwi Peels during water treatments; so, the role of several parameters affecting the process was assessed. The study encompassed thermodynamics, adsorption isotherms, and kinetics.

To extend the lifetime of Kiwi Peels, desorption experiments were carried out by using hot water or salt solutions. 10 cycles of adsorption/desorption were studied, evidencing the recycling of both pollutants and Kiwi Peels. Moreover, the solid-state pollutant photodegradation was proposed as a possible alternative for the adsorbent regeneration.

References:

[1] F. Facchini, B. Silvestri, S. Digiesi, A. Lucchese, Innovative Food Science & Emerging Technologies, 2023, 83, 103235.
[2] C.V. Berenguer, C. Andrade, J.A.M. Pereira, R. Perestrelo, J.S. Câmara, Processes, 2023, 11, 20.
[3] J. Gubitosa, V. Rizzi, D. Cignolo, P. Fini, F. Fanelli, P. Cosma, Sustainable Chemistry and Pharmacy, 2022, 29, 100749.
[4] J. Gubitosa, V. Rizzi, P. Fini, S. Nuzzo, P. Cosma, Physical Chemistry Chemical Physics, 2024.

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FIS-PO-010

Efficient removal of perfluorooctanoic acid (PFOA) from water with magnetic metal-organic frameworks (MOF)

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Poly- and Per-fluoroalkyl substances (PFAS) are a class of hazardous and bio accumulative compounds that have an impact on both the environment and human health[1]. The safety threat posed by Perfluoroalkyl acids (PFAAs) in drinking water is a growing concern, in particular perfluorooctanoic acid (PFOA) is widely diffused in Northern Italy[2]. Many degradation techniques have been developed over the last decade to address this issue[3]; unfortunately, they have the downside of releasing further environmentally toxic molecules or short-PFAS[4]. Some adsorption methods have been studied, such as activated carbon[5] or ion exchange resin filters[6], however they are not selective, saturate fast or are expensive. Magnetic particles functionalized with metal-organic frameworks coatings represent an innovative solution that could adsorb PFOA selectively without the need for filtration steps or the production of undesired byproducts.
In this work, a zirconium-based (UiO-66) and an iron-based (Fe-MIL-100) metal–organic frameworks have been synthetized and employed to functionalize magnetic particles. The obtained magnetic powders have shown great adsorption capacity, capturing up to 99% of the PFOA dissolved in water, offering a sustainable and efficient solution to PFAS contamination.

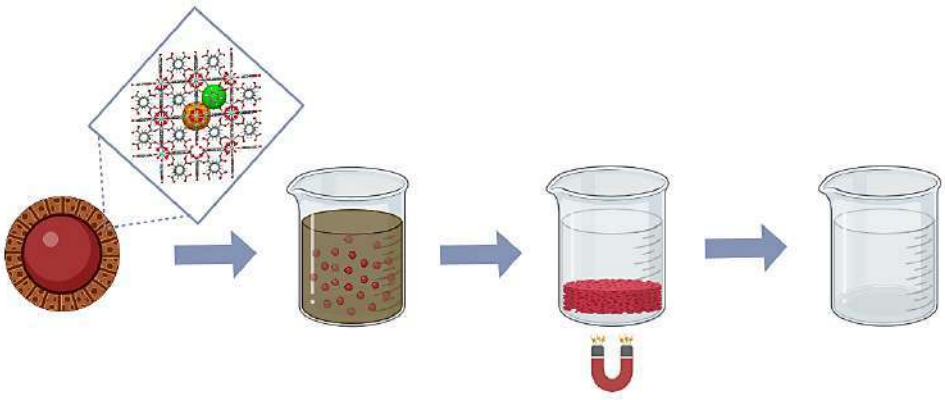

Figure 1: Magnetic particles with metal-organic frameworks functionalization and subsequent PFAS adsorption.

References:

[1] Brown JB, Conder JM, Arblaster JA and Higgins CP. *Environ. Sci. Technol.* 2020; **54**: 15202-15214.
[2] Ingelido AM, Abballe A, Gemma S, Dellatte E, Iacovella N, De Angelis G, Zampaglioni F, Marra V, Miniero R, Valentini S, Russo F, Vazzoler M, Testai E and De Felip E. *Environ. Int.* 2018; **110**: 149-159.
[3] Mirabediny M, Sun J, Yu TT, Åkermark B, Das B and Kumar N. *Chemosphere* 2023; **321**: 138109.
[4] Sharma S, Shetti NP, Basu S, Nadagouda MN and Aminabhavi TM. *Chem. Eng. J.* 2022; **430**: 132895.
[5] Liu W, Lin T, Zhang X, Jiang F, Yan X and Chen H. *Chemosphere* 2022; **309**: 136733.
[6] Woodard S, Berry J and Newman B. *Remediation* 2017; **27**: 19-27.

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FIS-PO-011

Refractory Ceramics for the Aluminium Foundries: Novel Perspectives for Greater Process and Product Sustainability

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The mastery of metallurgy represented a transformative leap for mankind, enabling the production from the first revolutionary tools and weapons to today's hi-tech materials. Global aluminium production is reported to be second only to that of iron, with the smelting of 70.593 MT of Al in 2023 alone[1]. Endless recyclability, reduced production costs, and eco-compatibility, combined with metal's extreme versatility, make aluminium foundries sustainability-conscious and cutting-edge to the extent that future projections anticipate an 80% increase in demand by 2050[2]. Castable refractory ceramics play a crucial role in the aluminium production process, thus special features such as high-temperature, thermal shock, chemical and mechanical resistances as well as formability, durability and insulating properties are required.

In this work, BN-doped ternary SiO_2-Al_2O_3-CaO ceramics were manufactured and fully characterised. The well-known SiO_2-Al_2O_3-CaO system is able to meet many demands[3]. Nevertheless, a deep insight into the mechanisms at the base of their performance in the specific application is highly necessary. Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) analyses confirmed the theoretical values of the major elements, while Scanning Electron Microscopy (SEM) provided morphological and structural information showing the heterogeneity of the ceramic product which consisted of a calcium aluminosilicate matrix in which fragments of silica and BN were dispersed. Moreover, SEM technique revealed that sintering caused a decrease in macroporosity with a concomitant increase in microporosity. X-Ray Diffraction (XRD) showed that the microstructure of the ceramic was a result of both amorphous and crystalline phases. Interestingly, the microstructures before and after the heat treatment appeared very similar despite a slight increase in the crystalline/amorphous ratio and the loss of two water-related phases, *i.e.*, aluminium hydroxide (*nordstrandite*) and calcium aluminium hydroxide hydrate. This phenomenon has already been observed and ascribed to water loss with consequent modifications in the crystalline lattice[4]. Furthermore, XRD patterns of samples treated at different sintering temperatures, *i.e.*, 850 °C, 950 °C and 1050 °C, permitted to determine a significant increase in cristobalite content as the temperature increased, and the formation of corundum at 1050 °C. In addition to the physicochemical characterization, thermal analyses and mechanical testing were started with the aim to disclose specific correlation between product characteristics and its performance.

Finally, a MatLab-based calculation tool was developed to estimate the heat losses occurring during the transportation of molten Al from the holding furnace to the casting station. This met the need for improved product sustainability combined with the possibility of creating uniqueness, whose purpose is to lead to products and processes customization.

References:

[1] International Aluminium Institute Statistical System. Available online on http://international-aluminium.org/statistics/.
[2] Circular Aluminium Action plan. Available online on http://www.european-aluminium.eu/.
[3] H. Mao, M. Hillert, M. Selleby, B. Sundman, J. Am. Ceram. Soc. 2006, 89, 298 – 308.
[4] M. Nilforoushan, N. Talebiaan, Iran J. Chem. Chem. Eng. 2007, 26, 19 – 24.

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FIS-PO-012

Designing g-C_3N_4/g-C_3N_4 nanoarchitectures by playing with urea/melamine precursor ratio

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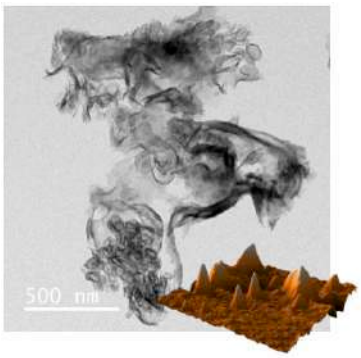
The metal-free polymeric graphitic carbon nitride (g-C_3N_4) is an emerging 2D layered graphene-like materials due to its exceptional properties *i.e.* thermal and chemical stability, non-toxicity, tunable band gap and visible light activity. For these reasons, nowadays, g-C_3N_4 finds applications in many fields like photodegradation of pollutants, photocatalysis for hydrogen production, carbon dioxide reduction, water splitting, solar light-driven photo-redox catalysis, photoelectric conversion[1]. Nevertheless, it's essential to highlight some g-C_3N_4 limitations, such as the high recombination rate of the photoinduced electron–hole pairs, the poor charge carrier mobility the chemical inertness itself and the low specific surface area[2]. For this reason, currently, considerable efforts are directed towards overcoming the aforementioned drawbacks[3], either by establishing g-C_3N_4/g-C_3N_4 or g-C_3N_4/graphene metal-free homo/hetero-junctions or g-C_3N_4/inorganic semiconductors and/or metals, etc.. hybrid materials. In this study, porous g-C_3N_4 nanoarchitectures are achieved through a facile and effective in-situ synthesis method involving the thermal treatment of different melamine (M) and urea (U) precursor mass ratios. The role of the precursors on morphology and structure, was analysed by means of many characterization techniques, including HRTEM, FESEM, X-ray diffraction, UV-visible, PL and FTIR spectroscopies. Some more, samples, obtained by mixing melamine (M) and urea (U) precursors, combine the advantage of high thermal stability and significant reaction yields, due to melamine action and greatly improved surface area, low dimensionality and short migration paths, due to urea action. Consequently, different "top-down" approaches have been optimized with the aim of further increasing the surface area and decreasing the dimensionality of the U-derived-g-C_3N_4 systems, thus exploiting the well-known "quantum confinement" effect typical of low-dimensional architectures.



Lastly, preliminary results also on the synthesis and characterization of low-dimensional-g-C_3N_4/oxides heterojunctions will be discussed, in order to highlight the role of morphology, structure, surface and bulk properties on the photocatalytic performance.

References:

[1] A. Thomas, A. Fischer, *et al.*, J. M. Carlsson, Journal of Materials Chemistry 2008, 18 (41), 4893-4908
[2] P. Negro, F. Cesano, S. Casassa, D. Scarano, Materials **2023**,16,3644
[3] A. Akhundi, M. A. Zaker, A. Habibi-Yangjeh, ACS ES&T Engineering 2022**,** 2 (4), 564-585.

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FIS-PO-013

Charge Instability in Multimodular Push-Pull Systems:

Excited-State Symmetry Breaking Under the Gaze of Ultrafast Time-Resolved Infrared Spectroscopy

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The interest for symmetric multi-branched electron donor–acceptor dyes has considerably increased over the last decade. These compounds are usually characterized by a large two-photon absorption cross-section and have also been introduced as promising chromophores for thermally activated delayed fluorescence providing low singlet–triplet gap. Additionally, these multibranched dyes can be viewed as simple models of organic conjugated polymers and are particularly useful for understanding the electronic excited-state properties of these materials. Whereas, as expected for compounds that do not possess a permanent electric dipole moment, their absorption spectra show almost no solvent-dependence, their fluorescence spectra display a strong solvatochromism suggesting a dipolar S_1 state. This behavior was rationalized in terms of a break-up of the symmetry in the excited state driven by structural and solvent fluctuations.[1,2] In this regard, the aim of our research has been the investigation of three symmetric and multidonor-acceptor compounds bearing one or two C-C triple bonds per branch.[3]

Specifically, in this work, these compounds were investigated in a wide set of organic solvents, to evaluate the impact of the medium, the nature of the donor group and the presence of multiple C-C triple bonds on their excited state dynamics. The first part of this study was carried out by means of steady-state and advanced spectroscopic techniques, such as nanosecond and femtosecond UV-Vis transient absorption and femtosecond broadband fluorescence up-conversion as well as non-linear two-photon excited fluorescence. Despite useful information on the excited-state lifetime, the data collected by electronic spectroscopies do not present any clear feature that could be assigned to the transition from a symmetric and quadrupolar excited state to an asymmetric dipolar state. For this reason, we decided to employ, for the first time in this kind of multimodular push-pull compounds, the Time-Resolved Infrared Spectroscopy to resolve the spatial distribution of the excitation within the molecules and then to follow the occurrence of the Excited-State Symmetry Breaking.

References:

[1] F. Terenziani, A. Painelli, C. Katan, M. Charlot, M. Blanchard-Desce, J. Am. Chem. Soc., 2006, 128, 15742-15755
[2] B. Dereka, D. Svechkarev, A. Rosspeintner, A. Aster, M. Lunzer, R. Liska, A. M. Mohs, E. Vauthey, Nat. Comm., 2020, 11, 1925-1936
[3] Y. Rout, A. Cesaretti, E. Ferraguzzi, B. Carlotti, R. Misra, J. Phys. Chem. C, 2020, 124, 24631-24643

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FIS-PO-016

PHOTOSYNTHETIC BACTERIA AND THEIR COMPONENTS FOR BIOELECTRONICS

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Photosynthetic microorganisms and their molecular components represent attractive tools for harvesting and conversion of solar light. The new era of biohybrid devices relies on the exploitation of isolated structures from these microorganisms, or the entire living cells, as the active components for photoconversion in optoelectronic devices and photoelectrochemical cells [1]. The bacterial reaction center (RC) extracted from the purple non-sulphur bacterium *Rhodobacter (R.) sphaeroides* has been integrated into photoactive transistors [2]. Polydopamine (PDA), a biocompatible polymer produced *via* self-oxidative polymerization of the dopamine monomer, has been used to immobilize RC without altering the enzymatic photoactivity, and producing photocurrents in photoelectrochemical cells [3].

Finally, assessed PDA biocompatibility with *R. sphaeroides* cells [4], we have been investigated different approaches for interfacing intact photosynthetic microorganisms with electrodes, enabling photoconversion of whole living cells of *R. sphaeroides* and *R. capsulatus*, using PDA as the interface material either as a coating on the cells' surface, or as a film entrapping the cells on the electrode surface [5, 6].

References:

[1] F. Milano, A. Punzi, R. Ragni, M. Trotta, G. M. Farinola, Adv. Funct. Mater. 2019, 29, 1805521.
[2] M. Di Lauro, S. la Gatta, C.A. Bortolotti, V. Beni, V. Parkula, S. Drakopoulou, M. Giordani, M. Berto, F. Milano, T. Cramer, M. Murgia, A. Agostiano, G.M. Farinola, M. Trotta, F. Biscarini, Adv. Electronic Mater. 2020, 6 (1), 1900888.
[3] M. Lo Presti, M. M. Giangregorio, R. Ragni, L. Giotta, M. R. Guascito, R. Comparelli, E. Fanizza, R. R. Tangorra, A. Agostiano, M. Losurdo, G. M. Farinola, F.Milano, M. Trotta, Adv. Electron. Mater. 2020, 2000140.
[4] R. Labarile, M. Varsalona, D. Vona, P. Stufano, M. Grattieri, G.M. Farinola, M. Trotta, MRS Advances 2023, 8(8), 423–428.
[5] R. Labarile, D. Vona, M. Varsalona, M. Grattieri, M. Reggente, R. Comparelli, G.M. Farinola, F. Fischer, A.A. Boghossian, M. Trotta, Nano Research 2023, 17, 875-881.
[6] G. Buscemi, D. Vona, P. Stufano, R. Labarile, P. Cosma, A. Agostiano, M. Trotta, G. Farinola, M. Grattieri, ACS Applied Materials & Interfaces 2022, 14 (23), 26631–26641.

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FIS-PO-017

New computer models for passive permeation through the lipid bilayer and protein channels

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The transport of substances across lipid membranes, either passive or active, is of vital importance for any living organism.[1] The permeability of the membrane determines which substances can pass through it and depends on the physicochemical properties of both the membrane components and the permeating substance. Being able to predict permeability is fundamental in therapeutic agent design, because even the most active one becomes ineffective if it is unable to cross the membrane(s) and reach the target. Our work is focused on passive transport and aims at providing a mathematical model that explicitly considers all the main processes that are involved. Mathematical models presented in the literature[2] are either too simplistic, by focusing on a few physicochemical parameters, or too complex, by including so many parameters to result of low human interpretability. Others are too time and resource demanding making them unsuitable for screening campaigns. Despite the model, consistent experimental data are needed to check it. However, methods for permeability measurement are only a few, each one with its own limitations. Starting from previous studies of the research group,[3] we measured the permeability of antibiotics and other substrates (40 in total) through E. coli outer membrane porin OmpF. We used the liposome swelling assay,[4] which although dates back to the 80s, it provides direct evidence of permeation while being simple and focused on the channel translocation. The results have been used to build a machine learning model with the smallest possible number of descriptors to preserve interpretability. We have also investigated the direct passive transport across the lipid bilayer, by using the same experimental protocol but removing the protein channel. Both non-permeant and permeant species have been investigated, thus, obtaining water and substrates apparent permeability coefficients. Good repeatability was achieved even by reducing substrate concentration as much as possible. We observed that vesicle swelling offers too low sensitivity, whereas working in the direction of shrinkage gave the best results. We built a mathematical model able to reconstruct the experimental curves by including all the relevant processes, namely, partition, diffusion, and osmotic pressure, with the corresponding parameters. Simulated curves were fitted to the experimental data through a Monte Carlo scheme. This approach allows to compare different substrates more precisely. The model allows to investigate in-silico the effect of each parameter separately.

References:

[1] W. Stillwell, in An Introduction to Biological Membranes (2nd ed), Chap. 19, Elsevier, 2016, 423-451.
[2] A. Bernardi, et al., Membranes 2023, 13, 851.
[3] H. Bajaj, et al., ACS Nano 2017, 11, 4598-4606.
[4] H. Nikaido, E.Y. Rosenberg, Journal of Bacteriology 1983, 153, 241-252.

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FIS-PO-018

Photocross-linked gelatin methacryloyl microparticles prepared by double emulsion method for drug delivery

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Despite the well-known versatility and biocompatibility of gelatin, this biopolymer has been underutilized due to the potential toxicity of traditional cross-linking agents, *e.g.*, glutaraldehyde, which are generally used to stabilize gelatin-based microparticles in aqueous environments at physiological temperature. Here we proposed a safer and more biocompatible alternative method which integrates a straightforward and effective double emulsion preparation protocol[1] with UV-activated cross-linking[2]. Photocross-linkable gelatin methacryloyl (GelMA), which has been proven to be suitable for tissue engineering[3] and drug delivery[4] applications, was selected as primary material for the preparation of porous microparticles. Photocross-linked GelMA porous microparticles with different degrees of substitution were comprehensively investigated using a variety of techniques, including optical and electron microscopy, as well as scattering methods, highlighting the significant impact of substitution degree, and photocross-linking on the microparticles' dimensions, surface morphology, nanoscale organization and swelling abilities. To demonstrate their potential application as delivery vehicles, the photocross-linked microparticles were loaded with a model drug (methylene blue) and the release in water was studied at two different temperatures (25°C and 37°C), resulting in a direct relationship between the release temperature and the drug quantity released. The release patterns, fitted with the empirical Weibull function, suggest a Fickian diffusion mechanism. Our results mark a substantial advancement towards the effective design and preparation of functional, porous gelatin-based cross-linked microparticles suitable for drug delivery applications.

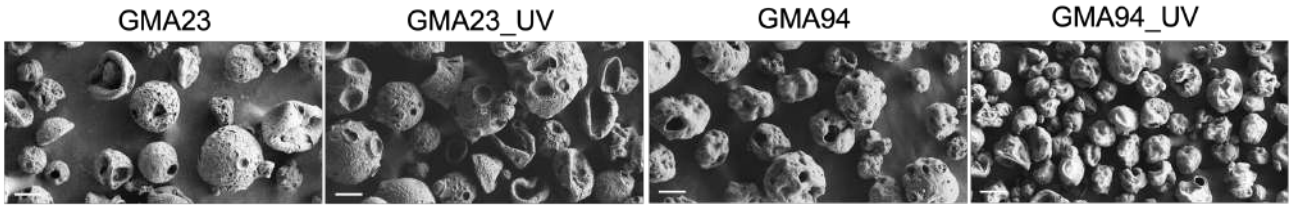

Figure 1: FE-SEM micrographs of GelMA porous microparticles. The scale bar is 100 µm.

References:

[1] R. Gelli, G. Mugnaini, T. Bolognesi, M. Bonini, Langmuir 2021, 37 (44), 12781-12789.
[2] C. E. Campiglio, N. Contessi Negrini, S. Farè, L. Draghi, Materials 2019, 12, 2476.
[3] J. Jiang, A. Liu, C. Chen, J. Tang, H. Fan, J. Sun, H. Fan, Colloids and Surfaces B: Biointerfaces 2020, 118, 110798
[4] A. H. Nguyen, J. McKinnery, T. Miller, T. Bongiorno, T. C. McDevitt, Acta Biomaterialia 2015, 13,101– 110.

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FIS-PO-019

Valorization of dairy waste stream: chemoenzymatic synthesis of bio-based emulsifiers

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Sugar fatty acid esters (SFAEs) are a class of non-ionic surfactants characterized by excellent interfacial tension reduction capability, low toxicity, and biodegradability. These properties make SFAEs extremely promising for cosmetic and food applications as emulsifiers, alongside to the fact that they can be obtained from renewable sources, thus answering the need for evermore sustainable and circular chemistry.[1] Herein, cheese whey permeate (CWP), the main waste stream of dairy industry, was used as starting material to produce bio-based surfactants. Specifically, CWP was enzymatically hydrolysed into a mixture of glucose and galactose which was then submitted to a two-step chemoenzymatic synthetic protocol.[2] The first step (Fischer glycosylation) was not straightforward since several parameter influenced both yield and isomeric ratio. Therefore, the reaction conditions were optimized by means of a chemometric study. In the second step an enzymatic esterification reaction was conducted to obtain an isomeric mixture of *n*-butyl 6-*O*-palmitoyl-D-glycosides and its surfactancy was deeply investigated in terms of static/dynamic interfacial tension and water-in-sunflower oil (W/O) emulsion stabilization capacity over time. Computational studies were conducted on isolated couples of anomers, namely pyranosides- and furanosides-based compounds, to study the role of the ring size on the final emulsifying properties of the isomeric mixture.

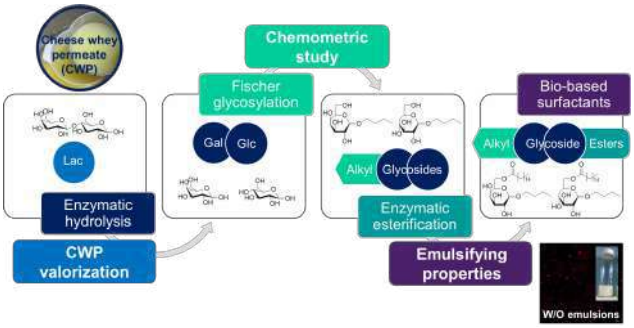

Figure 1: Chemoenzymatic synthesis of bio-based emulsifiers from cheese whey permeate.

This work has been supported by Fondazione Cariplo, grant n°2020-1094.

References:

[1] B. Estrine, S. Marinkovic, J. François, Biobased surfactants, 2019, 1, 365 – 385.
[2] S. Sangiorgio, E. Pargoletti, M. Rabuffetti, M.S. Robescu, R. Semproli, D. Ubiali, G. Cappelletti, G. Speranza, Colloids and Interface Sci. Commun., 2022, 48, 100630.

FIS-PO-020

CTAB and a thermoresponsive bile acid derivative form catanionic tubules: sorting out an unexpected composition ratio and a temperature induced tubule-tubule transformation

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Self-assembly catanionic nanotubes are an odd architecture with relevant applicative interests. Their formation is very rare and there is currently no clear understanding of their chemistry. Here we report the intriguing assembly of mixtures formed by CTAB (flexible surfactant) and a thermoresponsive bile salt derivative[1] (rigid surfactant, Tb or TBAC). The pure bile salt derivative aggregates into tubules at a temperature above 37°C.When catanionic mixtures are prepared, a peculiar phenomenon was observed: nanotubes form at a specific critical ratio, requiring a minimum portion of CTAB, namely bile salt derivative : CTAB = 9:1. Slightly different variations in CTAB amount, both up or below the critical ratio, create unfavorable conditions for the tubules homogeneity and stability. UV, Circular dichroism, SAXS and microscopy data suggest a molecular packing where the bile acid derivative creates the scaffold of the tubule's bilayer whereas CTAB co-adjuvates in screening the charged heads. Moreover, this system enables for a temperature induced tubule-tubule interconversion: indeed, by increasing the temperature on the catanionic tubules, the catanionic tubules break up and the pure Tb tubules form. The data highlight an innovative case within the narrow umbrella of catanionic nanotubes and encourage further exploration of the possibility offered by the catanionic combination of rigid molecules and flexible surfactants.

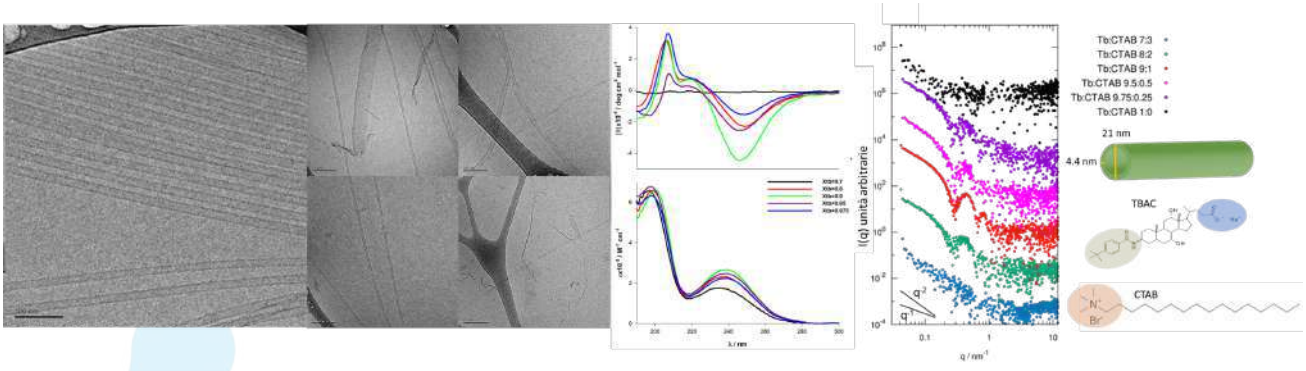

Figure 1: UV, Circular dichroism, SAXS and Cryo-TEM data.

References:

[1] L. Galantini, C. Leggio, Soft Matter 2009, 5, 3018–3025.

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FIS-PO-021

Multiscale Characterization and Imaging of nano/bio-materials by X-ray microdiffraction and microscopy

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X-ray scattering techniques can provide a large amount of structural and morphological information, both at the atomic and nano-scale, and are thus particularly suited to study composite/nanostructured materials. The crystalline components are mainly studied by Wide Angle X-ray Scattering (WAXS), providing information on the crystallinity and crystalline phases, as well as on possible texture. The nanoscale structure/morphology can be assessed based on the Small Angle X-ray Scattering (SAXS) signal and related to the possible crystallinity through combined SAXS/WAXS mapping. SAXS/WAXS/Absorption Microscopy is particularly suited to study biological tissues (or any structured material) with nano and/or atomic scale periodicity. The availability of high brilliance X-ray micro-sources for laboratory equipment allows nowadays to perform the aforesaid advanced X-ray characterization, in both transmission and reflection geometries, in the home laboratory, being such X-ray sources considered as "synchrotron-class". The synchrotron-class micro-source combined with the SAXS/WAXS system installed at IC-Bari (XMI-L@b, https://www.ic.cnr.it/laboratorio/xmi-lb/) has been successfully applied to the study of free-standing nano/bio-materials. A in-house developed package (SUNBIM) for the collection and analysis of X-ray microscopies with absorption and/or diffraction contrast, as well as data reduction for transmission and reflection geometries is freely available at http://www.ba.ic.cnr.it/softwareic/sunbimweb/, and constantly updated. Moreover, it has been successfully applied in grazing incidence reflection geometry (GISAXS/GIWAXS) for the study of several nanostructured films for advanced electronic applications. New tools with their respective application examples will be showcased, aimed at enhancing the quality of extracted information, distinguishing variations in density from structural variations in materials.[1-2] This work was supported by the research project "Potentiating the Italian Capacity for Structural Biology Services in Instruct Eric" (Acronym: ITACA.SB, project n° IR0000009) within the call MUR D.D. 0003264 dated 28/12/2021 PNRR M4/C2/L3.1.1, funded by the European Union NextGenerationEU.

References:

[1] D. Siliqi, L. De Caro, M. Ladisa, F. Scattarella, A. Mazzone, D. Altamura, T. Sibillano and C. Giannini. SUNBIM: a package for X-ray imaging of nano- and biomaterials using SAXS, WAXS, GISAXS and GIWAXS techniques. J. Appl. Cryst. (2016). 49, 1107–1114.

[2] D. Altamura, R. Lassandro, F. A. Vittoria, L. De Caro, D. Siliqi, M. Ladisa & C. Giannini. X-ray MicroImaging Laboratory (XMI-LAB), J. Appl. Cryst. (2012) 45, 869-873.

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FIS-PO-023

Development of mRNA nanovectors as non-viral tool to produce CAR-T cells: future prospectives and applications for CAR-T cell therapy of Glioblastoma

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Biocompatible Nanoparticles (NPs) have been extensively investigated in the therapeutic field for their application as drug and gene delivery vectors. In particular, lipid nanoparticles (LNPs) have been used in clinical setting as mRNA-based vaccines. LNPs have also showed to be a promising tool to generate personalized therapies in cancer immunotherapy, for example in the production of CAR-T cells[1].

The tremendous success of CAR-T cells in the treatment of B cell malignancies has revolutionized the field of cancer immunotherapy, but they have not been yet effective in treating all solid tumors. Specifically, for glioblastoma, a rare but serious and untreatable primary brain cancer, phase I clinical studies demonstrated safety, but modest efficacy. Recently, a retroviral-based CAR targeting B7-H3 (a membrane protein overexpressed in more than 70% of GBM, as well as in other cancers, but absent in normal tissues) was developed. B7-H3.CAR-Ts recognize and kill GBM cell lines *in vitro* and increase survival in GBM xenograft models[2]. Although these encouraging preclinical results, developing engineered CAR-Ts at clinical levels by viral-based gene transfer is costly and logistically difficult since it requires cell factories specifically designed for producing clinical grade viral vectors and transduced CAR T cells[3].

We propose the use of T cells, in which B7-H3.CAR expression will be obtained through non-viral lipid-based mRNA nanovectors (NVs), to demonstrate the efficacy of mRNA-B7-H3.CAR-Ts in a preclinical model of glioblastoma. We show the synthesis and characterization of mRNA loaded lipid-based nanovectors and their transfection efficiency. Positive results will accelerate the use of CAR-T cells in the clinical setting of glioblastoma, thus addressing one of the most urgent unmet needs in oncology.

References:

[1] X. Hou, T. Zaks, R. Langer, Y. Dong, Nat. Rev. Mater. 2021, **6**, 1078 – 1094.

[2] D. Nehama, N. Di Ianni, S. Musio, D. Hongwai, M. Patané, B. Pollo, G. Finocchiaro, J.J.H. Park, D.E. Dunn, D.S Edwards, J.S. Damrauer, H. Hudson, S. R. Floyd, S. Ferrone, B. Savoldo, S. Pellegatta, G. Dotti, EBioMedicine 2019, **47**, 33-43.

[3] M. Irving, E. Lanitis, D. Migliorini, Z. Ivics, S. Guedan, Hum. Gene Ther. 2021, **32**, 1044-1058.

FIS-PO-024

Physicochemical insights into peptide-based targeting of G-quadruplex DNA structures

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Protein-DNA interactions are crucial for fundamental cellular processes, including transcription and replication. In addition to interacting with double-stranded DNA, proteins also recognize the noncanonical DNA secondary structures, such as G-quadruplexes (G4s).[1] G4s are polymorphic structures formed within guanine (G)-rich strands, characterized by the presence of at least two G-tetrads, i.e. cyclic planar arrays of four guanines.[2]

We have explored whether it is possible to exploit the DNA recognition motif of G4-binding proteins to obtain peptides that selectively target G4s. Many G4-binding proteins feature an arginine and glycine-rich motif known as the RGG or RG-rich motif. Although this motif plays a crucial role in the recognition of such non-canonical structures, their interaction is still poorly understood.[3]

Aiming to develop peptide-based molecules capable of targeting G4s, we have focused our attention on two peptides: one containing an RGG motif shared by numerous human G4-binding proteins (NIQI),[4] and another derived from the DNA-binding domain of the yeast protein Rap1 ($Myb^{397-415}$).[5] We have studied their interaction with biologically relevant DNA G4s with different topologies (parallel, antiparallel, or hybrid) using a combination of physicochemical techniques, including circular dichroism spectroscopy, microscale thermophoresis, and isothermal titration calorimetry (ITC). Both peptides exhibited the ability to selectively bind and stabilize some G4s. ITC experiments have allowed us to elucidate the thermodynamics of peptide-G4 interactions. We also shed light on the key amino acids involved in the binding process by introducing point mutations.

Our findings contribute to lay the basis for the development of a new class of peptide-based G4 ligands as an alternative to small molecules.

References:

[1] V. Meier-Stephenson, Biophys. Rev. 2022, 14, 635 – 654.
[2] S. Burge, G.N. Parkinson, P. Hazel, A.K. Todd, S. Neidle, Nucleic Acids Res. 2006, 34, 5402 – 5415.
[3] V. Brazda, J. Cerven, M. Bartas, N. Mikyskova, J. Coufal, P. Pecinka, J. Cerven, M. Bartas, N. Mikyskova, J. Coufal, P. Pecinka, Molecules 2018, 23, 2341 – 2357.
[4] N. Grasso, R. Graziano, S. Marzano, F. D'Aria, F. Merlino, P. Grieco, A. Randazzo, B. Pagano, J. Amato, Int. J. Bio. Macromol. 2023, 253, 126749 – 126759.
[5] A. Traczyk, C.W. Liew, D.J. Gill, D. Rhodes, Nucleic Acids Res. 2020, 48, 4562 – 4571.

FIS-PO-025

Towards green protein-based nanohybrids as adaptive surfactants: study of protein-NP interaction for a better comprehension of interfacial properties of their films

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Proteins have surface active properties that make them able to adsorb at liquid interfaces [1] stabilizing emulsions and foams; moreover, with respect to synthetic surfactants, they are significantly more biodegradable and might also be obtained by waste materials, representing a promising eco-sustainable alternative to surfactants. However, given their large dimensions and complex multi-ordered structure, each characterized by its intrinsic flexibility and adaptability to environmental conditions, their adsorption properties dramatically depends on environmental conditions [2]. A possible strategy to stabilize protein films under dynamical conditions is based on the exploitation of nanoparticles (NPs), which when decorated by proper additives can adsorb irreversibly at interfaces thanks to their high desorption energy [3]. In this respect, protein-NP interactions and NP-induced protein structural changes in bulk solution are expected to play a crucial role in guiding adsorption at interface and determining interfacial film behaviour.

Here we present a comprehensive analysis, performed by a combination of spectroscopic and scattering techniques, of the interaction process in bulk conditions between model proteins such as Bovine Serum Albumin and negatively charged SiO_2 NPs as a function of different environmental parameters such as pH, ionic strength and salt nature, aimed at understanding and rationalizing the properties of mixed protein-NP interfacial films.

References

[1] T.T-Y. Le et al J Mol Liq 347 (2022) 118305
[2] P. Gahtori et al Langmuir 39 (2023) 15487
[3] R. Ruffino et al., Langmuir. 38 (2022) 12281

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FIS-PO-026

Quadruplex-forming oligonucleotides as tools in anticancer therapy: a physicochemical insight

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G-quadruplexes (G4s) are peculiar DNA structures formed by guanine-rich sequences characterised by guanine tetrads stabilized by Hoogsteen hydrogen bonds and monovalent cations[1]. G4s have been found in many sequences of human genome, such as promoter regions of the genes, including many oncogenes, therefore representing promising anticancer drug targets[2]. Particularly, G4 formation in oncogene promoters and their stabilization with G4-ligands can downregulate the expression of the corresponding oncoproteins[3]. In this context, the deep understanding of the energetics of G4 structure stability and their interaction with ligands is of pivotal importance to design molecules with highest affinity for G4s and improved biological activity[4]. In this regard, we applied calorimetric and spectroscopic methodologies in combination with biochemical and biological assays.

The energetics of molecular interactions and dynamical behaviour of G4/helicase complexes in the absence and presence of well-known G4 ligands, which can significantly interfere with several biological processes involving G4s, have also been investigated[5]. To obtain information on G4/helicase and G4/drug/helicase interactions in vitro, complementary physicochemical and biochemical methodologies were used for this study as well.

Acknowledgment: This work was supported by Italian Association of Cancer Research, AIRC (grant IG 2019 - ID. 23198)

References:

[1] D. Sen, W. Gilbert, Nature 1988, 334, 364 – 366.
[2] H. Tateishi-Karimata, N. Sugimoto, Chem. Commun. 2020, 56, 2379 – 2390.
[3] S. Balasubramanian, L.H. Hurley, S. Neidle, Nat. Rev. Drug Discov. 2011, 10, 261 – 275.
[4] F. D'Aria, B. Pagano, L. Petraccone, C. Giancola, Int J Mol Sci. 2021, 22, 448 – 460.
[5] E. De Piante, F. D'Aria, L.M.R Napolitano, J. Amato, S. Pirrello, S. Onesti, C. Giancola, Sci. Rep. 2023, 13, 12610 – 12620.

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FIS-PO-027

Glutathione Peroxidase-like Activity of Functionalized Tellurides: Insight into the Oxidation Mechanism through Activation Strain Analysis

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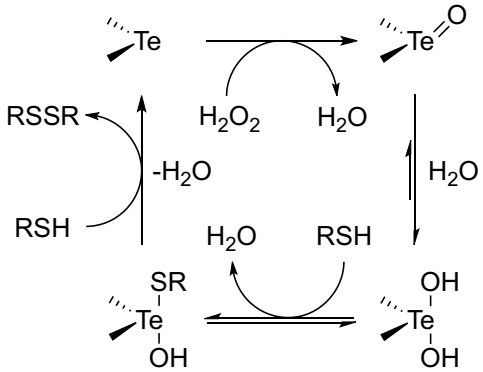
Glutathione peroxidases (GPxs) are a family of selenium-based enzymes that catalyze the reduction of hydroperoxides in living organisms, counteracting the formation of reactive oxygen species that may lead to cellular damage and degenerative pathologies.[1] Organotellurium compounds have been investigated as possible GPx mimics, since they often display a higher catalytic activity compared to the corresponding S and Se-equivalents (**Figure 1**). Recently, several novel β-substituted diorganotellurides were synthesized and evaluated as catalysts for the reduction of hydrogen peroxide.[2] The chemical nature of the substituent proved to have a crucial effect on the rate of oxidation of the thiol substrate. Specifically, the presence of a β-amino group on the telluride lead to a much higher catalytic activity, compared to other substituents.

In our study, an *in silico* approach was adopted to interpret experimental results and draw general conclusions on the reactivity of organochalcogenides with H_2O_2. The computational work has been conducted within the framework of Density Functional Theory, combined with the Activation Strain Analysis. The calculated activation energies for the reaction of the chalcogenides with H_2O_2 are consistent, both in gas-phase and in solvent, with the experimental evidence. We thereby conjecture a *low-barrier* alternative reaction mechanism, which is presumably involved when the β-amino moiety is found in its protonated form.



Scheme 1: GPx-like catalytic cycle of diorganotellurides. Two equivalents of a thiol substrate (RSH) per cycle are consumed to restore the initial oxidation state of the catalyst.

References:

[1] L. Flohé, S. Toppo, L. Orian, Free Rad. Biol. Med. 2022, 187, 113-122.
[2] D. Tanini, A. Grechi, L. Ricci, S. Dei, E. Teodori, A. Capperucci, New J. Chem. 2018, 42, 6077-6083.

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FIS-PO-028

Plasmonic thin films fabrication by additive manufacturing for biomedicine

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Lab-on-a-chip (LOC) devices have become widespread to study cellular processes and to implement disease modelling.[1] They merge microfluidic, microelectrodes and sensors, and make it possible to grow and monitor living cells. The core of the architecture is about the microelectrodes design. The established technique for thin film patterning is physical vapor deposition (PVD).[2] Despite being able to produce detailed microelectrodes, it is an expensive and time-consuming method. The spray coating technique, on the other hand, allows thin metallic layers to be produced easily and quickly. The advantages of this technique are manifold: a large area deposition can be achieved using less material and at the same time keeping the material properties unchanged.[2] Furthermore, by using appropriate shadow masks, it is possible to obtain microelectrodes with resolutions of a few µm.[3] It is herein presented the application of inkjet printing technology to produce water-soluble shadow masks, which will be used to produce thin nanostructured plasmonic films with a thickness of a few hundred nanometers. The presented approach is used for fabrication of metal microelectrodes with desired geometry, in an easy, fast, and greener way than traditional PVD techniques. In addition, spraying gold nanoparticles (AuNPs) produced by laser ablation in solution (LASiS) enables the formation of nanostructured films suitable for the occurrence of the SERS effect, allowing the detection of surface-adsorbed molecules. This would make it possible to exploit a further method - in addition to the established electrical and optical methods - to monitor the health and growth of living cells cultured on the surface of these devices.

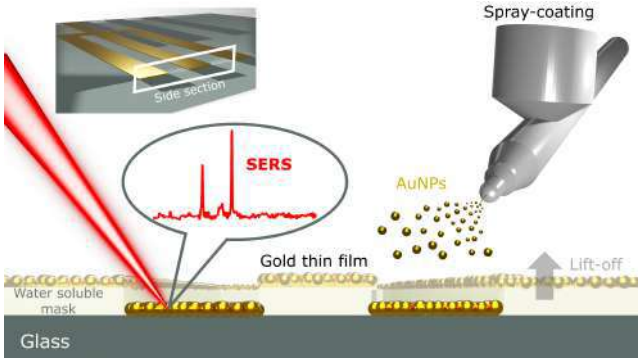

Figure 1: Schematics of the plasmonic microelectrode and the required fabrication steps.

References:

[1] K. W. Cho, W. H. Lee, B. S. Kim, D. H. Kim, Talanta, 2020, 219, 121269.
[2] D. S. Kim, J. Y. Jung, S. Seo, J. H. Kim, Applied Surface Science, 2023, 611, 155756.
[3] T. H. Park, J. Kim, S. Seo, Adv Funct Materials, 2020, 30, 2003694.

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Unveiling the impact of force fields and non-covalent interactions on the adsorption of (bio)molecules onto solvated metal nanosurfaces

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The computational investigation of (bio)molecule adsorption on metal surfaces at the atomistic level remains a challenging task. Within classical molecular dynamics (MD) simulations, selecting appropriate force fields (FFs) is crucial to accurately represent the complex interactions occurring at these interfaces.[1]

This contribution explores the influence of FFs on modeling the adsorption dynamics of selected biochemical molecules on an aqueous Au(111) surface by systematically comparing four combinations of molecule/gold/water FFs. Minimum distance, water coordination numbers, and Non-Covalent Interaction (NCI)[2] plots along the adsorption pathway are analyzed, and adsorption free energies are estimated.

Our findings, partly summarized in Figure 1, highlight how different FF combinations determine general trends in both structural and energetic features.[3] Also, the proposed protocol paves the way for a fruitful integration with multiscale QM/classical approaches for modeling surface-enhanced spectroscopies.[4]

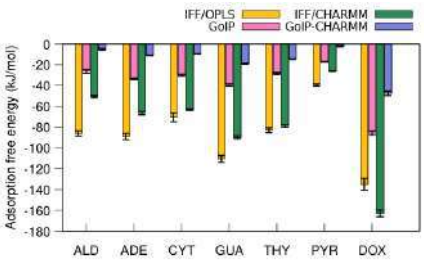

Figure 1: Adsorption free energies of the selected molecules - alanine dipeptide (ALD), adenine (ADE), guanine (GUA), cytosine (CYT), thymine (THY), pyridine (PYR) and doxorubicin (DOX) - obtained using the umbrella sampling method for all FFs.

References:

[1] M. Ozboyaci, DB Kokh, S. Corni, R. Wade, Q. Rev. Biophys. 2016, 49, 4, e4.
[2] R.A. Boto, F. Peccati, R. Laplaza, C. Quan, A. Carbone, J. Piquemal, Y. Maday, J. Contreras-García, J. Chem. Theory Comput. 2020, 16, 4150– 4158.
[3] S. Sodomaco, S. Gómez, T. Giovannini, C. Cappelli, J. Phys. Chem. A 2023, 127, 48, 10282–10294.
[4] P. Lafiosca, L. Nicoli, L. Bonatti, T. Giovannini, S. Corni, C. Cappelli, J. Chem. Theory Comput. 2023, 19, 12, 3616-3633.

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Cu/TiO_2 based catalysts for electrocatalytic CO_2 reduction

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Catalyst design to modify the electronic and geometric properties of copper-based electrocatalysts for carbon dioxide reduction reaction (CO_2RR) is a promising strategy to improve the selectivity towards one peculiar reaction product, such as methane, ethylene, or ethanol.[1]

In this work, two series of Cu-TiO_2 samples have been prepared in order to modify both the active surface area and the electronic structure of the Cu material. The study was carefully extended by varying the nominal weight ratio of copper (1%, 5%, 10%, 15%, 25%) deposited on a commercial TiO_2 P25 powder, employed as the Cu support, by means of two different synthetic methods: *i*) grafting (G), and *ii*) freeze drying (FD). Their catalytic activity has been assessed by loading the catalysts onto gas diffusion electrodes (GDEs) and using a flow-cell device.

The most efficient catalyst resulted to be the FD-prepared one containing 15 wt.% of copper, labeled as Cu/P25_15_FD and exhibiting significant selectivity for the production of ethylene. At an industrially relevant current density of 400 mA·cm^{-2}, the FD series suppressed hydrogen evolution reaction (HER) compared to the G series and CO_2RR products (CH_4, C_2H_4, CO) were favored by increasing the Cu loading. The high selectivity for CO_2RR of the FD series is in line with the fact that the rapid sublimation of the solvent allows the growth of small nanoclusters, as further confirmed by High Resolution-TEM images. Theoretical calculations in the literature support that a proper Cu atomic dispersion provides an abundance of catalytic sites, which is extremely advantageous for promoting CO_2RR.[2]

Further optimization of the most performing Cu/P25_15%_FD catalyst was achieved by systematically investigating the effect of additives, *i.e.* Nafion, added to the ink formulation of the spray-coated GDE and acting as an essential binding agent, simultaneously facilitating the CO_2 diffusion through the catalyst.[3] We found a clear correlation between the Nafion content and the FE toward CO_2RR, resulting in a bell-shaped trend peaking for the catalyst with a 4.1 mg cm^{-2} Nafion content. In this way we were thus able to further improve the production of ethylene, reaching a ca. 50% Faradaic efficiency.

References:

[1] X. Zhang, S-X. Guo, K. A. Gandionco, A. M. Bond, J. Zhang, Mater. Today Adv. 2020, 7, 100074.
[2] I. Barlocco, F. Maleki, G. Pacchioni, Chem. A Eur. J. 2023, 29, e202300757.
[3] M. Wang, L. Wan, J. Luo, Nanoscale 2021, 13, 3588-3593.

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SO_2 poisoning of Cu-CHA zeolite studied by *in-situ* IR spectroscopy

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Catalysts based on Cu-CHA zeolites, broadly employed for reducing NO_x emissions from diesel vehicles through the NH_3-SCR reaction, undergo low temperature deactivation by exposure to SO_2. It has been shown that deactivation occurs through a reaction with a $Cu^{II}[(NH_3)_4O_2]_2^+$ complex, which is generated during the activation of O_2 in the NH_3-SCR reaction cycle and plays an important role as reaction intermediate[1]. In this investigation, this reaction is investigated by vibrational spectroscopy using two samples with identical Cu loading but differing Si/Al ratios, to monitor the evolution of the NH_3 ligands in the process.

In-situ IR spectra were measured using an operando IR reactor cell working in transmission mode. The measurement comprised several steps: (1) pre-treatment in O_2 at 300°C, (2) reduction in 500 ppm NO/600 ppm NH_3 to form $[Cu^I(NH_3)_2]^+$, and (3) oxidation in 10% O_2 to form $Cu^{II}[(NH_3)_4O_2]_2^+$, followed by exposure to 50 ppm SO_2 in N_2 at 200°C. Steps (2-4) were executed at 200°C.

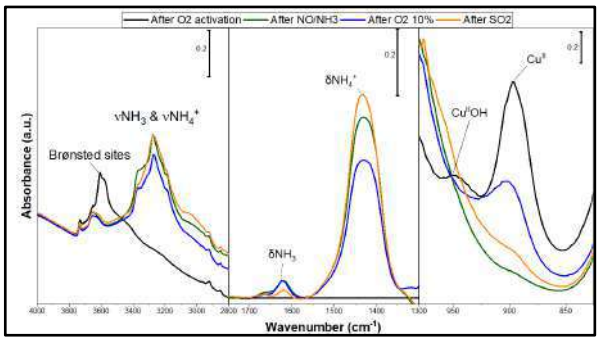

Figure 1- FTIR spectra of Cu-CHA with Cu=3.2 wt% and Si/Al=6.7 under different conditions at 200°C.

In-situ IR spectra show features related to a) Brønsted sites and νNH modes of NH_3 ligands and NH_4^+ formed by interaction with Brønsted sites; b) bending modes of NH_3 ligands and NH_4^+ (1622 cm^{-1} and 1430 cm^{-1}, respectively); c) fingerprints of framework coordinated Cu^{II} ions (fw-Cu^{II}) at 950 and 900 cm^{-1}, which disappear when the Cu ions are solvated by ligands. By following the changes during the different steps we observed an exchange between NH_4^+ and fw-Cu^{II} ions during the formation of the $Cu^{II}[(NH_3)_4O_2]_2^+$ complex, indicating that not all Cu ions are involved in its formation, with a dependence on the zeolite Si/Al ratio. During reaction with SO_2, some NH_3 ligands of the $Cu^{II}[(NH_3)_4O_2]_2^+$ are converted to NH_4^+ replacing fw-Cu^{II} sites, and some $(NH_4)_2SO_4$ is formed. [2] These results point out the mobility of Cu and NH_4^+ ions in catalytically relevant conditions and could help understand better the complex chemistry related to SO_2 poisoning.

References:

[1] A. Yu. Molokova, *JACS Au*, 2022, **2**, 787−792
[2] J. D. Bjerregaard, *J Catal*, 2023, **417**, 497–506.

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The role of metal-support interactions on the red-ox properties of Pd-TiO_2 catalysts

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In situ X-ray absorption spectroscopy (XAS), high-resolution scanning transmission electron microscopy (HR-STEM), Fourier-transform infrared (FTIR) spectroscopy, and density-functional theory (DFT) calculations were combined to uncover the effect of metal-support interactions on the red-ox properties of Pd NPs immobilized on TiO_2 (P25) using deposition-precipitation (Pd_dep) and photodeposition (Pd_photo) methods. These systems are employed in several catalytic reactions, including H_2 photocatalytic production,

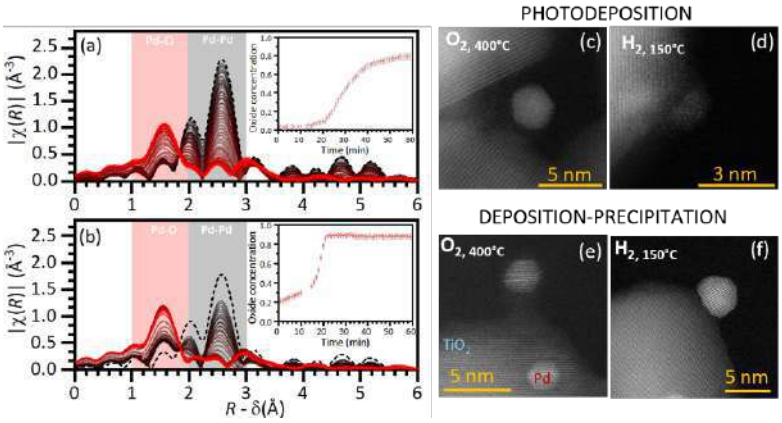

Figure 1. XAS data Pd_photo (a) and Pd_dep (b) samples during oxidation (from black to red); and HR-STEM for Pd_photo (c,d) and Pd_dep (e,f) under oxidizing and reducing conditions.

XAS data demonstrate that Pd_dep upon heating in O_2 experience surface oxidation already at room temperature (Figure 1b) and gets fully oxidized at ca. 200 °C. In contrast, the Pd_photo gets oxidized much slower, starting from ca. 250°C. According to *in situ* HR-STEM under oxidizing conditions, in Pd_dep a distinct PdO shell is formed around the NPs, that also reshape into a more spherical form with less contact with TiO_2. Pd_photo did not demonstrate any clear PdO shell formation. FTIR data reveal the presence of Pd^{2+} sites in Pd_photo, likely related to the presence of atomically dispersed Pd. Finally, DFT calculation predict a lattice contraction in Pd-particles upon oxidation, which was confirmed by XAS for Pd_dep, but was not observed for Pd_photo. Altogether, the observed data suggest a stronger metal-support interaction in Pd_photo sample, which strongly affects its red-ox properties compared to conventionally supported Pd. This work demonstrates the role of metal-support interactions on the red-ox properties of palladium NPs supported on TiO_2, which are crucial for the understanding their catalytic behavior, and suggests a strategy to tune these properties by varying the synthetic procedure.

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Insertion of Active Sites in ZEO-3 Matrix: A Promising Catalyst for Partial Oxidation of Bulky Molecules

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Zeolites are microporous silicates with a large variety of applications as catalysts, adsorbents, molecular sieves, and cation exchangers. Stable silica-based zeolites with extra-large pores are actively studied because they allow adsorption and processing of large molecules. Still, their synthesis procedures are usually challenging. In this work, a novel highly stable pure silica zeolite called ZEO-3 (IZA code: JZT) is being investigated.[1] This material has a multidimensional, interconnected system of extra-large pores open through windows made by 16 and 14 silicate tetrahedra, and is the least dense crystalline polymorph of silica, with a specific surface area of more than 1000 m^2/g. In preliminary synthetic attempts, it was found that with higher amount of the organic structure directing agent (OSDA), namely tricyclohexyl-methyl-phosphine hydroxide, i.e. $OSDA/SiO_2 = 0.82$ compared to the reference molar ratio 0.5 as from ref. 1, the structure is obtained along with higher crystallinity, even though the amorphous fraction increases upon calcination. Based on these preliminary results, further studies to correlate the effect of different concentration of OSDA ($0.5 < OSDA/SiO_2 < 1$) with the quality of the final material are ongoing. Future investigations will involve the insertion of metals such as Ti in the framework, to be exploited as catalytic active centres for partial oxidation of bulky molecules along with H_2O_2, a better understanding of the crystallization process, and the advanced characterization of the synthesized materials.

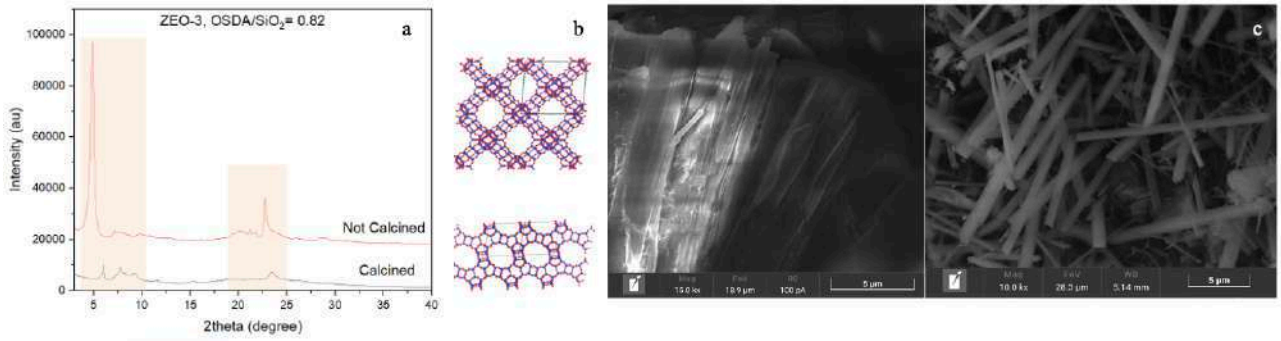

Figure 1: a) Effect of calcination on ZEO-3, $OSDA/SiO_2 = 0.82$, analysed by PXRD, b) Representation of (up)16- and (down)14-member ring windows of ZEO-3 framework. c) SEM images of the (left) not calcined ZEO-3 and (right) calcined ZEO-3.

References:

[1] Li, J., Gao, Z. R., Lin, Q. F., Liu, C., Gao, F., Lin, C., Zhang, S., Deng, H., Mayoral, A., Fan, W., Luo, S., Chen, X., He, H., Camblor, M. A., Chen, F. J., & Yu, J. (2023). Science (New York, N.Y.), 379(6629), 283–287.

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Effect of Plasmonic Nanoparticles on the Photocatalytic Properties of Nanostructured Silica

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Photocatalytic processes aim to use the energy of photons to drive reactions such as production of fuels and degradation of water contaminants. The most studied photocatalysts reported in the literature are nanostructured metal oxides, as TiO_2, ZnO, ZrO_2, etc. These are characterised by wide band gaps (3 – 5 eV) and absorption of the UV portion of the solar spectrum[1]. On the other hand, nanostructured silica has lower cost and restrained environmental impact, exhibiting, as well, photo-activation capacities in the UV region. Furthermore, thanks to its surface reactivity, silica represent an attractive substrate suitable for useful functionalisation aimed to improve the photocatalytic response[2,3]. In this perspective, particularly appealing strategies involve the exploitation of localised surface plasmon resonance (LSPR) effect of metal nanoparticles (MNPs) anchored on silica nanoparticles (SNPs). These materials have interesting synergistic effects when coupled[4], firstly endowing the composite material with enhanced absorption towards visible light, secondly assisting photocatalytic reactions by LSPR radiative and non-radiative decay processes (i.e scattering, energy transfer and heat conversion). In this work, a comprehensive study on the effect of both hydrophobic and hydrophilic MNPs on SNPs efficiency for the photo-degradation of organic pollutants is proposed. Thus, the evaluation of the parameters (i.e. MNPs size, stabilizer effect, aggregation) determining the photocatalytic properties of the composite materials is performed through a full characterization (Figure 1).

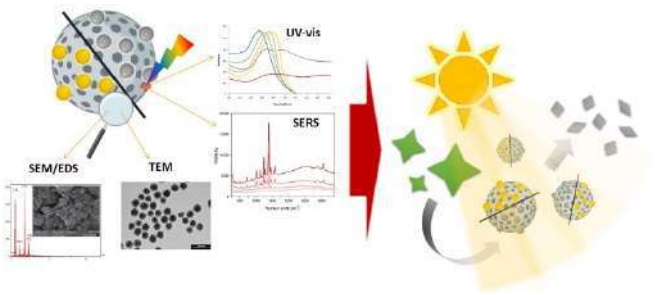

Figure 1: Graphical scheme of the scope of this research work. Some of the used techniques are reported.

References:

[1] A. Ganguly, O. Anjaneyulu, K. Ojha and A. K. Ganguli, CrystEngComm, 2015, 17, 8978–9001.
[2] R. Selvaggi, L. Tarpani, A. Santuari, S. Giovagnoli and L. Latterini, Applied Catalysis B: Environmental, 2015, 168–169, 363–369.
[3] R. D'Amato, G. Quaglia, R. Selvaggi, F. Marmottini and L. Latterini, Inorganics, 2023, 11, 430.
[4] G. Romolini, M. Gambucci, D. Ricciarelli, L. Tarpani, G. Zampini and L. Latterini, Photochemical and Photobiological Sciences, 2021, 20, 1161–1172.

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Multiscale multiconfigurational self-consistent field/fluctuating charges approach to simulate electronic properties of solvated systems

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Multi-reference self-consistent field (MCSCF) methods are used to overcome the limitations of single-determinant quantum mechanical (QM) approaches[1,2,3]. These methods incorporate many electronic configurations into what are known as multiconfigurational wave functions, allowing for a more accurate description of multireference electronic structures. This is particularly relevant for highly conjugated systems such as carotenoids or transition-metal enzymes[4,5].

Another crucial aspect, in addition to the choice of the QM method, is how to account for the influence of the environment surrounding the target molecule[6]. Indeed, when a molecule is embedded in a solution or a biological matrix, its properties can change significantly. Multiscale focused models, such as QM/Molecular Mechanics approaches, are successful methods for studying such complex systems[6,7]. Specifically, these approaches involve partitioning the system into a primary region treated at the QM level and a secondary region that describes the solvent, usually with electrostatics.

This study introduces a novel approach that couples MCSCF theory (CASSCF) with the fluctuating charges model (FQ)[8,9] to investigate the electronic properties of solvated systems. The hybrid QM/FQ model[10] captures the complex multi-configuration nature of molecules and the effects of the external environment, making it a promising tool for future research in various fields.

References:

[1] J. Hinze, J. Chem. Phys. 1973, 12, 6424 – 6432.
[2] E. Dalgaard, P. Jörgensen, J. Chem. Phys. 1978, 69, 3833 – 3844.
[3] B. Roos, P. Taylor, P.E.M. Siegbahn, Chem. Phys. 1980, 48, 157 – 173.
[4] R. Spezia, C. Zazza, A. Palma, A. Amedei, M. Aschi, J. Chem. Phys. A 2004, 32, 6763 – 6770.
[5] F. Neese, T. Petrenko, D. Ganyushin, G. Olbrich, Coord. Chem. Rev. 2007, 251, 288 – 327.
[6] T. Giovannini, F. Egidi, C. Cappelli, Chem. Soc. Rev. 2020, 49, 5664 – 5677.
[7] H. Lin, D. G. Truhlar, Theor. Chem. Acc. 2007, 117, 185 – 199.
[8] S. W. Rick, S. J. Stuart, B. J. Berne, J. Chem. Phys. 1994, 101, 6141–6156.
[9] C. Cappelli., Int. J. Quantum Chem. 2016, 116, 1532 – 1542.
[10] C. Sepali, L.Goletto, P.Lafiosca, M.Rinaldi, T. Giovannini , C. Cappelli, in preparation.

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Computational modeling of electronic excitations in solution

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The investigation of electronic transitions in solution is a useful tool to gather information on relevant biological systems. To this extent, accurate ab initio methods based on Quantum Mechanics (QM) can aid in the interpretation and rationalization of experimental results. Solvated systems are usually characterized by a very large number of atoms, and the straightforward application of QM methods is unfeasible from the computational point of view. A possible solution is to resort to multiscale modeling,[1,2] in which the solute is described at the QM level, while the solvent is modeled employing simplified embedding potentials. Among these methods, hybrid QM/Molecular Mechanics (MM) methods have proven to be particularly successful in the simulation of solvated systems.[3,4] In particular, QM/MM methods are capable of describing specific solute-solvent interactions such as hydrogen bonding patterns, that can play a role in the shaping of spectroscopic signals.[5]

From the solute's point of view, one of the most popular approaches for the calculation of excitation energies is Time-Dependent Density Functional Theory (TDDFT) since it represents a good compromise between accuracy and computational cost.[6] However, one of the major intrinsic drawbacks of TDDFT is the lack of nondynamical correlation, which is crucial for the simulation of multireference systems, e.g. conjugated systems or transition metal complexes.[7,8]

To overcome this limitation, in this contribution we propose a QM/MM computational strategy based on the combination of multi-configurational methods, grounded in the Complete Active Space Self Consistent Field (CASSCF)[9] approach, and the Fluctuating Charges (FQ)[10] force field. The resulting CASSCF/FQ method[11] is then applied to the calculation of vertical excitation energies of a set of molecules in solution, which paves the way for future applications on biological systems. A detailed comparison with reference and experimental data is also proposed.

References:

[1] A. Warshel, M.Levitt, J. Mol. Biol. 1976, 103, 227-249
[2] M. J. Field, P. A. Bash, M. Karplus, J. Comp. Chem. 1990, 11, 700-733
[3] H. M. Senn, W. Thiel, Angew. Chem. Int. Ed. 2009, 48, 1198– 1229
[4] H. Lin, D. G. Truhlar, Theor. Chem. Acc. 2007, 117, 185 – 199
[5] T. Giovannini, F. Egidi, C. Cappelli, Chem. Soc. Rev. 2020, 49, 5664
[6] Teale et al. Phys. Chem. Chem. Phys. 2022, 24, 28700-28781
[7] R. Spezia, C. Zazza, A. Palma, A. Amedei, M. Aschi, J. Chem. Phys. A 2004, 32, 6763 – 6770
[8] F. Neese, T. Petrenko, D. Ganyushin, G. Olbrich, Coord. Chem. Rev. 2007, 251, 288 – 327
[9] J. Olsen, Int. J. Quant. Chem. 2011, 111, 3267–3272
[10] S. W. Rick, S. J. Stuart, B. J. Berne J. Chem. Phys. 1994, 101, 6141–6156
[11] C. Sepali, L.Goletto, P.Lafiosca, M.Rinaldi, T. Giovannini , C. Cappelli, in preparation.

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S-Bearing Species at Interstellar Icy Grains: an *ab-initio* Study

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Binding energies (BEs) are crucial parameters to understand the evolution of molecular species in dense clouds, determining whether a species is frozen onto the grain surfaces or free in the gas phase. Nowadays, BEs are usually provided as single point values, however the predominant amorphousness of icy grains gives rise to a distribution of BE sites and values. Recently, ACO-FROST, an automatic procedure to simulate realistic icy grains has been released.[1] capable to build up models of amorphous ice up to 1000 molecules and to simulate a large variety of BE sites, see Figure 1 left panel.

In the present work, the aforementioned procedure was applied to compute BE distribution of S-bearing species, *i.e.,* H_2S, OCS, CH_3SH. S-species were selected in order to contribute to a long-standing issue in the field: the Sulphur depletion problem.[2] BEs were computed at DFT level (B97-3c) and then refined with one of the highest level of theory available (DLPNO-CCSD(T)). The previous reported BE values are overestimated with respect to our new BE distribution,[3] see Figure 1 central panel. Besides, frequencies distribution was calculated for OCS molecule and compared to the James Webb Space Telescope (JWST) observations[4] as reported in Figure 1 right panel. The computed distribution outstandingly reproduces JWST data indicating the robustness of the model studied and thus defining a novel computational tool to predict icy species vibrational features.

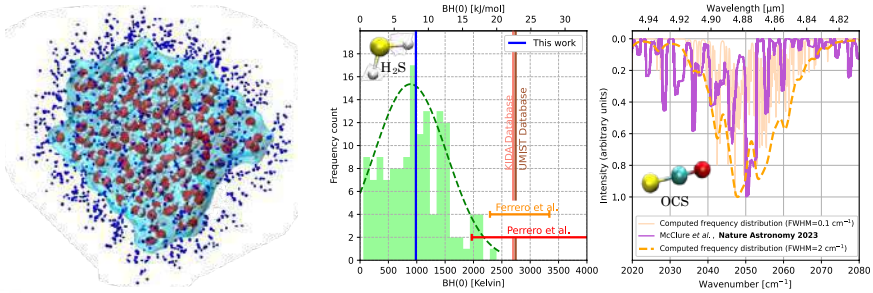

Figure 1: Left panel: 200-H_2O grain covered by a grid of 486 BE sampling sites. Central panel: BE distribution of H_2S compared with previous results. Right panel: Computed frequencies distribution for OCS molecule compared with JWST observations.

References:

[1] A. Germain, L. Tinacci, S. Pantaleone, *et al*., ACS Earth Space Chem. 2022, 6, 1286-1298
[2] R. Martin-Domenech, I. Jimenez-Serra, G. M. M. Caro, *et al*., Astron. Astrophys. 2016, 585, 1-9
[3] S. Ferrero, L. Zamirri, C. Ceccarelli, *et al.,* ApJ 2020, 904, 1-20
[4] M. K. McClure, W. R. M. Rocha, K. M. Pontoppidan, *et al.,* Nature Astronomy 2023, 1-13

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FIS-PO-043

Coffee for energy storage devices: a new tool for the energy transition

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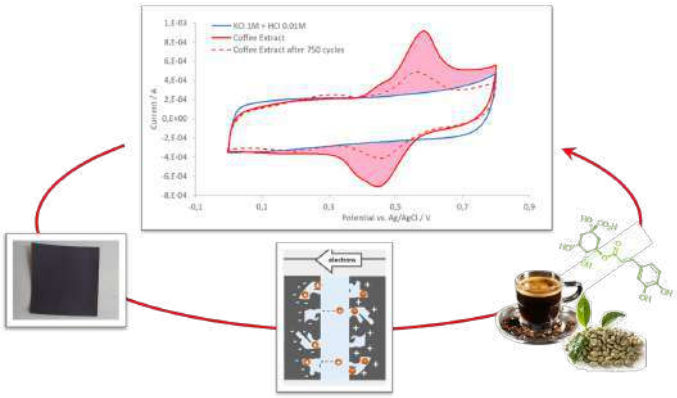
The extensive use of fossil fuels for energy production has brought about profound environmental changes. The aspiration to establish an energy transition based on natural and renewable sources clashes with the essential requirement for electrochemical energy storage devices to deliver high performance while relying on critical raw materials. Supercapacitors are fast gaining interest due to their intrinsic enhanced eco-friendliness, safety, long life-cycle, and high charge/discharge rates. Their major limitation, however, lies in the low energy densities in comparison to state-of-the-art metal-ion batteries. [1] To address this limitation and expand the applications of supercapacitors, a number of approaches have been explored, including the possibility of increasing the device energy density exploiting the Faradic current contribution of natural antioxidant molecules as redox additives in the electrolyte. [2] Waste generated from the coffee value chain has emerged as a promising solution. Despite being the third most consumed beverage globally, following water and tea, only approximately 1% by mass of the initial coffee cherry fruit is utilized, leaving over 10 million tons per year of by-products and waste that contain valuable chemicals, including antioxidant polyphenols, worth considering as resource. [3,4] We present a novel bio-based metal free supercapacitor developed from a carbon-based current collector, a water-based slurry and a bio-based binder formulation.

The symmetric supercapacitor exhibits a high specific capacitance of 105 F g^{-1} and an excellent cycle stability (capacitance retention after 10.000 cycles >95%). Preliminary findings indicate the feasibility of employing chlorogenic acid (extracted from coffee) as redox additive to aqueous electrolytes for advanced bio-based energy storage devices, enabling a new circular value chain based on waste from the coffee industry as possible sources for obtaining electrochemically active materials or molecules.



References :

[1] A. Abdisattar et al., Electrochem.commun. 2022, 142, 107373.
[2] T. Wang et al., J.Mater.Chem. A 2021, 9, 11839.
[3] P. Stufano et al., MRS Energy and Sustain. 2022, 9, 443-460.
[4] J. Selinger et al., Nanomaterials 2022, 12, 2647.

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Metal-doped active carbon from agro-food waste for solid state hydrogen storage

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Amidst the increasing demand for green energy and the pressing necessity for decarbonization to counteract the detrimental effects of greenhouse gas emissions, hydrogen (H_2) emerges as a promising, sustainable, and environmentally friendly renewable carrier and energy storage medium. However, unlocking its full potential necessitates the development of efficient and cost-effective storage systems. The utilization of porous materials such as Activated Carbons (ACs) for hydrogen adsorption represents an optimal solution for this issue. This kind of material can be easily prepared through a first step of pyrolysis of the biomass, obtaining the so-called *biochar*, followed by a thermochemical activation step to achieve a microporous structure.

These carbon-based materials boast numerous advantages, including low mass density and high storage capacity. Noteworthy results have been achieved by our research group using ACs derived from agri-food wastes, demonstrating hydrogen adsorption values of 4.2 wt% and 3.9 wt% at 77K and 6 bar on materials derived from melon peels and asparagus stems, respectively. However, the requirement to maintain extremely low temperatures poses a significant challenge, particularly for automotive applications.

Consequently, there is a growing interest in exploring Metal-Doped ACs. Exploiting the interactions between hydrogen and metallic nanoparticles (NPs) offers the potential to push the storage mechanism towards chemisorption, enabling higher operating temperatures, closer to ambient conditions. The spillover effect, in particular, is based on the dissociation of H_2 molecule on metal NPs and the migration of H atoms in the material, enhancing storage performance. To deepen this behaviour, ACs can be decorated with metals using, for example, the impregnation method. This technique, commonly employed in catalyst preparation [1], consists in stirring the solution of the metal precursor (*e.g.* nitrates of transition metals) with the carbon material, followed by chemical reduction or thermal treatment, in order to obtain zero-valent metal NPs dispersed in the carbon matrix [2]. The effect of different metals and experimental conditions is deeply investigated.

References:

[1] N.M. Deraz, J Ind Environ Chem 2018, 2, 19-21
[2] A. F. Peixoto, et al., Catalysts 2022, 12, 207.

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Perovskite-based high-entropy materials by solid-state microwave-assisted synthesis

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In the last decade the high-entropy materials (HEM) aroused hype in the scientific community[1] due to their versatility and properties tunability for a wide range of application, such as energy storage, catalysis, solar energy harvesting[2] among others. We refer to "high-entropy material" as a defined compound obtained by the combination of five or more elements (not as dopant), whose synergistic interaction, i.e. *cocktail effect* confers original properties respect to a pure metal or precursor[3]. However, the further addition of atoms in a crystalline structure causes a distortion of the lattice, due to the difference in the atomic radii. Therefore, the formation of HEM, should lie on crystalline structures that are more prone to perturbation, in order for new atoms to be host. Perovskites (general formula = ABO_3) come to the rescue, since they feature two cation sublattice sites, which make the structure more flexible and therefore they could be employed as building block for the HEM.

HEM are usually prepared by solid-state reactions, through mechanical treatment, sintering or a combination of both[4]. Especially for high-entropy oxides, the sintering step is necessary, which is indeed the most energy-consuming process. Alternatively, the heat treatment could be replaced by the microwave-assisted heating that dramatically decreases the amount of required power, given the reduced processing time[5]. In addition, such a high-heating-rate process provided by solid-state microwave syntheses (MWS) promotes non-equilibrium reactions, effectively achieving metastable phases such as the HEM.

In this work, the MWS is employed to obtain various perovskite-based HEM. The reference structure is $BaTiO_3$, where the perovskite B site (Ti) was partially substituted from three different elements in the same ratio: $Ba(Ti_{0.25}Zr_{0.25}Y_{0.25}Hf_{0.25})O_3$. To get to this phase, a crucial role is played by the tuning of the MWS parameters, such as heating rate, dwelling time, and final temperature, which could also provide multiple formation pathways, through intermediate phase as $Ba_{1.08}Y_{0.11}Hf_{0.91}O_3$, as confirmed by *ex situ* X-ray powder diffraction (PXRD). The effects of syntheses conditions are also investigated by scanning electron microscope (SEM) and Energy Dispersive X-ray Analysis (EDX), to evaluate both morphology and homogeneity of the final products, which are key parameters for the overall performance of the HEM.

References:

[1] E. George, P. & Ritchie, R. O. MRS Bull. (2022) 47, 145–150.
[2] S. Barbarossa, et al. J. Alloys Compd. (2023) 935, 167965.
[3] M. Anandkumar, & E.Trofimov. J. Alloys Compd. (2023) 960, 170690.
[4] R. Z. Zhang, & M. J. Reece. J. Mater. Chem. A (2019) 7, 22148–22162.
[5] C. Singh, V. Khanna, & S. Singh. Mater. Today Proc. (2023) 73, 241–248.

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Impact of Lithium Halides Redox Mediators on Singlet Oxygen Evolution in Aprotic Li-O2 Batteries

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Aprotic lithium−oxygen batteries (aLOBs) are considered as one of the most interesting high density secondary batteries[1]. Therefore, overcoming the limits that hinder their employment is a key target in order to fulfil the increasing demand for energy storage systems. A significant drawback lies on the high overpotentials needed upon charge to oxidize the non-conductive discharge product Li_2O_2. This is due to the fact that, at high operating voltages above 4.0 V vs. Li^+/Li^0, many parasitic processes that lead to cell damage and early failure are triggered[2,3]. A major role in these detrimental phenomena is played by the formation of molecular oxygen in its singlet excited state, which is highly reactive and unmanageable[4].

With the aim of mitigating the charge overpotentials, many redox mediators (RMs), soluble catalysts that facilitate Li_2O_2 oxidation, are proposed in literature[5]. Among them, lithium halides LiI and LiBr are considered attractive because of their favourable thermodynamics, simplicity and reduced costs[6,7].

However, their impact on parasitic processes, including the formation of singlet oxygen, needs to be further explored. Our studies aim at revealing the correlation between thermodynamical and kinetical properties of LiX redox mediators, that vary basing on the solvent employed, and their tendency to favour singlet oxygen evolution. The spin trap 4-oxo-TEMP was used as probe of singlet oxygen and detected by EPR spectroscopy. Moreover, in order to obtain a more reliable and quantitative analysis of the singlet oxygen evolved, fluorescence measurements were carried out using 9,10-dimethylanthracene as probe molecule. The results demonstrate a strong correlation between solvation, kinetics and singlet oxygen evolution in LiX-mediated Li-O_2 batteries[8,9].

References:

[1] Y. Wang, Y.C. Lu, Energy Storage Materials, 2020, 28, 235-246.
[2] A. Varzi, et al., J. Power Sources, 2020, 480, 228803.
[3] A. Pierini, S. Brutti, E. Bodo, npj Computational Materials, 2021, 7:126.
[4] E. Mourad, et al., Energy Environ. Sci., 2019, 12, 2559-2568.
[5] C. Zhang, et al. Advanced Energy Materials, 2020, 10(27), 2000201.
[6] W. J. Kwak, et al. J. Mater. Chem. A, 2015, 3, 8855-8864.
[7] W. J. Kwak, et al., Energy Environ. Sci., 2016, 9, 2334-2345.
[8] A. Pierini, et al., Journal of Physical Chemistry A, 2023, 127(44), pp. 9229–9235.
[9] A. Petrongari, et al., ACS Applied Materials and Interfaces, 2023, 15(51), pp. 59348–59357.

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Exploring Redox Mediators and Non-Toxic Electrolytes for Lithium-Oxygen Batteries: An Experimental and Computational Study

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Over the past decade, lithium-oxygen aprotic batteries (aLOBs) have emerged as a promising advance in energy storage technologies, provided they realize a substantial portion of their theoretical specific energy. However, their path to commercialization faces obstacles due to several technical challenges[1].Current implementations exhibit limited energy efficiency and a departure from reversible electrochemistry. This discrepancy can be attributed to the insulating nature of the discharge product, lithium peroxide, Li_2O_2, and the formation of singlet oxygen resulting in the need for high charge overpotentials[2]. The presence of singlet oxygen initiates parasitic chemistry, leading to the formation of secondary products and contributing to the degradation of battery components. This interrupts the reversibility of the redox process, further complicating the efficiency of the overall system. A promising strategy to address the slow decomposition kinetics of Li_2O_2 involves the use of redox-active and soluble molecules known as redox mediators[3], RMs. These serve as catalysts for the oxidation of Li_2O_2, significantly reducing the charge overpotential that attends as the source of harmful singlet oxygen formation. Unlike solid catalysts, redox mediators have the advantage of enjoying a larger reaction interface as they are dispersed in the electrolyte. The catalytic effectiveness of the RM is strongly influenced by the environment in which it operates. Therefore, the choice of solvent in the electrolyte is a key factor, as it must be able to stabilize the species acting as the mediator. RM can pose a risk of ionic short-circuiting due to a shuttle effect between the anode and cathode. This can lead to corrosion at the lithium metal anode, causing the loss of the active redox mediator and the oxidizing species. One solution to this problem could be the use of self-defending[4] RM, which serve a dual function as catalysts for the oxidation of the discharge product and as protectors of the lithium metal anode. Based on the information just presented, our contribution involves a combined experimental and computational approach to investigate the effective pairing of RM and solvents to address some of the critical issues affecting these systems.

References:

[1] L. Qin, L. Sckeryantz, J. Zheng, N. Xiao and Y. Wu. J Am. Chem. Soc., 2020, 142, 11629-11640.

[2] Luntz, A., McCloskey, B. Nat Energy 2, 17056 (2017).

[3] A. Nakanishi, M. L. Thomas, H.-M. Kwon, Y. Kobayashi, R. Tatara, K. Ueno, K. Dokko, M. Watanabe. J. Phys. Chem. C 2018, 122, 1522−1534.

[4] Zhang, T.; Liao, K.; He, P.; Zhou, H. Energy Environ. Sci. 2016, 9 (3), 1024–1030.

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FIS-PO-048

Sustainability of green hydrogen production: the state-of-the-art of technologies from an eco-design perspective

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Hydrogen plays an essential role as an enabler of the energy transition as it can make a significant contribution to storing and distributing renewable energies and for the decarbonization of hard-to-abate sectors and energy-intensive industries[1].

Although hydrogen can be seen as a clean energy vector, currently its global production is derived from fossil fuels. Low-emission hydrogen, better known as green hydrogen, is referred to as the hydrogen obtained using electrolysis coupled with a renewable electricity source and therefore having no associated emissions, but nowadays it accounts only for 0.7% of the total hydrogen demand (95 Mton by 2022)[2].

With the aim of increasing green hydrogen production to meet the target of the growing sustainable hydrogen demand, in line with the target set by the strategic research and innovation agenda of the Clean Hydrogen Partnership[3], several alternatives to water and steam electrolysis have been developed based on photoelectrocatalytic water-splitting processes and thermochemical processes using renewable or recycled carbonaceous feedstocks.

Nevertheless, challenges regarding raw materials used, equipment set-up, the energy losses during the entire supply chain, and the environmental consequences within the scaling-up process, are still critical points that require methodological scientific investigation to address the potential of green hydrogen to implement a new global economy.

In this work, we present a comparative analysis of the emerging processes for green hydrogen production in alternative to electrolysis-based technologies (currently closer to market) from an environmental life cycle assessment perspective aiming at highlighting the strengths, drawbacks, and hotspots in terms of resource and process efficiency.

References:

[1] Abdin, Z.; Zafaranloo, A.; Rafiee, A.; Mérida, W.; Lipiński, W.; Khalilpour, K. R. Renewable and Sustainable Energy Reviews, 2020, 120, 1 – 32.
[2] International Energy Agency (IEA), Global Hydrogen Review 2023, 2023, 1 – 174.
[3] Strategic Research and Innovation Agenda (SRIA), Key findings and conclusions of the agenda process for the European research and innovation initiative on green hydrogen. Final version., 2022, 1 – 28.

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On the evolution of stability and quality of bake-on PDMS coatings upon extended thermal treatment

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Siliconization of glass primary packaging containers is increasingly adopted in order to reduce drug-glass interactions in primary packaging. Bake-on siliconization is used when a robust and well-adhered PDMS layer is required[1]. In this process, a PDMS emulsion is sprayed in the containers, which are then heat-treated in order to obtain a thin densified coat. Before use, the containers are washed and depyrogenized before filling. In this study, we explore the stability and the quality of siliconization layers upon these further treatments. Stability and quality of the PDMS layer upon further extended thermal treatments have become recently of particular concern due to the evolution of filling technologies. In fact, we observe a trend in filling machinery manufacturers towards higher capacity and speed of all phases of the process (washing-depyrogenation-filling). Because of the different specific speeds of the different phases, the depyrogenation oven is often used as a buffer for matching the speeds of the upstream and downstream phases. This imply a variable duration of depyrogenation, whose duration is increased when the downstream phases do not accept new vials. In this study, standard siliconized vials were subjected to a heat treatment in a muffle at 300°C in of air at different exposure times ranging from 2 to 96 hours. The vials thus obtained were analyzed by optical, SEM and AFM microscopy, contact angle with water. The same samples were also exposed to a selection of drug simulants including surfactants, complexing agents and proteins, and the quality of the PDMS after exposure was characterized with the same techniques. The data obtained from different analyses show that the bake-on PDMS layer remains stable upon extended heat treatments with minor changes in morphology and hydrophobicity.

References:

[1] S. Funke, J. Matilainen. H. Nalenz, K. Bechtold-Peters, H.C. Mahler, W. Friess, European Journal of Pharmaceutics and Biopharmaceutics, 104 (2016) 200-215

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Unveiling the Effect of Resins on Dynamics of Elastomeric Compounds with Solid-State NMR and Viscoelastic Analysis

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In the tire industry, resins are essential ingredients because of their curing, reinforcing, and tackifying properties. They modify the rheological behaviour of rubber compounds, improving processability and enhancing mechanical properties.[1] Resins change the dynamics of the polymer chain, which affects the viscoelastic behavior and the mechanical characteristics at the end. In this research, we focused on comparing the effect of a natural- and a petroleum-origin resins on SBR compounds. The resin content was varied from 15 to 45 parts per hundred parts of rubber. To gain insights into the molecular dynamics and structural properties of the elastomeric blends, we employed different Solid-State Nuclear Magnetic Resonance techniques,[2-3] combined with dynamic-mechanical, rheometric, calorimetric and chemical analyses. These techniques have provided a comprehensive understanding of the mechanical, thermal and vulcanisation properties of the elastomeric compounds, as well as of the polymer chain dynamics, as affected by the resin nature and content.

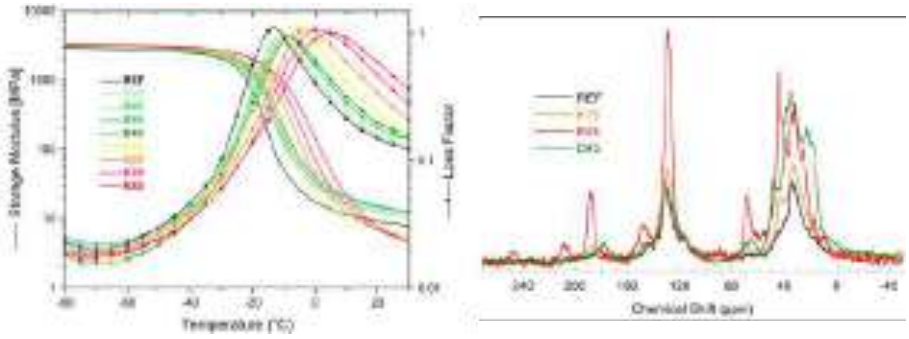

Figure 1: Dynamic Mechanical Analysis results and ^{13}C NMR spectra of some of the investigated compounds.

References:

[1] P.O. Powers Rubber Chem. Technol. 1963, 36(5), 1542–1570.
[2] M. Pierigé, F. Nerli, F. Nardelli, L. Calucci, M. Cettolin, L. Giannini, M. Geppi, F. Martini Appl. Sci. 2023, 13(3), 1939.
[3] F. Nardelli, L. Calucci, E. Carignani, S. Borsacchi, M. Cettolin, M. Arimondi, L. Giannini, M. Geppi, F. Martini Polymers 2022, 14(4), 767.

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Fabrication of Solid-like Capsules for Air-Tolerant Luminescent Quantum Dots

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Semiconductor quantum dots (QDs) have become highly adaptable materials, possessing distinct physico-chemical properties that can be tuned through a variety of methods including morphological control and surface passivation.[1] The groundbreaking advancements in QDs research were recently recognized with the Nobel Prize in Chemistry in 2023, underscoring their profound impact on technology and society.[2]

Generally, QDs are treated and studied under nitrogen conditions since their optical characteristics could be irreversibly degraded when they are exposed to oxygen for long time.[3] Considerable focus has been directed towards the investigation of QDs in solution; however, there is a discernible lack of established methodologies for their integration into solid-state systems. The aim of this study is to develop oil-core silica-shell microcapsules, thereby establishing a compartmentalized solid-like system dispersible in water and potentially capable of tolerating air exposure.[4] Through this strategy, a dual protection mechanism against oxygen is achieved, where the silica shell constitutes a physical barrier against oxygen diffusion while unsaturated fatty acids can act as oxygen scavengers.[5,6]

We studied CdSe- and PbS-QDs in oleic acid with different capping ligands. The oily dispersions were then encapsulated in silica microcapsules and characterized via steady-state PL, time-resolved PL, SEM, SAXS, and EDX to determine optical and morphological properties of the core-shell systems. After solid-state analyses, dispersions of CdSe/capsules and PbS/capsules were prepared in water to determine the influence of the medium. Through this approach, successful QDs encapsulation was achieved for the two different nanocrystals exhibiting remarkable stability in aqueous environment when working in air-balanced environment.

References:

[1] Z. Xu, et al., Accounts of Chemical Research, 2020, 54.1, 70-80.
[2] A. L. Efros, L. E. Brus, ACS nano, 2021, 15.4, 6192-6210.
[3] H. Moon, et al., Advanced Materials, 2019, 31.34, 1804294.
[4] L. Latterini, et al., 2018, Dalton Transactions, 47.26, 8557-8565.
[5] G. Quaglia, et al. Journal of Materials Chemistry C, 2022, 10.23, 9073-9080.
[6] A. J. Svagan, et al., ACS nano, 2014, 8.8, 8198-8207.

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3D Ordered Metallic-NCs Superlattice: investigating the capping-agent role

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Metallic nanocrystals (M-NCs) are of great interest due to the possibility of controlling the plasmonic band through three-dimensional self-assembly arising from the interactions between neighboring NCs, which can result in new properties non-present in the original constituents of the superlattice. That is because the Localized Surface Plasmon Resonance is highly affected by the surface-surface distance between the NCs. Capping agent shell plays a key role in this kind of structuring particularly the interactions between the carbon chains of such shell and the organic solvent in which are dispersed the NCs. To better understand if this kind of interaction can influence, we carried out an extensive study on recently obtained Au-NCs capped with oleylamine. We dispersed such NCs into four different solvents, characterized by increasing dielectric constant: cyclohexane, toluene, ethyl ether, and chloroform. This resulted in a different extension of the oleylamine alkyl chain in such solvents. After this first characterization, through a microemulsion method, adding water and using oleic acid as a functionalizing agent, we induced the self-assembly of such NCs into the abovementioned superlattices in water. The characterization of such superlattices was carried out through a multi-technique approach exploiting TEM, SAXS, and UV-Vis approach which allowed us to understand the key role of the interactions between the alkyl chain of the capping agent and the organic solvent in such a structuring process.- The functionalization procedure, carried out on all the samples gave interesting results, with different kinds of superlattices obtained which translated into different optical properties of the resulting systems. Of great interest are the results obtained for the optical properties of such superlattice, which is clear from Figure 1 B, monodisperse Au-NCs show the typical absorption band at around 520 nm, while the structured superlattice of Au-NCs shows a huge blue shift of more than 300 nm since we can identify a clear peak at 205 nm. These results show the power of such ordered 3D organization which gives origin to completely new and engineerable properties that open the route to uncountable new applications and developments.

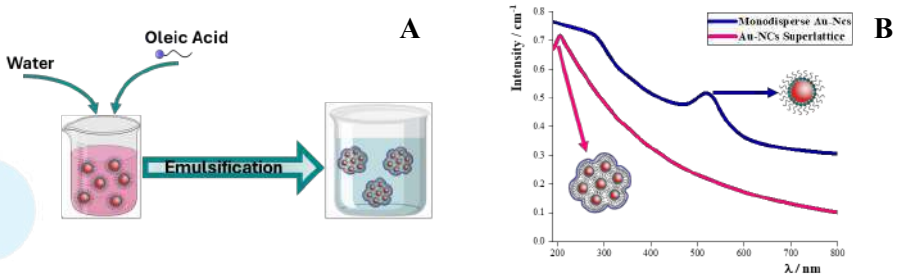

Figure 1. UV-Vis Spectra of unstructured Au-NCs (A), and UV-Vis Spectra of structured Au-NCs

References:

[1] N. Gallucci et al, *Journal of Colloid and Interface Science,* 2024, 659, 926-935
[2] W. Wei et al., *iScience*, 2019, 11, 272-293

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Investigation of the luminescent properties of silicate-based phosphors

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Luminescent materials can emit photons after the absorption of energy. Among these, inorganic emitters, also known as "phosphors", are of great interest due to their excellent stability, if compared to their organic counterparts. Usually, phosphors consist of an inorganic host matrix in which luminescent ions are located as dopants[1]. Silicates, along with aluminates, are widely studied as host to produce high efficiency phosphors, displaying great chemical stability, high water resistance and relatively low calcination temperature[2]. Rare-earth ions are often used as luminescent ions in phosphors due to their capability to emit visible light under UV-Visible excitation, with very high quantum yields[3]. Europium is a very fascinating element and it is widely studied since its luminescent properties can be tuned by engineering the surrounding media[4]. In this work we focused our attention on silicate-based phosphors, choosing europium as luminescent centre. We investigated different synthetic strategies, trying to rationalize how the properties of europium are dependent on the crystal environment, with the purpose of achieving the best performances. The as-synthesized phosphors are then included into different matrices and the mutual effects of the interactions between the two components have been investigated. The final goal is to develop innovative luminescent devices to be used as lighting sources.

Figure 1: Luminescent properties of Europium-doped silicates in powder and into hydrogels.

References:

[1] Z. Xia, Z. Xu, M. Chen, Q. Liu, Dalton Transactions 2016, 45, 11214.
[2] L. Fernandez-Rodriguez, A. Duran, M.J. Pascual, Open Ceramics 2021, 7, 100150.
[3] C.R. Ronda, T. Jütsel, H. Nikol, Journal of Alloys and Compounds 1998, 275-277, 669-676.
[4] M.D. Mehare, C. M. Mehare, H.C. Swart, S.J. Dhoble, Progress in Materials Science 2023, 133, 101067.

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Interfacing graphene with photochromic molecules

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Photochromic molecules are molecular switches that can be toggled between two or more states by one of the most abundant energy sources found in nature, i.e. light. Their structural design enables to programme their chemical and physical properties [1-3], such as their capability of absorbing visible light, the time-responsiveness to the optical stimuli, the stability of the various states, etc. The optically-modulated changes in their structural, mechanical and electrical properties[4,5] has been exploited for the fabrication of multi-responsive (nano)devices[6,7].

In this work, we report on the self-assembly of a photochromic diarylethene (DAE) molecules equipped with two alkyl sidechains. We demonstrate that the exposure of this molecule to blue or green light makes it possible to switch it between two thermodynamically stable isomers [5]. The efficient photoresponsive nature of this DAE was revealed in studies performed solution and in the solid state. The structural, electronic and optical properties of ultrathin DAE films onto graphene have been investigated, and exploited for the fabrication of light-responsive electronic devices based on this hybrid assemblies.

References:

[1] Zhang, Z. *et al*., *Nat Commun* **2019**, 10, 4232
[2] Díaz, S. A., Gillanders, F., Jares-Erijman, E. A. & Jovin, T. M, *Nat Commun* **2015**, 6, 6036
[3] Feringa, B. L., *J. Org. Chem.* **2007**, 72, 6635-6652
[4] Mativetsky, J. M. *et al.*, *J. Am. Chem. Soc.* **2008**, 130, 9192-9193
[5] Bonacchi, S. *et al.*, *Angew. Chem. Int. Ed.* **2015,** *54*, 4865–4869
[6] Orgiu, E. *et al., Nat. Chem.* **2012**, *4*, 675
[7] Hou, L. *et al.*, *Nat. Nanotechnol.*, **2019**, *14*, 347

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Electronic Properties at the TriPyrenBoroxine/Au(111) interface

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The study of the adsorption and self-assembly of organic molecules on metallic surfaces, with the aim of understanding the electronic interaction between the organic active layer and the underlying metallic surface, plays a key role in determining the possible applications of these systems in organic-based opto-electronic devices. Among the various systems studied, very promising results have been obtained with boronic acids derivatives, namely Boroxines, which derive from a self-condensation reaction of three boronic acids molecules leading to a six-membered ring made up of alternating boron and oxygen atoms. Notably, Boroxines are much studied due to their high chemical and thermal stability, the wide range of applications of these compounds in synthetic organic chemistry and the well-established procedures for 3D COFs formation. Concerning their electronic properties, the presence of an ultra-fast charge delocalization channel between the boroxine ring of TriPhenylBoroxine (TPB) molecules and the underlying Au(111) substrate was evidenced[1], thus suggesting good performances of the interface in terms of electronic transport. With this in mind, in present work we explore the properties of TriPyrenBoroxine (TPyB) /Au(111) interface. Pyrene has spectral features in the UV-Vis range, which might be exploited to promote specific electronic transitions in TPyB molecules and to study optical-induced electron dynamics both within the organic film and from the organic film towards the underlying Au(111) substrate. In detail, a TPyB molecules film on a Au(111) substrate has been grown, by thermal treatment of 1-Pyreneboronic Acid (PyBA) in a quartz crucible at a temperature of about 300°C in Ultra-High Vacuum (UHV) conditions. The organic film formation has been monitored by XPS (X-ray Photoelectron Spectroscopy), to verify the actual presence of TPyB molecules on the Au(111) substrate; then, the system has been studied through NEXAFS spectroscopy (Near Edge X-ray Absorption Fine Structure), in order to determine both the molecular orientation and the unoccupied electronic states. Charge dynamics has been explored by RPES (Resonant PhotoEmission Spectroscopy), 2PPE (Two-Photon PhotoEmission) Spectroscopy and pump-probe spectroscopy. The study confirmed the occurrence of ultra-fast charge delocalization at the interface and revealed the presence of dynamics of charge with three different characteristic lifetimes, namely in the s, μs and ps regimes. Finally, for a further molecular valence electronic transitions characterization and to study the equilibrium reaction between PyBA and TPyB molecules, UV-Vis spectroscopy measurements in solution have been performed, whose results have been compared to the theoretical values obtained from TD-DFT calculations (Time-Dependent Density Functional Theory).

References:

[1] D.Toffoli, M.Stredansky, *Chem. Sci.,* **2017,** *8* (5), 3789-3798.

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Templated Self-Assembly of Transient Branched Au Nanoshells

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Self-assembly of metal nanoparticles (NPs) represents a versatile tool for creating materials with new structures and intriguing collective properties. Our work in this field is focused on the design of different self-assembly strategies to form hybrid superstructures, exploiting the templating ability of peptides and proteins.[1] At this aim, we have devised a one-pot procedure to obtain peptide-gold superstructres (AuSP; 200 nm) where a monolayer of 5nm AuNPs surrounds a peptide core.[2] Together with being chiroptically active, AuSPs could act as template to control the formation of a transient 3D-branched Au-nanoshell (BAuNS) stabilized by sodium dodecyl sulphate (SDS). The BAuNS dismantles upon SDS concentration gradient equilibration over time in the sample solution, leading to NP disassembly and regression to PAuSS. Notably, BAuNS assembly and disassembly promotes temporary interparticle plasmonic coupling, leading to reversible and tunable changes of their plasmonic properties.[3]

References:

[1] C. Pigliacelli, D. Maiolo, Nonappa, J. Haataja, H. Amenitsch, C. Michelet, P. Sànchez Moreno, I. Tirotta, P. Metrangolo, F. Baldelli Bombelli, Angew. Chem. Int. Ed. 2017, 56, 16186-16190.
[2] C. Pigliacelli K.B. Sanjeeva, Nonappa, A. Pizzi, A. Gori, F. Baldelli Bombelli, P. Metrangolo, ACS Nano 2019, 13, 2158-2166.
[3] A. Marchetti, A. Gori, A.M. Ferretti, D. Arenas Esteban, S. Bals, C. Pigliacelli, P. Metrangolo, Small 2023, 2206712.

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FIS-PO-059

The Interaction between Fluorescent Molecules and Plasmonic Nanoparticles: From SERS to SEF

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The electric field intensity can be locally enhanced thanks to metallic nanoparticles (or surfaces) that give rise to localized surface plasmon polaritons (SPPs). This mechanism is the basis for electromagnetic enhancement (EM), which plays a crucial role in amplifying Raman signals within Surface Enhanced Raman Spectroscopy (SERS).

Raman scattering, however, is not the only process affected by the increase in the electric field intensity; fluorescence can increase as well, resulting in Surface Enhanced Fluorescence (SEF).

While SERS peaks at very close distances from the metal surface, fluorescence is often quenched at such proximity, necessitating distances of the order of a few nanometers to tens of nanometers for SEF[1]. The distance from the metallic surface, however, is not the only factor affecting these phenomena; particle material, morphology[2], as well as excitation wavelengths are also involved.

Here, the interaction between a fluorescent molecule and a plasmonic nanoparticle is studied to deeply investigate the balance between these two processes. Plasmonic nanoparticles of different materials (silver and gold spherical nanoparticles) as well as different morphologies (gold nanorods) are employed. Additionally, different distances as well as different excitation wavelengths are explored. All these parameters are evaluated to obtain a deeper understanding of all the complex mechanisms involved in the interaction between a fluorescent molecule and a plasmonic nanoparticle.

References:

[1] K. A. Kang, J. Wang, J. B. Jasinski and S. Achilefu, Fluorescence Manipulation by Gold Nanoparticles: From Complete Quenching to Extensive Enhancement, Journal of Nanobiotechnology, 2011, 9, 16.

[2] L. Litti, J. Reguera, F. J. G. de Abajo, M. Meneghetti and L. M. Liz-Marzán, Manipulating chemistry through nanoparticle morphology, Nanoscale Horizons, 2020, 5, 102–108.

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Stabilizing carbynes

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Carbyne is the name given to a chain of sp carbons. Despite several claims, existence of a solid consisting of such chains has not been substantiated. Solids with sp^3 carbons, namely diamond, and sp^2 carbons, namely graphene, C-nanotubes and fullerenes, are well known and widely accepted. Chains of sp carbons can occur in two forms: cumulenic with equal bonding between all atoms, and polyynic, with alternating short and long bonds deriving from a Peierls instability. In the first case the interpretation is that bonds are all 'double bonds' whereas in the second case bonding arises from alternating 'single and triple bonds'. Although the polyynic form is more stable, chains of sp carbons are too reactive to condense into a solid.

Stabilization has been achieved by attaching large groups at the ends of the chains, which suggests the importance of the chain-ends.

In this work, we show how gold nanoclusters obtained by laser ablation can stabilize solids formed from sp carbon chains, pseudocarbynes.[1,2,3] Model calculations also make it possible to hypothesize that a cumulenic structure can also stabilized.[4]

References:

[1] P. Tarakeshwar, P. R. Buseck, H. W. Kroto, J. Phys. Chem. Lett. 2016, 7, 1675–1681.
[2] H. Kim, P. Tarakeshwar, N. M. Fujikado, K. Evraets, A. K. Jones, M. Meneghetti, P. R. Buseck, and S. G. Sayres, J. Phys. Chem. C 2020, 124, 19355-19361.
[3] H. Kim, P. Tarakeshwar, M. Meneghetti, P. R. Buseck and S. G. Sayres, Carbon 2023, 204, 546-551.
[4] P. Tarakeshwar, M. Meneghetti, J. Wu, R. Lloyd Whetten, M. Jose Yacaman, P. R. Buseck, Carbon 2023, 215, 118493.

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FIS-PO-061

"Preparation and characterization of PET (Polyethylene terephthalate) nanoparticles by using a solution of HFIP: Chloroform 1:1 (80%) and water (20%)"

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Nano- and microplastic toxicology has appealing global consideration. As matter of fact, the plastic materials are disposed in to the environment and degrade by releasing micro- and nano plastic, which are very dangerous, due to their potential to bypass the biological membranes. In order to perform toxicological studies on human cells, it is necessary to produce particles with nanometric dimension, which can be difficulty extracted and characterized from environmental matrices [1]. In this work, we have produced of PET Nanoparticles from commercial grade PET resin, by grinding the PET pellets and dissolving the powder in a solution of hexafluoro isopropanol: chloroform (1:1), then extracted in water. By using this feasible method, PET nanoparticles have been characterized by UV spectrophotometer, optical microscope (bright field), scan electron microscope (SEM) and dynamic light scattering (DLS). Furthermore, PET fluorescence properties have also been characterized by spectrofluorometric techniques.
This work approaches a simple and easy way for PET nanoparticles production, which can be very useful for the study of cell toxicology of this kind of plastic. Furthermore, the spectroscopic properties of PET can be used for the evaluation and quantification of PET nano- and microparticles in environmental samples.

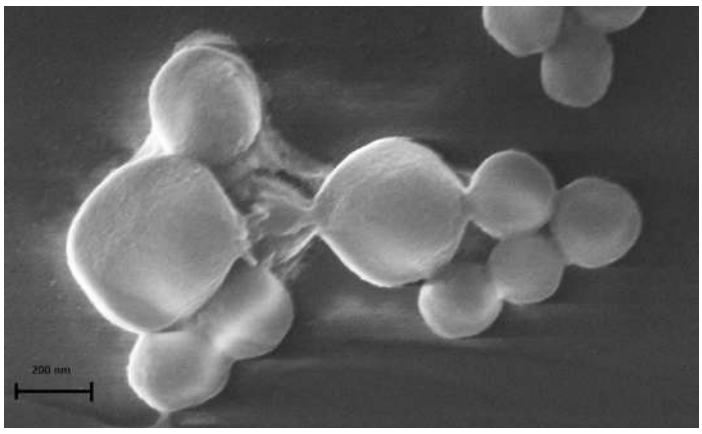

Figure 1: SEM image of PET nanoparticles.

References:

[1] Rodríguez-Hernández, A. G.; Muñoz-Tabares, J. A.; Aguilar-Guzmán, J. C.; Vazquez-Duhalt, R. A novel and simple method for polyethylene terephthalate (PET) nanoparticle production. *Environmental Science: Nano*. **2019**, 6(7), 2031-2036. DOI: org/10.1039/C9EN00365G

[2] Zhao, K.; Wei, Y.; Dong, J.; Zhao, P.; Wang, Y.; Pan, X.; Wang, J. Separation and characterization of microplastic and nanoplastic particles in marine environment. *Environmental Pollution*. **2021**, 118773. DOI: org/10.1016/j.envpol.2021.118773

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Operando Solid State NMR of photo-responsive materials: new hardware and experiments

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Solid State Nuclear Magnetic Resonance (SSNMR) is one of the most powerful techniques for obtaining a deep understanding of the structural and dynamic properties of materials, over very wide spatial (0.1-100 nm) and time (10^{-11}-100 s) scales[1]. The possibility of performing SSNMR experiments on photo-responsive materials while they are interacting with light is very attractive, since it could reveal the structural and dynamic modifications occurring in the material due to its interaction with light. This appears of particular interest in the field of photovoltaics since it can improve the understanding of the material performance and its design. In this contribution we present the preliminary results of the project PRIN 2022 "NUTSHELL", aimed at developing SSNMR apparatuses for performing SSNMR spectroscopic and relaxation experiments on organic and inorganic photoactive materials during their illumination.

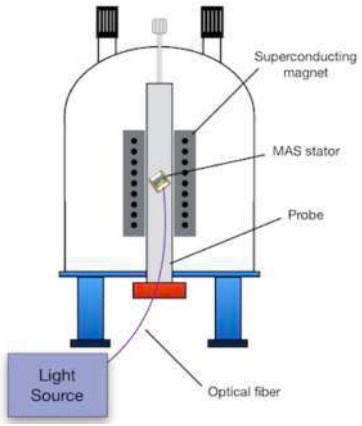

Figure 1: scheme of a Solid State NMR spectrometer working under illumination.

References:

[1] K. Müller, M. Geppi, "Solid state NMR: Principles, Methods, and Applications". Wiley-VCH, 2021.

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Exploring the depth of Deep eutectic solvents: structural insights and molecular dynamics

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A deep eutectic solvent (DES) stands out as an interesting solvent due to its distinct thermic properties, resulting in a significant decrease of the mixture's melting point (MP). The recent introduction of type V DES represents a highly biocompatible alternative to traditional solvents by being both hydrophobic and free from chlorides and metal ions. The formation of these DESs relies heavily on the structural attributes of their precursors, distinguishing between hydrogen bond acceptors (HBAs) and hydrogen bond donors (HBDs).[1]

The main aim of this study is to quantify the depth that makes such a DES. Our interest lies in comparing precursor pairs with and without hydroxyl groups, aiming to guide DES formulation with minimal alterations to the compounds. The addition of a hydroxyl group to one of the components can significantly alter the solid-liquid equilibrium (SLE). Consequently, our investigation seeks to examine the role of all interactions that take place in these systems, focusing specifically on π-π stacking.[2]

This study concerns comparing the eutectic mixture formed by trimethoxybenzene (TMB) and 1,3-diacthylbenzene (13DAB) with the DES formed by 3,5-dimethoxyphenol (DMP) and 13DAB.

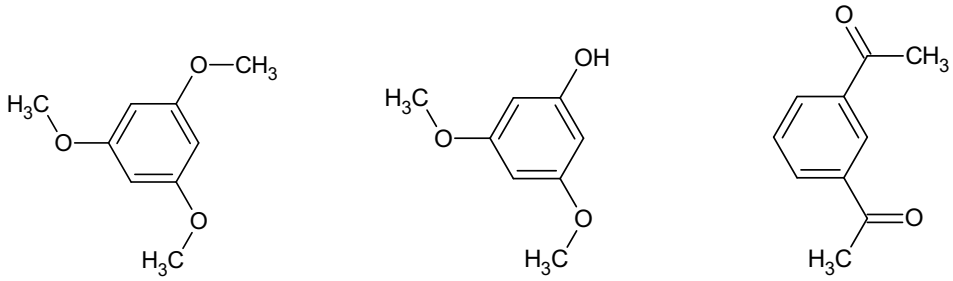

Figure 1: The molecules of TMB, DMP and 13DAB are respectively reported.

We have adopted a combined approach between experimental measurements and theoretical calculations. Most combinations of organic compounds exhibit eutectic behavior that can be easily predicted by conductor-like screening model (COSMO) calculations. Then, thermic characterization is conducted using differential scanning calorimetry (DSC), while molecular level can be investigated with MD's simulations.

References:

[1] M. Busato, G. Mannucci, P. D'Angelo, ACS Sustainable Chem. Eng. 2023, 11, 8988-8999.
[2] G. Mannucci, J. A. P. Couthinho, P. D'Angelo, ACS Sustainable Chem. Eng. 2024, 12, 2862–2870.

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Reactivity and stability of the High Entropy Oxide (Mg,Co,Ni,Cu,Zn)O

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High entropy oxides (HEOs) are single-phase materials composed of five or more cations, some of which stabilized in an unconventional chemical environment, different from that of the simple oxide phase, due to the large configurational-entropy contribution[1]. Despite their potential to yield compounds with unique and promising properties for energy storage, catalysis and thermoelectricity, the role of entropy in the stabilization process is still debated[2], and very little is known about their compositional stability range[3]. An interesting question to address is the role of individual cations in the HEO stability. Currently, one of the most studied HEO, and the subject of our research, is the first one synthesized in 2015 by Rost et al., i.e. (Mg,Co,Ni,Cu,Zn)O. CuO is known to be the most destabilizing component within the solid solution. Through a multicomponent diffusion couple (DC) between CuO and the quaternary oxide containing all cations present in the aforementioned HEO except Cu, we assessed Cu mobility and reactivity. The DC was heated in a tubular furnace at 1000°C for different reaction times. Once the diffusion occurred, the DC cross-section was examined through SEM-EDS for morphological and compositional analysis, and through EBSD (Electron Backscatter Diffraction) to determine the structure in the different sample regions.

Our findings revealed Cu's high diffusivity within the solid solution, and the formation of a product layer, due to the other cations diffusion, with general formula $Cu_2(Mg_xCo_yNi_zZn_n)O_3$, compatible a distorted gugghenite structure (Cu_2MgO_3). Interestingly, EDS analysis also revealed a high solubility limit of Cu within the diffusion region (33%) not reproducible via ex-situ synthesis; indeed, powders obtained via Pechini method showed a Cu solubility limit of 28% with a progressive and long-range structural distortion observed for Cu percentage higher than 25%. Another attempt to assess the single components' role in HEO reactivity was made by progressively reducing the number of components from the quaternary oxide in the DC. First, a DC between the ternary oxide (Mg,Co,Ni)O and CuO was then set-up. We found no product layer is formed demonstrating the Zn has a pivotal role in determining the guggenite stability. By further reducing the number of components in the solid solution a clear trend in the Cu diffusion length was not observed implying that there is no direct correlation between the diffusion kinetics and the number of components, as instead suggested for high entropy alloys. It would be reductive to model high entropy oxide behaviour only based on the configurational entropy of the system. Every composition is unique and has to be analysed considering the nature and the reactivity of every single oxide in the solid solution.

[1] C. M. Rost, E. Sachet, T. Borman, A. Moballegh, E. C. Dickey, D. Hou, J. L. Jones, S. Curtarolo, J. P. Maria, Nat. Commun., 2015, 6, 8485.
[2] M. Fracchia, M. Coduri, M. Manzoli, P. Ghigna, U. A. Tamburini, Nat. Commun., 2022, 13 (1), 1–4.
[3] M. Coduri, L. R. Magnaghi, M. Fracchia, R. Biesuz, Chem. Mater., 1–24.

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Preparation and physicochemical characterization of a Cobalt-based Deep Eutectic Solvent

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Deep eutectic solvents (DESs) are a novel class of liquid mixtures characterized by significant depressions of the melting point compared to those of their neat constituents, usually compounds classifiable as Hydrogen Bond Donor (HBD) and Hydrogen Bond Acceptor (HBA) species[1]. These materials are promising "designer" solvents[2] exhibiting a host of tunable physicochemical properties as a function of the nature and ratio of their components[3]. Unfortunately, achieving this "tunability" remains elusive due to the many difficulties associated with the development of predictive models for DES physicochemical properties[4]. These difficulties arise from two factors: the inherent complexities in describing DESs through computational simulations[5], as well as the absence of a comprehensive dataset of their physicochemical properties necessary for empirically derived predictive models[6].

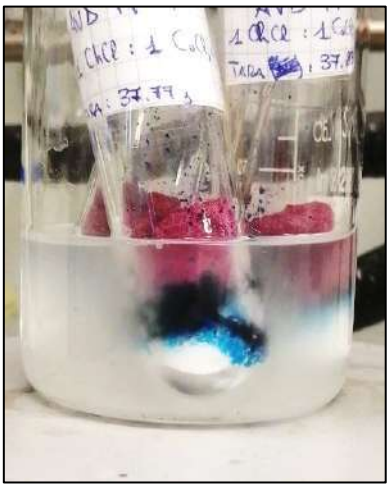

Figure 1: Preparation of DES by mixing Choline Chloride (white) and Cobalt Chloride Hexahydrate (pink) with a molar ratio of 1:1. The formation of a new, deep blue liquid phase can be observed at the interface of the two precursors.

Our research aims to bridge this informational gap by carrying out a systematic evaluation of DES physicochemical properties and how these change as a function of the identity of their constituents. In this work, we report the physicochemical characterization of a DES composed of Choline Chloride as HBA and Cobalt Chloride Hexahydrate as HBD. Cobalt-based DESs were prepared by simply mixing the precursors in different molar ratios and heating them at 70°C for 30 min (Figure 1). Physicochemical properties such as thermal stability, viscosity, electrical conductivity, density and electrochemical window were characterized in a wide range of temperatures and compositions.

References:

[1] E.L. Smith, A.P. Abbott, K.S. Ryder, Chemical Reviews, 2014, 114, 11060–11082
[2] M. Francisco, A. Van den Bruinhorst, M.C. Kroon, Angewandte Chemie International Edition, 2013, 52, 3074-3085
[3] JA Sirviö, R. Haataja, A.M. Kantola, T. Suopajärvia, H. Liimatainen, Journal of Materials Chemistry A, 2020, 8(16), 7935–7946
[4] C. Velez, O. Acevedo, WIRE Computational Molecular Science, 2022; 12:e1598
[5] C.R. Ashworth, R. P. Matthews, T. Welton, P. A. Hunt, Physical Chemistry Chemical Physics, 2016, 18(27), 18145–18160
[6] K.A. Omar, R. Sadeghi, Journal of Molecular Liquids, 2022, 360, 119524

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IND-MD-01

Char from pyrolysis of plastics: from secondary product to raw material

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One of the by-products of the pyrolysis of plastics is the Char. The Char is composed by one organic part (manly carbon) and another inorganic (typically Calcium salts, Titanium oxide and aluminum). Currently there are only a few areas of use for this by-product; this aspect, in the future, could become a problem by increase in the available quantity due to the diffusion of pyrolysis plants. It's necessary to find a flexible way to reuse Char like a raw material, even better if this is done within a decarbonization framework. The aim of present work has been to define an industrial process which took in consideration all those aspects. A method was therefore studied to allow char to be included in the chemical production chain in order to obtain new products and in the meantime give a contribute to CO_2 reduction.

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IND-MD-02

Ad-hoc synthesized catalysts and commercial ones: their catalytic applications in the perspective of sustainability

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Since her education years until today, Prof. Claudia Antonetti's main research interests have focused on **applied catalysis and sustainable chemistry**, investigating with particular attention both the **synthesis, characterization, and application of *ad-hoc* prepared catalysts** and the **optimization of catalytic processes, even in the presence of commercial systems, for the valorization of biomasses**, including waste ones, and/or the platform chemicals derived from them, always working in the perspective of sustainability.
During the seminar, many examples regarding the **synthesis, characterization and applications of nanostructured catalysts** based on different metals, such as **Ru, Pd, Au, Cu, and Ag** will be presented, showing promising performances in several reactions of industrial interest, such as the selective hydrogenation of benzene to cyclohexene, of phenol to cyclohexanone, of *p*-chloronitrobenzene to *p*-chloroaniline and of cinnamic aldehyde to hydrocinnamaldehyde. Among the synthesized catalysts, the role of Prof. Claudia Antonetti as **Principal Investigator of the PRIN 2020 LEVANTE project "LEvulinic acid Valorization through Advanced Novel TEchnologies"** is particularly noteworthy: in this project, the University of Pisa team has studied the synthesis of biomass-derived catalysts, demonstrating a strong effort to promoting sustainability and circular economy.
Regarding **commercial catalysts,** Prof. Claudia Antonetti has investigated their use for the catalytic conversion and valorization of a wide range of biomasses, including waste ones, under sustainable reaction conditions. The studied approaches involved the use of **heterogeneous acid systems, salts, mineral acids and metallic catalysts**, obtaining significant catalytic performances. Several examples of commercial heterogeneous acid catalysts (**niobium phosphate and Amberlyst A70**) and commercial salts (**copper nitrate**) for the production of 5-hydroxymethylfurfural will be shown, together with its conversion to 2,5-bis(hydroxymethyl)furan and to 2,5-bis(hydroxymethyl)tetrahydrofuran in aqueous solution adopting commercial metallic systems (**5 wt% Ru/C, 5 wt% Pd/C, 5 wt% Pt/C**). In addition, successful examples of use of commercial mineral acids, such as **sulfuric acid**, will be discussed, adopted for the *one-pot* alcolysis reaction of many cellulosic residues to *n*-butyl levulinate, an excellent additive for diesel engines.
Finally, Prof. Claudia Antonetti has collaborated and continues to **collaborate with large, medium and small companies** in several projects funded by the companies themselves and/or by the Tuscany Region and/or by the European Community, as evidenced also by her **patent activity**.

Acknowledgements
The author would like to thank the Italian Ministero dell'Istruzione, dell'Università e della Ricerca for funding the PRIN 2020 LEVANTE project (Progetti di Ricerca di Rilevante Interesse Nazionale Bando 2020, 2020CZCJN7).

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Structural Characterization of Olefin-based Multiblock Copolymers by Chain Shuttling Technology

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Aim of this Ph.D. project was to understand the complex and elusive molecular structure of olefin-based multiblock copolymers (OBCs), obtained via chain shuttling technology (CST). The CST is a process in which reversible trans-alkylation reactions take place between two organometallic catalysts through the mediation of a chain shuttling agent (i.e., diethyl-zinc). Since the two organometallic catalysts differ in their comonomer incorporation ability, the repeated exchanges of the growing polymeryl chains between the catalytic metal centers lead to OBC constituted by alternating blocks of different comonomer content. Furthermore, as a result of the stochastic shuttling process that involves homo- and hetero-shuttling events, the resultant OBCs feature a statistical distribution of block lengths and of number of blocks/chain. In particular, ethylene-based multiblock copolymers represent the latest breakthrough in polyolefins and are characterized by alternating hard and soft blocks. The crystallizable hard blocks are constituted by HDPE with very low comonomer content (1-octene, 1-hexene, or another α-olefin), whereas the soft amorphous blocks are constituted by random ethylene/1-alkene copolymers with high comonomer content.

To address the complexity of these systems, research activities were first focused on the systematic characterization of paradigmatic Infuse™ commercial samples, which are the first example of OBCs synthetized in chain shuttling conditions. The commercial grades were selected as benchmarks, since they are available in large quantity, and used to test the different experimental and semi-empirical methods aimed at assessing the non-uniform polydisperse microstructure, the average molecular mass of the blocks, the average number of blocks/chain, and the distribution of methylene sequence length in the hard blocks. Analysis of the inter- and intrachain heterogenous microstructure and of the segmental mobility of the hard and soft blocks have been reported in Chapters 3 and 5.

In a second step, in order to grasp what is the effect of different operating parameters in the chain shuttling copolymerization on the microstructure, phase separation, and on the final properties, OBCs were synthetized ad hoc in a Parallel Pressure Reactor system (PPR), since the high-throughput synthetic approach allows to explore the entire set of variables. A thorough analysis, reported in Chapter 4, of microstructure and morphology was then carried out to understand the role of variables such as weight fraction of hard and soft blocks, different comonomers and differences in comonomer contents between the blocks, different values of segregation strength (χN values), and differences in the distribution of block size.

By closing the disambiguation loop, it has been possible to determine OBCs microstructure and architecture and correlate them univocally to material structure and morphology.

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IND-KN-01

Exploiting Precision Polymers for the Fabrication of Polymeric Nanoparticles

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The Amphiphilic block copolymers (BCP) can spontaneously segregate (self-assembly) in distinct phases, due to opposed interactions with a selective solvent, generating polymeric nanoparticles (NPs) in solution. The final particle morphology can be predicted to some extent from structural parameters and by thermodynamic considerations, but kinetic effects rising from the macromolecular nature of the amphiphiles further enrich the picture. In fact, it is possible to obtain morphologies ranging from core-corona micelles to vesicles and wormlike micelles. Several methodologies for the synthesis of amphiphilic precision BCP can be exploited, particularly relevant are controlled radical polymerizations, as Reversible Addition-Fragmentation chain-Transfer (RAFT), Photo-induced Electron/energy Transfer (PET)-RAFT[1,2] polymerization, or living ring opening polymerization (ROP). Polymerization-Induced Self-Assembly (PISA) can be also employed together with RAFT and PET-RAFT. These methods allow the synthesis of block copolymers with effective control over ratio between the two blocks, the molecular weight and molecular weight distribution. RAFT is a robust and reliable technique that can be used with a large variety of vinyl monomers (acrylates, acrylamides, functional styrenes, dienes) meanwhile ROP, catalysed by organic bases with low nucleophilicity, is suitable for monomers like lactide, glycolide, ring strained lactones and cyclic carbonates. In both cases preformed polymers, like poly(ethylene oxide), can be used as first block on which polymerize the second one. By means of a careful choice of the common solvent and a controlled process of switching to the selective solvent (water in this case) it is possible to obtain a large variety of morphologies for simple diblock copolymers. More specifically the complex self-assembly behavior of two families of BCP, poly(styrene)-block-poly(dimethylacrylamide) (PS-b-PDMA)[3] and poly(ethyleneoxide)-b-poly(lactic acid) (PEO-b-PLA),[4] will be described by means of Dynamic Light Scattering, Atomic Force Microscopy, Transmission Electron Microscopy and Cryogenic Electron Microscopy. Finally the morphology of NPs directly obtained by PISA-PET-RAFT for the system poly(butylacrylate)-block poly(dimethylacrylamide) will be also described.[6]

References:

[1] V. Bellotti, R. Simonutti, Polymers 2021, 13, 1119.
[2] V Bellotti, C Daldossi, D Perilli, M D'Arienzo, M Stredansky, C Di Valentin, R. Simonutti, Journal of Catalysis 2023, 115074.
[3] A. Bianchi, M. Mauri, S. Bonetti, K. Koynov, M. Kappl, I. Lieberwirth, H.-J. Butt, R. Simonutti, Macromolecular rapid communications 2014, 35, 1994-1999.
[4] R. Simonutti, D. Bertani, R. Marotta, S. Ferrario, D. Manzone, M. Mauri, M. Gregori, A. Orlando, M. Masserini, Polymer 2021, 218, 123511.
[6] V. Bellotti, G. Beretta, R. Simonutti, Polymer 2023, 271, 125804.

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IND-OR-001

Molecular imprinted poly-3,4 ethylenedioxythiophene for supercapacitor application

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Molecular Imprinting Polymers (MIPs) due to their high selectivity versus target molecule have been extensively applied into a lot of different research and application areas (high performance sensors, chromatographic application, solar cells).[1,2] Moreover, they can be easily synthetized by a low cost and environmentally friendly processes. In this work, MIPs are applied to engineering the surface electrode to enhance the specific capacitance of electrode for supercapacitor device. Poly 3,4-ethylenedioxythiophene (PEDOT) was prepared by electrochemical method and tested as electrode materials in supercapacitor. Two different template molecules (oxalic acid and ascorbic acid, PEDOT-MIPs) were used to demonstrate the positive effect of molecular imprinting on capacitance of PEDOT-based electrode. FE-SEM, cyclic voltammetry, electrochemical impedance spectroscopy and galvanostatic charge-discharge analyses were done to completely characterize these materials. The small molecular dimension of oxalic acid influences the film morphology, leading to MIP electrode with the highest performance. Finally, a symmetric supercapacitor based on these electrodes was produced and tested in different conditions (evaluating also its stability under cherge-dischrge cyles). The obtained results shows the possibility of applying the molecular imprinting approach to enhance the electrochemical properties of electrode materials for supercapacitor application.

References:

[1] N. Sangiorgi, A. Sangiorgi, F. Tarterini, A. Sanson, Electrochimica Acta 2019, 305, 322– 328.
[2] T. Sajiini, B. Mathew, Talanta Open 2021, 4, 100072.

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IND-OR-002

Branched poly-L-lactide from renewable polyols as nanosystems for drug delivery

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Branched polymers have emerged as promising carriers for drug delivery since they have a higher surface area and more available functional groups compared to linear counterparts.[1] These characteristics enable them to encapsulate or conjugate a larger amount of drug molecules. In addition, the branching architecture can be engineered to control the release kinetics of drugs by modifying the degree of branching or the composition and length of branches. Herein, the synthesis of branched poly-L-lactide (PLLA) is reported by using renewable polyols, glycerol (Gly) and diglycerol (DGly) as initiators. In order to evaluate the effect of branching chain length on polymer physico-chemical properties and drug availability, different L-lactide (L-LA)/OH molar ratios (8, 16 and 24) were investigated (Figure 1).

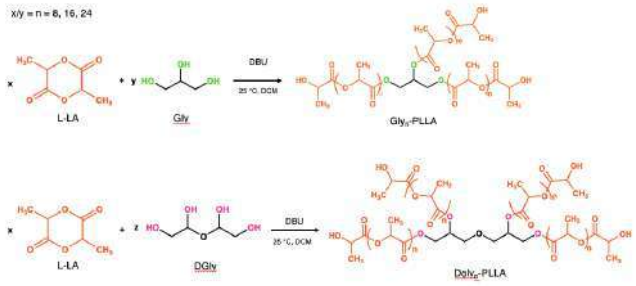

Figure 1: Synthesis of branched PLLA by using glycerol (Gly) and diglycerol (DGly) as initiators.

Polymers with molecular weight (MW) ranging from 4100 to 20000 g mol^{-1} were obtained. An increase in polymer MW and gyration radius was observed with increasing L-LA/OH molar ratio. All branched polymers were amorphous, except for the polymer with the longest branches (DGly24-PLLA), and able to self-assemble in water giving 200 nm-in size polymer nanoaggregates. Usnic acid (UA), a hydrophobic, antimicrobial and anticancer natural compound, was encapsulated in the polymer nanoaggregates. Following encapsulation, a significant increase in UA apparent solubility in water together with a reduced toxicity *in vitro* was observed, highlighting the potentialities of the synthesized systems as carriers for drug delivery.

References:

[1] A. B. Cook, S. Perrier, Advanced Functional Materials, 2020, 30(2), 1901001.

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IND-OR-003

Curcumin-Based Polymer Derivatives for Pollutants Sensing Applications

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Volatile organic compounds (VOCs) are ubiquitous pollutants in water and air matrices because of their emission sources, which could be both biogenic and anthropogenic. The development of smart polymer-based sensors might provide cheap, reliable, and rapid responses, especially compared to the expensive and time-consuming common analytical methods.

To provide more sustainable devices, the use of naturally derived chromophores as sensing units is a main goal in modern materials science. In this context, Curcuminoids have already been investigated as useful optical sensors for different applications: from pH evaluation to organic and inorganic species detection[1]. Furthermore, the possibility of forming stable complexes of Curcumin with selected metal ions (such as Zn(II) cations) increases the types of chemical species to be detected[2]. However, the application of these systems on an industrial scale must overcome their poor adhesion on the surface of common substrates.

In this communication, to obtain filmable systems suitable for the detection of pollutants in fluids, Curcumin-based polymer derivatives were developed through a covalent approach, aiming to link the curcumin molecule as a side chain group. The starting co-monomers were chosen to guarantee the filmability and adhesion of the final system on different substrates. The presence of suitable functional groups allows to covalently link the Curcumin moiety, which was successively metalated with Zn(II) ions. The so-obtained polymeric sensors (with and without complexed metal) were structurally and functionally characterized.

The functional characterization of the polymeric sensors was performed through sensing experiments using models of VOCs (such as ethanol, toluene, acetone, ethylenediamine, pyridine, and ammonia), exposing thin films of the sensors to the pollutants in the gas phase, and monitoring the related spectroscopic variations.

Experimental data show that the new copolymers, thanks to the synergy between curcumin and the polymer backbone features, allow for an easy and cheap approach to the detection of polar and non-polar VOCs.

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References:

[1] R.R. Paden, et al., Materials Today: Proceedings, 2021, 46, 1711 – 1717; M. Pavai, et al., Food Analytical Methods, 2015, 9, 1046-1052.
[2] M.Y. Khorasani, et al., Materials Science and Engineering: C, 2019, 103, 109792.

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IND-OR-004

Gold nanoparticles supported on poly(2,6-dimethyl-1,4-phenylene oxide) as active catalyst in aerobic oxidation of alcohols: the potential of a porous polymer support

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Sustainable oxidation of alcohols to carbonyl compounds is a research topic of increasing interest in green chemistry for the synthesis of valuable fine chemicals, pharmaceuticals, agrochemicals, biomolecules, and materials from biomass. Gold nanoparticles (AuNPs) stands out among the heterogenous metal catalysts for their activity and selectivity under mild conditions in the aerobic oxidation route using eco-friendly oxidant such as dioxygen or peroxides. The AuNPs based catalysts are typically stabilized by deposition/inclusion in metal oxides, carbonaceous materials and organic polymer support;[1] more recently, porous organic polymers (POPs) have attracted significant interest because of their easy synthesis and functionalization, low cost, stability and possibility of processing under different morphology (powder, monoliths, films) providing spectacular examples of confined catalysis. Here, we report on the aerobic oxidation of AuNPs embedded in poly(2,6-dimethyl-1,4-phenylene oxide) (PPO) matrix where the nano porosity of the polymer support is able to efficiently sorb small organic molecules from air or water, even in trace levels.[2]

The AuNPs-PPO catalyst (2 %w of Au) was readily prepared by co-precipitation in methanol of the *in situ* prepared AuNPs and PPO, followed by annealing at 170°C; spherical nanoparticles of 7 nm were characterized by WAXD and TEM analysis. The porosity of the polymer support was thus modulated using mixture of organic solvents (toluene, chloroform, tetrachlomethane) and water to produce a variety of gold catalysts showing different morphology. The AuNPs-PPO catalysts were preliminary tested in the benchmark aerobic oxidation of 1-phenylethanol and benzyl alcohols showing high TOF and good thermal stability (30-100°C) in the presence of 1 equiv. of KOH as Brosted base activator. Interestingly this gold catalyst exhibits excellent selectivity in oxidation of benzyl alcohol to produce exclusively benzaldehyde when the catalytic run is carried out a 30°C in water /chloroform mixture (1:1 v/v). Direct oxidative cross esterification of cinnamyl alcohol with aliphatic alcohols was successfully obtained to produce alkyl cinnamates in the presence 1-butanol and 1-hexanol. On the basis of these results, we moved our scientific interests towards more challenging and interesting targets in sustainable catalysis. The synthetic protocol defined in the benchmark oxidation runs was thus extended to the aerobic oxidation of furanic compounds from biomass such as furfural, furfuryl alcohol, furfural and 5-hydroxymethylfurfural. The main results in this field will be discussed in the light of the chemical physical properties of the polymer support that imparts specific selectivity in the reactivity pattern.

References:

[1] Sharma, A.S., Kaur, H., Shah , D., RSC Adv., 2016, 6, 28688

[2]Auriemma, F.; Daniel, C.; Golla, M.; Nagendra, B.; Rizzo, P.; Tarallo, O.; Guerra, G., *Polymer* 2022, *258*, 125290.

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IND-OR-005

Hydrophobic poly(ester-urethane)s coatings from tomato cutin for recyclable paper

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Lately, many researchers are focusing on the development of new sustainable coatings to address the familiar challenges linked with the use of polymers derived from fossil sources, commonly employed in paper coatings[1]. Bio-based polymers obtained from biomass are an appealing alternative since they can be usually easily biodegraded[2], thus limiting the environmental impact. Among the available biomasses, one of the most widespread is from by-products of the tomato processing industry, that are very rich in natural biopolymers, such as polyesters. The main component of tomato waste, especially peels, is cutin, that is an amorphous polymeric network of polyhydroxylated C16 and C18 fatty acids monomers cross-linked by ester bonds[3]. The most important role of this biopolyester is to avoid water loss from plant internal tissue, due to its high hydrophobicity, that thus make cutin particularly suitable for applications as coating.

In recent years, a few technologies have been developed to obtain cutin monomers from tomato agro-wastes at an industrial scale, in particular through alkaline hydrolysis[4]. In our work, we exploited these hydrolysed cutin monomers to produce hydrophobic poly(ester-urethane)s, in order to merge the biodegradability of the polyester component and the versatility and adhesivity of the polyurethane component. The synthesis was carried out in two steps: firstly, a copolymerization between cutin monomers and 1,4-butanediol, that allowed us to obtain polyesters with different degrees of conversion (30, 38 and 50%); secondly, reaction of the three prepolymers with isophorone diisocyanate to prepare different poly(ester-urethane) resins. The products were deeply characterized by spectroscopic (FT-IR, ^{1}H and ^{13}C-NMR) and thermal (TGA, DSC) analysis and subsequently applied as coating on two different types of paper. The morphology of the coatings was observed by SEM investigation and the barrier properties to liquid water and grease were also evaluated, showing an excellent impermeability of the samples. Lastly, biodegradability and recyclability tests were carried out on the coated papers, yielding promising preliminary results.

References:

[1] M. Mujtaba, J. Lipponen, M. Ojanen, S. Puttonen, H. Vaittinen, 2022, 851, 158328.
[2] A. Samir, F. H. Ashour, A. A. Hakim, M. Bassyouni, 2022, 6(1), 68.
[3] A. Heredia, 2003, 1620(1-3) 1-7
[4] A. Cifarelli, I. M. Cigognini, L. Bolzoni, A. Montanari, 2019, 11, 33-45

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IND-OR-006

Catalytic Chemical Upcycling of Elastane

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Synthetic fibres are widespread in nowadays society due to their high performances and versatility as well as low price with a global projected to reach 81 Mt in 2025.[1] Nevertheless, only a minor amount get recycled (13%) whereas the majority get either landfilled either recovered, being one of the major global sources of microplastics and of pollution.[1] Elastane, a polyurethanes fibre, is often presents in clothes in a relatively low amount (below 5%). Nevertheless, elastane critically hampers the fibre's mechanically recyclability.[2] It is essential to selectively extract and cleave elastane from fibres to enable the recuperation of those synthetic materials (Figure 1).

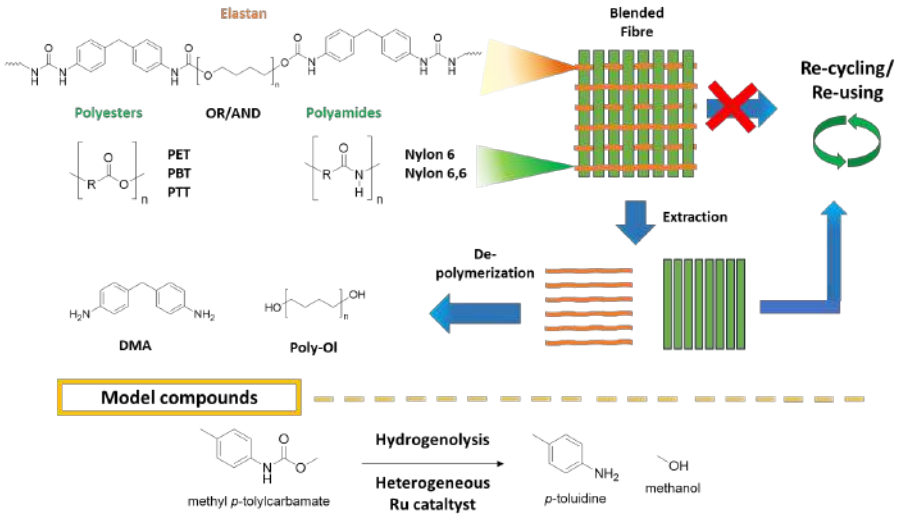

Figure 1: Possible strategy for the elastane-containing textiles (**up**) recycling of elastane blended fibres, (**down**) carbamate hydrogenolysis as model compound.

A possibility is to selectively separate the blended fibres by extraction, followed by selective catalytic de-polymerization of the polyurethane into the major precursor, namely diamine (a.o.4,4'-Methylenedianiline DMA) and a polyols. To date, few studies have been focusing on polyurethanes and elastane depolymerization, by solvolysis using inorganic bases or Ru-based homogeneous catalysts.[2-3] Therefore, the development of heterogeneous catalysts for this purpose is greatly needed.

Due to the intrinsic complexity of polyurethanes, such as elastane, the development of catalytic active, selective catalysts is extremely challenging. Alternatively, monomeric carbamate, such as the methyl p-tolyl carbamate represents a viable model compound to establish catalytic processes.

Herein, we are developing Ru-supported catalyst for the selective hydrogenolysis of carbamate toward amine and alcohol to be in a second stage applied to blended textiles.

References:

[1] Textile Exchange, Preferred Fiber & Materials Market Report, October 2022. [2] Johansen, Martin B., et al. Green Chemistry 25.24 (2023): 10622-10629. [3] Wang, Zheng, et al. Journal of Catalysis 428 (2023): 115165.

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IND-OR-007

Single-Atom Catalyst Shaping Via Photopolymerization 3D-Printing

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This study introduces a novel solution to the design of structured catalysts through the integration of single-piece 3D printing with single-atom catalysis. Structured catalysts are widely employed in industrial processes, as they provide optimal mass and heat transfer, leading to more efficient use of catalytic materials. These materials are conventionally prepared using structured (ceramic or metallic) bodies, which are washcoated and impregnated with the catalytically active layer. However, this approach may lead to adhesion issues with the active layer. By employing photopolymerization printing, a stable and active single-atom catalyst is directly shaped and incorporated herein into a stand-alone single-piece structured material. The battery of characterization methods confirms the uniform distribution of catalytic species and the structural integrity of the material. Computational fluid dynamics are also applied to demonstrate enhanced momentum transfer and light distribution within the structured bodies. The materials are finally evaluated in the continuous-flow photocatalytic oxidation of benzyl alcohol to benzaldehyde, an important reaction to prepare biomass-derived building blocks. The innovative approach for catalyst manufacturing reported herein circumvents the complexities of traditional methods, offering scalability and efficiency improvements, and highlights the transformative role of 3D printing in catalysis engineering, with new avenues to tackle adhesion issues and revolutionize catalytic design across diverse domains.

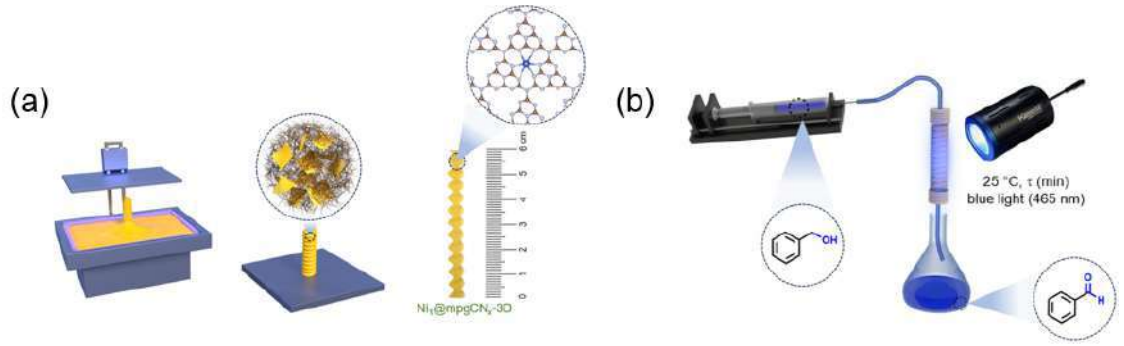

Figure 1: (a) 3D-printing of the structural catalyst and (b) Catalytic tests for benzyl alcohol oxidation.

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IND-OR-008

Stability of Ba-based Dual Function Materials (DFMs) for cyclic CO_2 capture and hydrogenation probed by operando FT-IR

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Dual function materials (DFMs) allows the cyclic capture and hydrogenation of CO_2 over the same material, in principle increasing the efficiency of the carbon capture and utilization processes [1]. The most investigated application for DFMs is the capture of CO_2 from combustion flue gases coupled with the hydrogenation of the stored CO_2 to CH_4. To this aim, DFMs requires a basic metal (alkaline and/or alkaline-earth) to selectively capture CO_2 from flue gases, and a transition metal to convert it into CH_4 upon (green) H_2 exposure. The formulation and stability of these materials are still debated [2], and mechanistic insights on deactivation phenomena are needed to allow for the rational design of these materials. In this study, a $Rh/Ba/Al_2O_3$ DFM is cycled and characterized at different operating conditions by *operando* FT-IR, coupling surface and gas phase analysis. Temperature plays a critical role not only for the methanation rate but also for CO_2 adsorption, determining the geometrical arrangement of the adsorbed carbonates. The basicity of the adsorption sites can also influence CO_2 adsorption, as more basic sites are responsible for more stable carbonates [3], which need higher temperatures to desorb/react. When CO_2 and water are present in the adsorption atmosphere, the CO_2 storage capacity is decreased due to the competition for the same adsorption sites. Nevertheless, in these conditions Ba is still able to adsorb significant amounts of CO_2 in the form of bidentate and ionic carbonates. However, the ability of Ba to form strongly bound carbonates (**Fig 1A**) can also backfire, by leading to a progressive accumulation of sturdy carbonates on the DFM (**Fig 1B**), ultimately leading to a decrease in CH_4 production as the cycles proceed (**Fig 1C**).

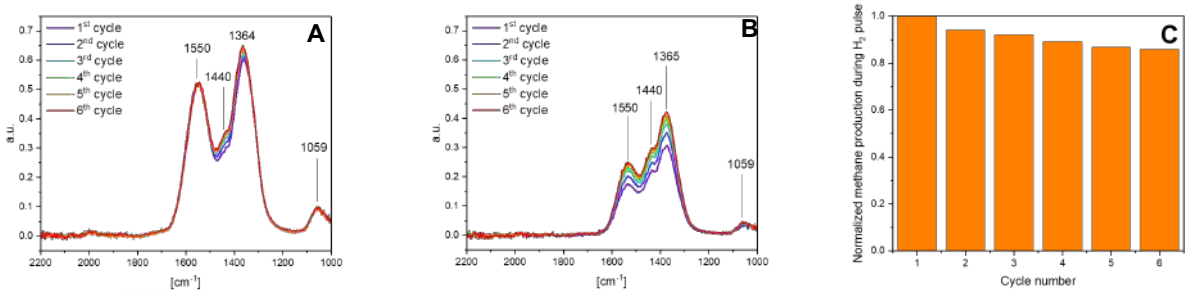

Figure 1: **A**: Carbonates at the end of the adsorption steps; **B**: Residual carbonates at the end of the hydrogenation step; **C:** Progressive loss in CH4 evolved from the DFM during the hydrogenation steps of 6 consecutive cycles. Experimental conditions: 350°C, 200 L(STP)/h/g, P = 0 barg; adsorption: 1% CO_2, 5 min; hydrogenation: 4% H_2, 5 min

References:

[1] Duyar et al., *J CO_2 Util* 2016, 15, 65-71.
[2] Jeong-Potter et al., *Appl Catal B: Environ*, 310, 121294
[3] Bermejo-López at al., *J CO_2 Util* 2022, 58, 101922.

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IND-OR-009

Operando-Raman Analysis of Surface Carbon Formation and Its Implications on Methane Dry Reforming Kinetics on Rh-Based Catalysts

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Methane Dry Reforming reaction (MDR) is a promising route for biogas valorization. Nevertheless, MDR industrial scalability is constrained by catalyst deactivation due to carbon deposition, a phenomenon with mechanisms and kinetic implications still under debate.[1,2] In our investigation, we have combined kinetic measurements in an annular reactor, time-resolved and spatially-resolved *operando* Raman spectroscopy to shed light on the carbon formation pathway and its kinetic consequences during MDR over Rh-based catalysts.

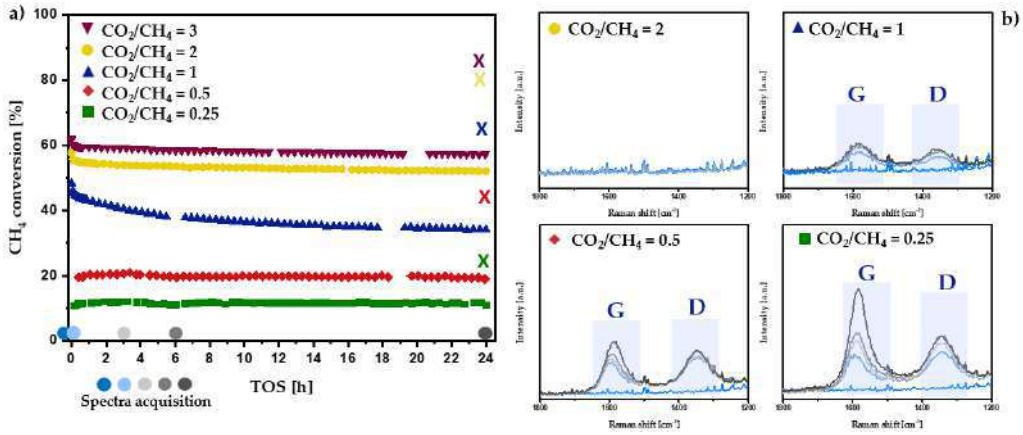

Figure 1: a) Experimental and equilibrium ("X" symbol) CH_4 conversion over 24 h MDR tests on 4% Rh/Al_2O_3 catalyst for inlet CH_4 = 8 vol.% at different CO_2/CH_4 ratios (between 3 and 0.25). T = 600°C, P = 1 atm, GHSV = $1.4*10^6$ $NL/kg_{cat}/h$; b) Time-resolved *operando* Raman spectra acquired before the reaction, at TOS = 5 min, 3 h, 6 h and 24 h.

Our findings (Figure 1.a) indicate that the concentration of CO_2 does not significantly alter MDR kinetics at the start of reaction. However, carbon deposition markedly impacts catalyst stability and activity. The coking process is strongly dependent on the CO_2/CH_4 ratio, and specifically, at a CO_2/CH_4 ratio ≤ 1, carbon formation is evident within 24 hours (Figure 1.b). The resulting carbon aggregates decrease the availability of Rh surface, leading to deactivation and providing an apparent kinetic dependence on CO_2. Additionally, spatially-resolved *operando* Raman spectra has unveiled a descending trend of carbon deposits along the reactor axial coordinate, while tests performed with the addition of a small fraction of O_2 (0.8 vol.%) proved to hamper carbon deposition. In summary, this work highlights the critical role of a multi-technique approach in deepening our understanding of catalytic processes, especially when intrinsic kinetics are obscured by deactivation.

References:

[1] J. Wei, E. Iglesia, J. Catal. 225 (2004) 116–127

[2] A. Donazzi, A. Beretta, G. Groppi, P. Forzatti, J. Catal. 255 (2008) 259-268

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IND-OR-010

One-pot syncrude production via CO_2 hydrogenation over promoted iron-based catalyst

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The conversion of CO_2 into long-chain hydrocarbons using low-carbon H_2 is particularly appealing for the production of aviation fuels, where a high energy density is required and closing the emission gap is particularly challenging. In most of the R&D papers on this topic, CO_2 is firstly reduced to CO via reverse water-gas shift, and then CO is converted into hydrocarbons via Fischer-Tropsch synthesis (FT). Developing a one-pot process where CO_2 is transformed into long-chain hydrocarbons in a single reactor via a modified Fischer-Tropsch (MFT) process can increase the overall efficiency, helping the final products to become competitive on their fossil-based equivalent[1]. To this aim, a coprecipitated iron catalyst promoted with Zn, Cu and K, which has shown good performances in the FT[2], was studied in the MFT using an experimental setup allowing the speciation and quantification of all products up to C_{30+} (waxes). The catalyst showed high conversion, comparable if not higher than what seen in FT conditions but with higher selectivity towards lighter products (C_{5+} selectivity in FT reached around 60%, while it is little more than 30% in MFT conditions, Fig 1A). Nevertheless, a high productivity towards C_{5+} species was seen (108 mg/h/g_{cat} at 300 °C, 30 barg and 78 mg/h/g_{cat} at 300 °C, 10 barg) and the product distribution hardly changed in the hundreds of hours during which the catalyst was studied, witnessing its stability (Fig 1A). Considering the syncrude fraction, almost 65% of its weight is in the kerosene fuel range i.e., C_8-C_{16} (Fig 1B). Furthermore, in the perspective of economic competitiveness, it is possible to boost the syncrude productivity by olefins oligomerisation, being the products very rich in light olefins, or even by hydrocracking of heavier cuts.

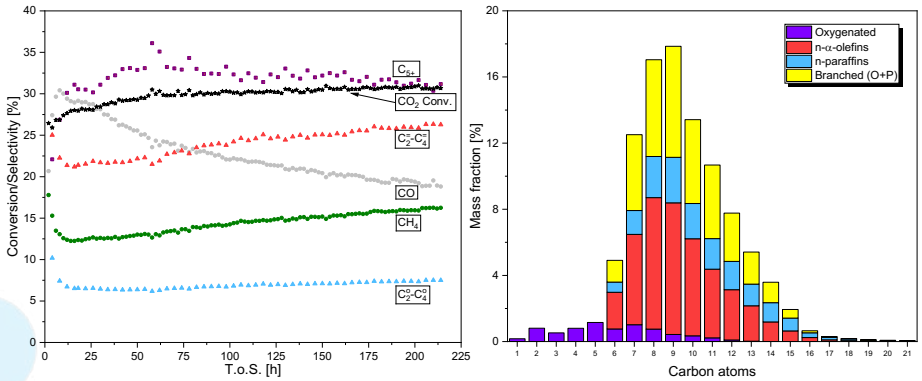

Figure 1. A) Conversion and selectivity at 300 °C, 10 barg versus time on stream (T.o.S.). B) syncrude composition at 300 °C, 10 barg, H_2/CO_2=3:1 mol/mol.

References:

[1] J. Wei, Q. Ge, R. Yao, Z. Wen, C. Fang, L. Guo, H. Xu, J. Sun, Nature Communications 2017, 8, 15174
[2] S. Li, A. Li, S. Krishnamoorthy, E. Iglesia, Catalysis Letters 2001, 77, 195-207

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IND-OR-011

Regenerable Ni-Al catalysts in Methane Dry Reforming: the core-shell structure case

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Hydrogen is selected as one of the main green energy vectors for the future, but its production is still not zero emission. One way to convert this production in a green optic is to exploit CO_2 by Methane Dry Reforming (MDR), that is estimated to have a negative CO_2 balance (-0.44 kg per kg of syngas)[1]. Unfortunately, compared to the classic Steam Reforming, MDR is still not economically advantageous because of the lack of an active, selective, and stable catalytic system. The most studied are Ni supported ones, that suffer of Ni sintering but also coke deposition, because of inevitable side reactions. To minimize these problems, different approaches can be followed. In previous studies is demonstrated that inserting metal promoters in low amount can be effective in preventing coke deposition[2], but also operate on catalyst synthetic method and so on shape and morphology, can be advantageous. In this work, we prepared Ni/Al_2O_3 by incipient wetness impregnation and by co-precipitation, comparing them to a not so common structure for MDR and Ni/Al_2O_3 catalysts: the core shell one ($Ni@Al_2O_3$). This type of catalyst should prevent the coke deposition on the active phase (Ni), that is protected by the shell made of alumina[3]. We tested the catalytic systems at 650°C with a GHSV of 12000 h^{-1}. The $Ni@Al_2O_3$ exhibited an optimal stability, a major selectivity towards H_2 and a lower CO_2 activation energy. We performed some regeneration cycles, being able to repristinate the catalyst's activity. The fresh and exhausted catalysts were characterized by different techniques such as TPR, TPO, TPD, N_2 physisorption, XRD, SEM, EDX and TEM. The core shell catalyst resulted to be a proper structure to minimize the MDR process problems.

References:
[1] H. Er-rbib, C. Bouallou, F. Werkoff, Chemical Engineering Transaction, 2012, 29, 163–168.
[2] M. Pizzolato, G. Da Pian, E. Ghedini, A. Di Michele, F. Menegazzo, G. Cruciani, M. Signoretto, Catalysis Today, 2023, 418, 114041.
[3] E.Yang, E. Nam, Y. Jo, K. An, Applied Catalysis B: environmental, 2023, 339, 123152.

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IND-OR-012

Solar energy conversion via photo-thermo-catalytic H_2 production

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Photo-thermo-catalysis (PTC) has recently emerged as an innovative technology able to synergistically combine photocatalysis and thermocatalysis, resulting in a greater solar spectrum utilization and better performances[1]. This proves PTC to be a promising strategy for large scale production of solar fuels[2].

In this work, the PTC H_2 production via methanol steam-reforming ($CH_3OH + H_2O \rightarrow CO_2 + 3\ H_2$) has been investigated under both UV-vis irradiation and dark conditions in the 30-350 °C temperature range, over different oxide materials[3].

Temperature was found to strongly affect the photoactivity of pristine TiO_2, in terms of both hydrogen production rate (r_{H_2}) and selectivity towards the different CH_3OH oxidation products (H_2CO, CO and CO_2). The introduction of heat in the system boosts the r_{H_2} from 2 to 40 mmol h^{-1} g_{cat}^{-1} under UV-vis irradiation at 30 and 350 °C, respectively. Moreover, the surface decoration with Pt nanoparticles led to an impressive increase of r_{H_2} up to ca. 340 mmol h^{-1} g_{cat}^{-1} under irradiation at 350 °C.

However, under these conditions, CO is obtained as main CH_3OH oxidation product, limiting the production of H_2. An increased selectivity to CO_2 (from 5% to 55%) was obtained together with a greater r_{H_2} upon CeO_2 addition in catalyst formulation, promoting the Water Gas Shift reaction ($CO + H_2O \rightarrow CO_2 + H_2$).

Due to the large solar energy absorption capability, $LaFeO_3$ was investigated for the same purpose. This perovskite exhibits a different behaviour compared to TiO_2, where an increase of r_{H_2} from 0.25 to 1.75 mmol h^{-1} g_{cat}^{-1} was observed moving from 30 to 350 °C under irradiation. Its PTC properties were significantly improved by substitutional doping of Fe(III) with Cu(II), where the 20% substitution resulted in a maximum r_{H_2} of 28.5 mmol h^{-1} g_{cat}^{-1}.

The effect of heat and light on the H_2 production and selectivity was studied by *in-situ* DRIFT (Diffuse Reflectance Infrared Fourier Transform) analysis[4]. This allows to study the dynamic of all the reactants, intermediates, and products and thus to understand the reaction mechanism.

References:

[1] R. Ma, J. Sun, D. H. Li, J. J. Wei, Inter. J. Hydrogen Energy 2020, 45, 30288-30324
[2] A. Iglesias-Juez, et al. Curr. Opin. Green Sustainable Chem. 2022, 37, 100652
[3] G. L. Chiarello, D. Ferri, E. Selli, Appl Surface Science. 2018, 450, 145-154
[4] G. L. Chiarello, M. Bernareggi, E. Selli, ACS Catal. 2022, 12, 20, 12879-12889

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IND-OR-013

Advancing decarbonization: experimental perspectives on CO_2 methanation

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Carbon dioxide capture, conversion and storage (CCCS) technologies are becoming crucial in representing a route for the use of carbon dioxide as C1 building block[1]. On the other side, renewable energies face the issue of intermittency, so the surplus energy from renewable resources could be stored in the guise of green hydrogen, which however still lacks a capillary distribution network. It can be used for CO_2 methanation as an interesting solution, due to wide methane grid existing worldwide and the clear regulatory framework.

In our study the methanation of carbon dioxide was approached thanks to the use of two continuous experimental setups. Specific focus is put on the direct methanation of biogas streams to obtain upgraded biomethane. The initial catalysts screening was performed in an Incoloy 800 tubular reactor under atmospheric pressure. Subsequently, high-pressure tests and Gas Hourly Space Velocity (GHSV) screening in the range of 3000 h^{-1} to 400000 h^{-1} were conducted using a PID FR-50, equipped with a SS-316 tubular reactor and a continuous G/L separator. Numerous materials were used to support the Ni active phase, such as Al_2O_3, ZrO_2, TiO_2, ZSM-5, SiO_2, MgO and CeO_2. Catalysts were obtained through the use of various techniques, including wet-impregnation, sol-gel, co-precipitation, radio frequency (RF) thermal plasma and Ultrasound-Assisted synthesis technique. The effect of mixed supports, such as Al_2O_3/CeO_2 and ZrO_2/CeO_2 has been investigated as well. Testing has been done both on pure CO_2 streams, supposed coming from a CO_2 capture process, and on biogas streams, without prior separation.

Several catalysts showed interesting performance and, among them, 36% Ni/Al_2O_3 and 36% Ni/ZSM-5 achieved high CO_2 conversion, approaching the thermodynamic equilibrium. Overall, the use of Ni catalysts, despite the relatively high loading, has proven to be suitable for methanation, presenting an alternative to noble metal-based catalysts.

References:

[1] S.A. Theofanidis, A.N. Antzaras, A.A. Lemonidou, Curr. Opin. Chem. Eng. 39 (2023) 100902.
[2] M. Tommasi, S.N. Degerli, G. Ramis, I. Rossetti, Chem Eng Res Des. 201 (2023) 457–482.

Acknowledgments

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IND-OR-014

Ti/Zr/O Mixed Oxides for the Catalytic Transfer Hydrogenation of Furfural to GVL in a Liquid-Phase Continuous-Flow Reactor

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Thanks to its high reactivity furfural (FUR) can be used as platform chemical to produce a great amount of high-value chemistry compounds. Among these, γ-valerolactone (GVL), a promising five-carbon cyclic ester potentially valuable as 'green' additive for bio-based fuels or as substituent of monomers to produce polymers nowadays derived from oil.[1] The conversion of furfural (FUR) into γ-valerolactone (GVL) includes many reaction steps (*Figure 1*). Reduction steps, which are the most complicated from an environmental point of view, can exploit MPV (Meerwein-Pondorf-Verly) mechanism using isopropanol as H-donor rather than gaseous H_2. The latter choice, together with the use of an appropriate heterogeneous catalytic system characterized by either Lewis or Brønsted acidity, enables the realization of a more sustainable process. ZrO_2 is reported to be highly efficient in hydrogenating furfural (FUR) thanks to its strong Lewis acidity that favors the first and the last steps of the one-pot reaction (*Figure 1*). However, being characterized by weak Brønsted acidity, this oxide is not capable of catalysing the entire cascade reaction. Synthetizing Ti/Zr/O mixed oxides with different molar ratio allows to modulate the acidity characteristics of the overall material. This work aims to study the catalytic performance of Ti/Zr/O mixed oxides in the cascade reaction from furfural (FUR) to γ-valerolactone (GVL) in a continuous liquid-phase plant. The catalysts were synthetised by co-precipitation at controlled pH and characterised by BET, TPD-NH_3, XRD and XRF. Screening tests were made in a PFR alike reactor at defined conditions to assess which one was the most promising catalyst. The latter was then used to evaluate the influence of reaction conditions on the catalyst performance. Promising results have been obtained working with Ti/Zr/O (1:1 molar ratio), reaching selectivities of 45% of furfuryl isopropyl ether (FPE), 20% of GVL and total conversion of FUR. Furthermore, the reaction mechanism was studied, discovering that the conversion of FPE in isopropyl levulinate (IPL) is totally prevented in the conditions used.[2]

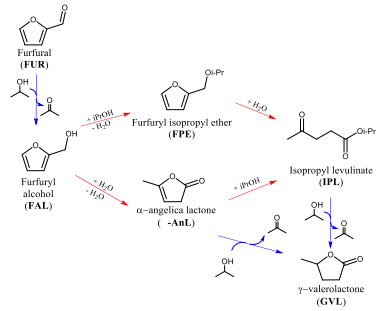

Figure 1: schematic cascade reaction from furfural (FUR) to γ-valerolactone (GVL); blue and red arrows point out Lewis and Brønsted catalysed steps respectively.

References:

[1] Alonso, D. M.; Wettstein, S. G.; Dumesic, J. A. *Green Chem.* **2013**, 584–595.
[2] Saotta, A.; Allegri, A.; Liuzzi, F.; Fornasari, G.; Dimitratos, N.; Albonetti, S. *ChemEngineering* **2023**, 23.

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IND-OR-015

Hydrogen production by CH_4 decomposition via chemical looping process

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Methane decomposition chemical looping (CLD) emerges as a promising and innovative method for hydrogen production, characterized by its ability to efficiently convert different feedstocks into high-purity hydrogen while significantly reducing greenhouse gas emissions. Furthermore, hydrogen obtained through CLD presents an eco-friendly alternative, devoid of direct emissions of air pollutants or greenhouse gases. Additionally, it facilitates the utilization of a wide spectrum of low-carbon energy sources, enhancing its sustainability and adaptability[1]. In this context, supported nickel-based catalysts exhibit promising potential owing to their catalytic activity and stability in reforming processes[2]. The preparation methods of these catalysts are crucial in order to design their structure, thus influencing their performance in CLD applications. The present study focuses on the performance of Ni and Ru-Ni catalysts supported on $LaMnO_3$, synthesized through precipitation assisted by microwave irradiation and sol-gel citrate methods. The redox stability was checked by performing multiple redox cycles during chemical looping experiments carried out isothermally alternating the gas composition every 10 minutes from 15 vol% of CH_4 in N_2 (reduction) to 15 vol% of CO_2 in N_2 (oxidation). The CLD temperature was selected for each sample based on temperature programmed reduction tests with methane, choosing for each sample the temperature of maximum reduction. Through a comprehensive examination encompassing structural, morphological, and catalytic analyses, it was possible to study the impact of synthesis techniques on the performance of these catalysts in hydrogen production via chemical looping decomposition. This research efforts to furnish valuable insights pivotal for the development of efficient and sustainable processes crucial for meeting the escalating demand for clean energy solutions in the contemporary era.

References:

[1] H. Ozcan, R. S. El-Emam, B. Amini Horri, 2023, 382, 135295
[2] M. Voldsund, K. Jordal, R. Anantharaman, 2016, 41, 4969-4992

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IND-OR-016

Separation of hydrogen from natural gas in distribution pipelines using electrochemical hydrogen compressor (EHC)

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Nowadays energy plays a fundamental role in our society and hydrogen seems to have a key role in a scenario dominated by depletion of fossil fuels, global warming, and rising energy demand[1]. However, its use is limited by storage and transport problems[2]. A possible solution is blending hydrogen into natural gas pipeline network. The separation, purification, and potential storage of this energy vector are therefore important challenges. In this study, low-temperature Electrochemical Hydrogen Compressor (EHC) with Nafion membrane was investigated and tested in hydrogen separation from different methane-hydrogen mixtures. This technology is based on the oxidation of impure hydrogen at the anode and the evolution of pure, high-pressure hydrogen at the cathode[3,4]. The core of this device is the proton exchange membrane (PEM). This component is crucial for EHC system performance, a membrane with high ionic conductivity is required to reduce ohmic losses. In addition, the membrane must have high mechanical, thermal and chemical stability to withstand working conditions. Therefore, it was decided to test three different Nafion membranes, namely N-115, N-117 and N-212. On the best once, the effect of temperature and hydrogen inner flow was evaluated. The purification of hydrogen from a gas mixture was tested and methane/hydrogen molar ratio ranging from 10/90 to 90/10 was investigated (Figure 1b). The efficiency of the system and the purity of the obtained hydrogen obtained were also evaluated, confirming the effective actual purification efficiency of the system. Further studies will focus on the study of the compression step to also evaluate this aspect of EHC technology. Tests carried out to date have highlighted how, in this respect, the criticality factor is linked to the back diffusion of hydrogen from the cathode to the anode.

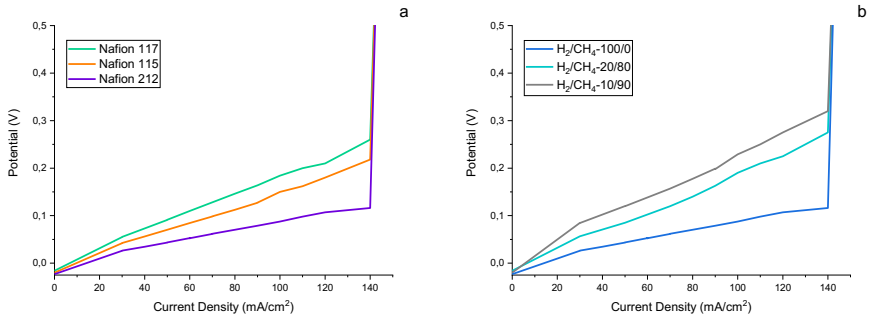

Figure 1. (a) Polarization curves and resistance value obtained for the tested MEAs and (b) polarization curves at different methane/hydrogen molar ratio. Process conditions: ambient pressure for both cathode and anode, 30°C, hydrogen inner flow 20 mL/min, humidity of the gas constant over 90%.

References:

[1] U.S. Energy Information Administration, can be found under https://www.eia.gov/todayinenergy, **2019**.
[2] R. K. Ahluwalia, J. K. Peng, *Int. J. Hydrogen Energy* **2009**, *34*, 5476–5487.
[3] E. Zanella, G. Tonsi, et al, *Chem. Eng. Trans.* **2023**, *105*, 61–66.
[4] M. Rhandi, M. Trégaro, F. Druart, J. Deseure, M. Chatenet, *Chinese J. Catal.* **2020**, *41*, 756–769.

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IND-OR-017

From biomass valorisation to new biomaterials

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Nowadays, the social and environmental impact associated with the exploitation of fossil resources has resulted in the search for more environmentally friendly alternatives. Lignocellulosic materials, one of the most important natural sources for the production of high added-value materials or biopolymers, are very attractive due to their biodegradability, sustainability and ease of recycling. The increasing of these properties represents an important goal also for eco-design. With this perspective, this work focused on the valorisation of lignocellulosic biomass through different strategies for the development of new materials for various applications within the manufacturing industry. On the one hand, natural fibres or waste fibres can be used through different appropriate protocols of pre-treatments for the production of biomaterials by exploiting the cellulose fraction of the starting biomass. On the other hand, it is possible to design new polymer formulations through the synthesis of new biomonomers and biopolymers obtained from biomass[1]. In particular, biomonomers obtained from saccharides by introducing polar and reactive groups can influence both the properties of the final products and the sustainability and ease of recycling. Starting from these biomonomers, various acrylic and vinyl copolymers can be synthesized. Based on the experimental results, these copolymers show particular interest for the preparation of new adhesives and other polymer formulations with significant application properties for eco-design strategies.

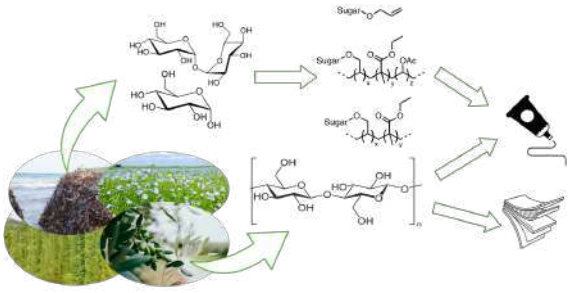

Figure 1: From biomass to new biomaterials.

References:

[1] G. Poggi, A. Papacchini, S. Baracani, A. Cappitti, G. Marini, M. Marrini, R. Giorgi, A. Salvini, J Appl Polym Sci. 2022, 139

Acknowledgements: Thanks to NextGenerationEU for project MICS PNRR MUR – PE11 Spoke 2

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IND-OR-018

Levulinate esters valorization: the production of γ-valerolactone and consecutive products through an innovative gas-phase continuous flow process

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Obtaining chemicals and fuels from biomass is a key step for a sustainable development. From this prospective, cellulose is a potential source for a vast array of bioderived platform molecules, such as ethanol, levulinic acid (LA) and its esters (LE). A promising route consists of the reduction and cyclization of LE to produce γ-valerolactone (GVL), an important platform molecule that find several applications in the chemical industry as green solvent, additive for fuels and intermediate for organic synthesis (figure 1). Usually, this reduction is carried out in the liquid-phase and batch conditions involving the utilization of hydrogen at high-pressure (5-100 bar), in the presence of expensive noble-metal-based catalysts[1]. In this regard, a more suitable approach consisting in the catalytic transfer hydrogenation (CTH) mediated by secondary alcohols as H-donor has recently shown interesting results using zirconia based catalyst[1,2]. More recently, our group has proved the possibility to achieve high LE conversion and a GVL yield close to 70%, using a bio-based primary alcohol, namely ethanol, under continuous flow, gas-phase conditions at relative mild conditions (250°C, 1 bar)[2]. On the other hand, the catalyst is subjected to deactivation due to the deposition of heavy carbonaceous species on its surface. For this reason, the acid/base properties of the catalytic system were optimized by including other metals (and metalloids) in the zirconia structure. Surprisingly, decreasing the basic sites density and introducing the Bronsted acidity, the catalyst lifetime was strongly extended. Moreover, the Bronsted acid sites can catalyze consecutive reactions to produce ethyl pentenoates (EP), which are high value-added compounds, that find several applications in chemical industry due to their dual functionality.

MUR is acknowledged for the financial support provided through the LEVANTE project "LEvulinic acid Valorization through Advanced Novel TEchnologies", PRIN-Bando 2020, Prot. 2020CZCJN7.

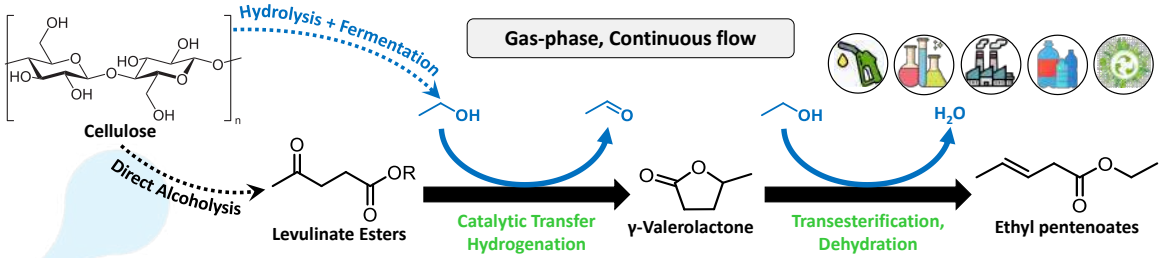

Figure 1: LE reduction to GVL and other reduction products using EtOH as H-donor.

References:

[1] T. Tabanelli et al., ACS Sustainable Chem. Eng., 2019, 7, 9937−9947
[2] P. Vásquez et al., ACS Sustainable Chem. Eng., 2019, 7, 8317−8330

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IND-OR-019

High accuracy DLP printing of porous γ-Al_2O_3 catalysts: a revolutionary approach to catalyst shaping

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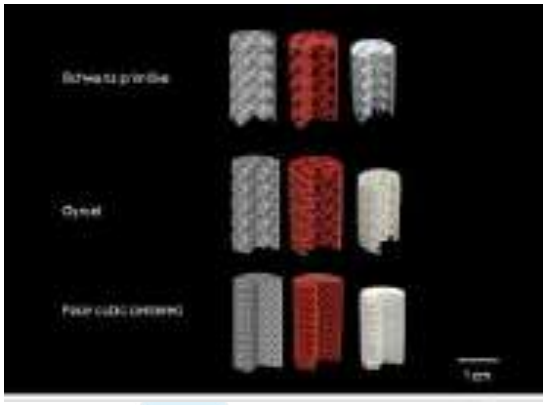
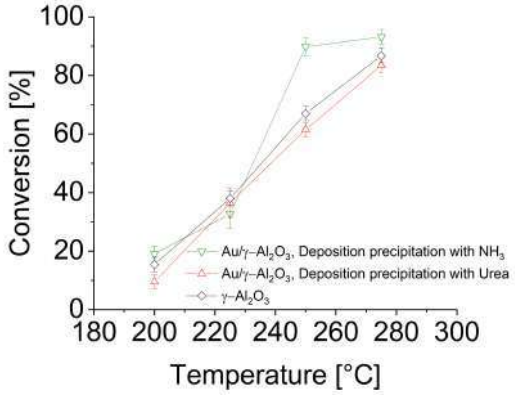
3D printing, or Additive Manufacturing (AM), is one of the key technologies of the fourth industrial revolution (Industry 4.0) as it will transform the whole concept of manufacturing. Applied to catalyst shaping, 3D printing paves the way for completely new architectures which have the potential to enhance mass and heat transfer rates in shaped catalysts. Digital Light Processing (DLP) is a highly promising printing technology among the different 3D printing alternatives owing to excellent printing resolution (Fig. 1a) and a high printing speed[1]. When applying DLP printing for ceramic materials, important catalyst requirements (such as the specific surface area) are often sacrificed to obtain mechanically stable parts. Herein, a novel methodology to DLP 3D print γ-Al_2O_3 supports with a good mechanical stability and a high surface area is described. Introduction of active gold nanoparticles on the alumina supports was explored with different deposition methods and the catalytic activity was demonstrated in the oxidative dehydrogenation of ethanol. It was demonstrated that it is possible to tune the location of the active metal within the catalyst structure by changing deposition method, with remarkable differences in the observed catalytic activity (Fig. 1b)[2]. The obtained results demonstrate a high potential of the technology to remove all the constrains in catalyst shaping, paving the way to new features and avant-garde structures in catalyst design.



a)



b)

Figure 1: a) Demonstrative printed lattices at different printing steps (left: CAD design, center: green body and right: γ-Al_2O_3) and b) conversion of ethanol as a function of temperature for pure γ-Al_2O_3 and Au/γ-Al_2O_3 with different deposition methods.

References:

[1] O. Santoliquido, G. Bianchi, P. D. Eggenschwiler, A. Ortona, Int. J. Appl. Ceram. Technol. 2017, 14, 1164–1173.
[2] L. Mastroianni, V.Russo, K. Eränen, M. Di Serio, D. Yu. Murzin, T. Salmi, Catal. Sci. Technol. 2024,14, 1336-1348.

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IND-OR-020

Solvent-free condensation of ethyl levulinate with phenol promoted by Amberlyst-15: kinetics and modeling

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Diphenolic acid and its esters (DPEs) are regarded as highly promising bio-based monomers for the production of epoxy resins, polycarbonates and polyurethanes[1]. In fact, they can be synthesized from biomass-derived chemicals such as levulinates and phenol in solvent-free conditions and in the presence of Brønsted acid catalysts[2]. In particular, levulinic acid and its alkyl esters are highly available and considered among the top-10 most valuable bio-based chemicals by the U.S. Department of Energy.

Choosing ethyl levulinate (EL) as the substrate, different heterogeneous catalysts have been screened and compared with sulfuric acid as a homogeneous reference catalyst. Amberlyst-15 ion-exchange resin showed the best performance, even after recycling. The general reaction scheme consists of the main reaction i.e., the condensation of EL with phenol producing the ethyl ester of diphenolic acid (DPE), and of a secondary reaction, i.e. trans-esterification of EL with phenol. The kinetic investigation was conducted in a batch reactor producing an extensive experimental matrix. Namely, the reaction temperature, the molar ratio phenol-to-EL, the catalyst load and the mixing rate were varied. The effect of the water concentration, i.e. the co-product of DPE on the reaction rate was investigated as well. The composition of the mixture during the experiment was analyzed both qualitatively and quantitatively with ^{1}H- and ^{13}C-NMR. Finally, a mathematical model was developed considering diffusion limitations inside the catalyst particles. The experimental data were implemented in the kinetic model and the estimation of rate and adsorption parameters was conducted with non-linear regression analysis with gPROMS software.

References:

[1] Z. Qian, Y. Xiao, X. Zhang, Q. Li, L. Wang, F. Fu, H. Diao, X. Liu , Chem. Eng. J. 2022, 435.
[2] A. R. Bader, A. D. Kontowicz, J. Am. Chem. Soc. 1954, 76, 4465–4466.

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IND-OR-021

Process Intensification in Green Extraction of Agri-Food By-Product: Bioactive Potential Applications and Sustainability Assessments

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According to the Food and Agriculture Organization (FAO), approximately one-third of global food production is lost or wasted in various stages of the food supply chain, with fruits and vegetables often experiencing losses of up to 50% [1]. To tackle this, adopting the Circular Economy approach and striving for a "zero waste" strategy is crucial. Food waste can be transformed into valuable resources, such as antioxidants, phenolic compounds, and dietary fibers, which find applications in functional foods, nutraceuticals, and cosmetics. The underlying principles of green extraction revolve around not only reducing waste but also enhancing efficiency while simultaneously mitigating potential risks to human health and the environment [2]. This approach, referred to as "process intensification" can be attained through the adoption of enabling technologies that seek to optimize heat and mass transfer, thereby promoting elevated yield and conversion rates. In this study, microwave-assisted extraction (MAE) in water is applied to recover metabolites from blueberry pomace (BP), by-product of blueberry juice process, while refining temperature, extraction times, additives and bioactive fractionation strategies. The total phenolic, anthocyanin, and tannin contents of the extracts were determined, as well as their antioxidant activity using both chemical and electrochemical methods, alongside assessment of thermal stability. Furthermore, the potential applications of BP extract as functional ingredient are investigated through *in vitro* enzyme inhibition assays (α-amylase, β-glucosidase, acetylcholinesterase, tyrosinase, and elastase), as well as evaluation of anti-inflammatory and cytotoxic properties on living cells. Finally, the overall sustainability of the process was done screening different Green Metrics as Reaction Mass Efficiency, E-factor and Process Mass Intensity and more elaborated one as ComplexGAPI and AGREEPrep. Among these metrics, GREEN MOTION emerged as the most suitable indicator of sustainability for the examined process.[3] The collected data support the application of an eco-friendly valorization protocol, and associated evaluation methodologies, for transforming an agri-food residue into bioactive products. Furthermore, both its efficacy and sustainability have been demonstrated, paving the way for its potential application to similar plant-based food by-products.

References:

[1] FAO. Technical Platform on the Measurement and Reduction of Food Loss and Waste. 2022. Available online: https://www.fao. org/platform-food-loss-waste/en/).
[2] F. Chemat, M. Abert-Vian, A.S. Fabiano-Tixier, J. Strube, L. Uhlenbrock, V. Gunjevic, G. Cravotto, Trends Anal. Chem. 2019, 118, 248–263.
[3] T.V. Tony Phan, C. Gallardo, J. Mane. Green Chem., 2015, 17, 2846.

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IND-OR-022

Kinetic and catalytic aspects involved in the esterification of oleic acid with trimethylolpropane to produce bio-based lubricants

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The esterification of oleic acid (OA) with trimethylolpropane (TMP) is the preferred synthetic route to obtain trimethylolpropane trioleate, a commercially significant bio-based lubricant characterized by low-toxicity and biodegradability[1]. Understanding the kinetics of this esterification reaction is crucial for optimizing the synthesis of green lubricants, particularly when utilizing waste materials like used cooking oils (UCO), thereby promoting sustainability within a circular economy framework. Oleic acid, representing UCO due to its prevalence in vegetable oils[2], serves as a suitable substrate for this purpose. Besides, branched polyols, such as TMP (a triol), is widely used to produce polyol esters with enhanced tribological properties as well as thermal and oxidation stability[3]. Despite its importance, the kinetics of this reaction is underexplored, especially when promoted by heterogeneous catalysts.

This research work explores the kinetics of oleic acid esterification with trimethylolpropane in a batch reactor. It compares both the uncatalyzed reaction and that promoted by a heterogeneous catalyst (i.e. tungsten trioxide supported on silica, etc.) particularly focusing on temperature, catalyst bulk density, and reactants' molar ratios effect. The conversion of oleic acid was evaluated through its acidity number using acid-base titration. Additionally, the concentration profiles of the products, including mono-, di-, and tri-esters, were obtained using ^{1}H-NMR technique. An essential aspect of this investigation is understanding the uncatalyzed reaction kinetics due to the significant autocatalytic effect resulting from OA's acidic nature, particularly at temperatures higher than 100°C. Under these conditions, heterogeneous catalyst amounts exceeding 1 wt% relative to the total reactant mass are necessary to observe a notable catalytic effect. Furthermore, optimal triesters concentrations occurred under stoichiometric conditions between TMP functional groups and OA. Finally, a kinetic model was developed to simulate the system's behavior and the experimental data underwent nonlinear regression analysis to derive kinetics and thermodynamic parameters.

References:

[1] N. Zainal, N. Zulkifli, M. Gulzar, HH. Masjuki, Ren. Sust. En. Rev. 2018, 82, 80.
[2] D. W. Lee, K.Y. Lee, Catal Surv Asia 2014, 18, 55–74.
[3] P. Nagendramma, S. Kaul, Ren. Sust. En. Rev. 2012, 16, 76.

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IND-OR-023

MW-assisted Anisole Hydrogenation over Commercial Supported Catalysts

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Hydrogenations are among the best studied reactions as they are fundamental in petrochemical and coal chemistry, environmental industries, and fine chemicals production.[1] It is estimated that about 25 % of all chemical transformations involve at least one hydrogenation step. Starting from the first hydrogenation reaction of lignin-based chemicals carried out by Harris and Saeman,[2] most of the research aim to transforming monomers derived from lignin depolymerization through hydrogenation reactions. Currently, hydrogenations of lignin-based chemicals can be carried out using hydrogen gas or through the transfer hydrogenation (TH) route, using a H-source solvent (such as formic acid, isopropyl alcohol, or alkanes).[3] Biomass is constituted by lignocellulosic (LB) or non-lignocellulosic (non-LB) materials.[4] Considering lignocellulosic biomass, specifically the three main chemical components (cellulose, hemicellulose and lignin), only lignin has been rewarded less attention as for the bioconversion to biofuels, due to complex structure of the polymer,[5] despite it is characterized by a great amount of functional groups that are important active sites for further chemical modifications.

Among the various transition-metal-based catalysts, ruthenium and rhodium are mainly employed for hydrogenations of aromatics.[6,7] This work aims to investigate the MW-assisted anisole hydrogenation in the presence of Ru or Rh catalysts with molecular H_2 and using an opportunely selected solvent. The conditions were optimised by reducing both the reaction time and temperature and using environmentally friendly and recyclable solvents to increase the sustainability of the process.

References:

[1] Zhang, L.; Zhou, M.; Wang, A.; Zhang, T.; *Chem. Rev.,* **2020**, *120* (2), 683–733.
[2] Saeman, J. F.; Harris, E. E.; *J. Am. Chem. Soc.*,**1946**, *68* (12), 2507–2509.
[3] Vriamont, C. E. J. J.; Chen, T.; Romain, C.; Corbett, P.; Manageracharath, P.; Peet, J.; Conifer, C. M.; Hallett, J. P.; Britovsek, G. J. P.; *ACS Catal.,* **2019**, *9* (3), 2345–2354.
[4] Verdini, F.; Gaudino, E. C.; Canova, E.; Tabasso, S.; Behbahani, P. J.; Cravotto, G.; *Molecules,* **2022**, *27* (11), 3598.
[5] Wang, F.; Ouyang, D.; Zhou, Z.; Page, S. J.; Liu, D.; Zhao, X.; *J. Energy Chem.* **2021**, *57*, 247–280.
[6] Foppa, L.; Dupont, J.; *Chem. Soc. Rev.,* **2015**, *44* (7), 1886–1897.
[7] Alshehri, F.; Feral, C.; Kirkwood, K.; Jackson, S. D.; *React. Kinet. Mech. Catal.,* **2019**, *128* (1), 23–40.

IND-OR-024

Precursor Strategies for the Preparation of High-Molecular Weight Conjugated Polymers with Tailorable Redox Properties

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Conjugated polymers, characterized by small bandgaps and accessible states, are exceptionally versatile materials that have found application in disparate fields such as organic electronics, photocatalysis, sensing, healthcare, and energy storage technologies. By combining a plethora of different units and broad variety of preparation methodologies, synthetic chemistry is the most powerful tool a chemist has to control the electronic properties and the arrangements of the polymeric chains, thus allowing the preparation of materials withtailored properties and enhanced performances.

However, the intrinsic electronic properties of the units and the aggregation-prone nature of these materials, often hinder the synthetic process, producing materials with a low degree of polymerization which can present processability issues and different properties compared to their high-MW analogues.

When the use of solubilizing side chains to circumvent these problems is not possible or ineffective – as in those cases where a high specific density of responsive units is beneficial or when immobilization of the activematerial is needed, the use of polymeric precursors and reliable transformation strategies (that can form quantitatively the target materials) can offer an efficient way to access high molecular weights conjugated polymers with a high density of functional units.[1]

In this contribution, I will describe two novel approaches based on the use of different polymeric precursor for the preparation of fully-conjugated materials with a high density of active centres. In particular, these recursors comprise either reversibly-masked quinoid groups, that allow the insertion of expendable solubilizing chains, or aromatic units connected via succinyl linkers, that can undergo pyrrolization in the presence of a primary amine, thus allowing for the insertion of active side groups. Finally, I will show the application of fully-conjugated materials obtained through this strategy as organic cathodes for metal-ion batteries, OFETs with different polarities and miulticolored electrochromic surfaces.

Part of this study was carried out within the POLiBATT project – funded by European Union – Next Generation EU within the PRIN 2022 PNRR program (D.D.1409 del 14/09/2022 Ministero dell'Università e della Ricerca) and the European Union's Horizon 2020 Research and Innovation Program under the Marie Skłodowska-Curie Grant Agreement MP3 – No. 885881.

References:

[1] M. Carlotti, T. Losi, F. De Boni, F.M. Vivaldi, E. Araya-Hermosilla, M. Prato, A. Pucci, M. Caironi, V. Mattoli, Polymer Chemistry 2023, 14, 4465 – 4473.

IND-OR-025

BiOBr/LECA as novel sunlight-driven device for drug photodegradation: harnessing sustainability as a keystone to help vulnerable communities

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Nowadays, preserving freshwater is crucial, especially in developing countries, where the risk of disease transmission is elevated.[1] Ibuprofen (IBU) and diclofenac (DCF) are nonsteroidal anti-inflammatory drugs (NSAIDs), whose concentration in surface waters is increasing due to the rapid growth/aging of world population.[1] So, the possible purification/reuse of wastewater represents a challenging task. Among the strategies to abate NSAIDs, photocatalysis exploits solar energy - a free and clean resource. Its potential is to significantly aid the development of regions frequently impoverished and densely populated, demonstrating a practical application of renewable energy in enhancing global water quality. However, the most part of photocatalytic systems hides a practical limitation, *i.e.*, the difficult recovery as powders from the reaction mixture, causing contamination issues and additional costs. In this context, sustainable floating photocatalysts are viable alternatives to be used: their floatability on the air-water interface maximizes both light absorption and surface aeration, enhancing pollutant removal efficiency and reducing post-treatment costs.[1] However, finding a simple, cheap, and universally accessible method for applying photocatalysis in water purification, especially in communities with limited access to clean water, remains an ongoing challenge.

Herein, we propose the development of an innovative sunlight-driven device composed by bismuth oxybromide (BiOBr) grown on a naturally derived material (Lightweight Expanded Clay Aggregate, LECA), to clean surface waters under natural solar irradiation. Photodegradation of IBU and DCF was investigated in laboratory- and real-scale experiments. The BiOBr/LECA photocatalyst fully degrades DCF, whereas restricted abatement of IBU is observed (Figure).[1] The identification of specific transformation products (TPs) during the degradation reveals that this behaviour is related to the different structures of drugs. Reusability tests demonstrate the high stability of the floating composite. These encouraging results pave the path toward a promising novel and sustainable paradigm for water remediation. In this way, the existing limitations can be overcome, advancing the field of water purification.

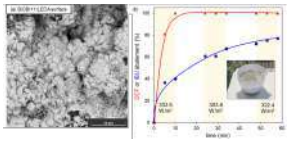

Figure: (a) FESEM images; (b) Real-scale photodegradation of 3:1 w/w drugs mixture (10 mg·L^{-1}, simulated drinking water, 60 g BiOBr11/LECA) under natural solar light (daily medium irradiation from Milan meteorological station).[2]

References:

[1] M.G.Galloni, E.Falletta, M.Mahdi, G.Giordana, A.Cerrato, D.C.Boffito, C.L.Bianchi, Adv. Sus. Syst. 2024, 2300565.
[2] Arpa Lombardia, https://www.arpalombardia.it/temi-ambientali/meteo-e-clima/form-richiesta-dati/.

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IND-OR-026

Sustainable Luminescent Solar Concentrators with Superior Photodegradation Resistance Employing Heptagon-Embedded Polycyclic Aromatic Dicarboxyimides as Emitters

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Photostability is crucial for fluorophores used in Luminescent Solar Concentrators (LSCs), enduring extended sunlight exposure over years.[1] UV radiation can alter the structure of organic emitters, reducing LSC efficiency and causing panel replacement, with economic costs and environmental implications. In this study, we tested two push-pull dyes comprising distorted heptagonal inclusions – namely, Peri2F and Nap2Car[2]– as emitters for bulk LSCs, with concentration ranging from 100 ppm to 250 ppm. The use of chemically regenerated monomer, rather than synthetic monomer, for PMMA slab production has a Global Warming Potential about four times smaller, thereby enhancing the sustainability and circularity of large-scale LSC fabrication. The most effective Peri2F/recycled PMMA system yielded an η_{dev} of 0.7%, lower than that of devices comprising the state-of-the-art emitter LR305.[3] Remarkably, Peri2F showed a far superior resistance to photodegradation. Forecast analysis estimated that the LSC containing 100 ppm of Peri2F can match LR305 performance in PMMA after about 1 year of use, with only 2% decrease in initial emission intensity.

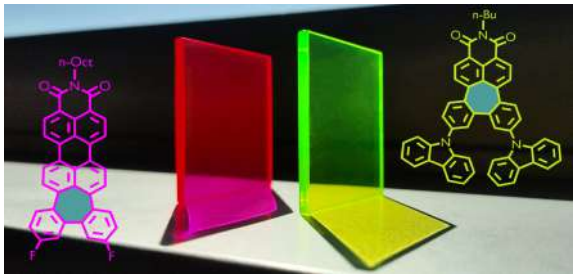

Figure 1: Peri2F (left) and Nap2Car (right) molecular structures and LSC appearances.

References:

[1] J.-M. Delgado-Sanchez, Sol. Energy Mater. Sol. Cells, 2019, 202, 1-8
[2] K. Kantarod et al., Chem. Commun., 2022, 58, 9468-9471
[3] M. Bartolini et al., ACS Appl. Energy Mater., 2023, 6, 4862-4880

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IND-OR-027

Process intensification for removal of new pharmaceutical compounds from water

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Nowadays, the diffusion of new emerging contaminants (ECs) (e.g. surfactants, pesticides, pharmaceutical compound, personal care product, etc.), present in the range concentration of ppt (ng/L) or ppb (µg/L), represent an environmental critical issue. Therefore, it is necessary find new technologies for drugs removal that escape by conventional wastewater treatment processes. Adsorption is the best technique to remove pollutants from water, due to its easy scalability, low cost, versatility, no undesired by-products generation and possibility to reuse the adsorbent into a new cycle of water treatment. Iopamidol (IPM) is a non-ionic X-ray contrast media, injected into the human body at high concentration (1.5 mol/L)[1], and relies into the aquatic environment in no-metabolized form[2]. The new challenge is to design a wastewater treatment plant capable to remove ECs efficiently, allowing the reuse of the aquatic matrix obtained. The best adsorbent for Iopamidol removal is activated carbon, so an adsorption study from batch to continuous flow was performed in this work. Ibuprofen (IBP) is a non-steroidal anti-inflammatory drug used in the treatment muscle pain and inflammation, which concentration in the wastewater is around 18–6297 ng/L[3]. Cellulose is a main component of natural plants, is the most abundant and renewable biomass resource on earth and is if pyrolyzed is a good adsorbent to remove IBP from water. For the intensification of the IPM and IBP adsorption process different kinetics were obtained using different devices, batch comparing a common stirrer with rotating bed reactor (RBR, Spinchem®), ultrasound probe merged into the aqueous solution and, finally, application of the continuous flow with and without ultrasound.

References:

[1] M. Bourin, P. Jolliet, F. Ballereau, 1997, Clin-Pharmacokinet, 32, pp. 180–193.
[2] R. Paparo, M. E. Fortunato, G. Carotenuto, F. Uggeri, L. Nicolais, M. Di Serio, M. Trifuoggi, V. Russo, 2023, Langmuir, 39, pp. 18983–18994.
[3] S. N. Oba, J. O. Ighalo, C. O. Aniagor, C. A. Igwegbe, 2021, Science of The Total Environment, 780, p. 146608

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IND-OR-028

Purge ratio vs Spike & Purge, who wins?

A real case during an API production

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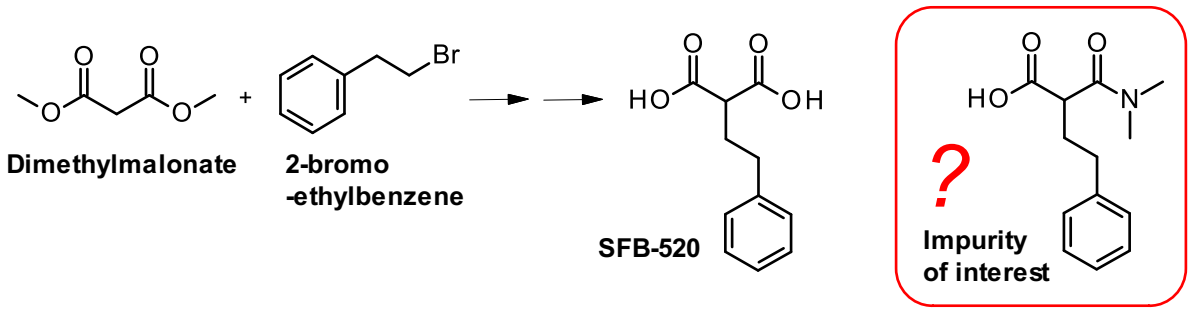
In order to satisfy the requirements of Regulatory Agencies regarding the production and release of an Active Pharmaceutical Ingredient (API), many factors need to be taken into account.

Many resources, both in terms of time and money, may need to be invested to ensure that the specifications set for both the starting materials and intermediates are enough to guarantee the production of an API with an analytical profile complying with ICH regulations.

While a purely theoretical approach can minimize both costs and timelines, can it take the place of experimental studies while yielding comparable assurances of success?

We present here the case of an impurity considered critical and detected in the initial steps (Scheme 1) of the synthetic process of Sodium Phenylbutyrate. In the work carried out the theoretical "Purge Ratio" approach of determining the fate of each impurity was compared with the experimental approach of "Spike & Purge" of the impurity previously identified and synthesized.



Scheme 1

References:
[1] C. Barber et al. Regulatory Toxicology and Pharmacology, 2017, 90, 22-28
[2] A. Teasdale et.al. Org Process Res Dev, 2013, 17, 221-230

IND-OR-029

A comparison between the solar photoreforming of natural and synthetic polymeric derivates for the H_2 production

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The Hydrogen is considered one of the most promising energy vector candidates for the future. The photocatalytic hydrogen production is present in top ten emerging technologies in chemistry. In particular, the photoreforming (PR) of organic substrates is an attractive way to obtain green H_2 together with the valorization of waste or biomass. This process combines the water reduction with the oxidation of a sacrificial agent using a semiconductor. In this context, in this work, it is presented a comparison, in terms of H_2 production, of two polymeric derivates used for the PR as a natural polymer i.e. the glucose (production of $80*10^9$ t/y) and a synthetic polymer as polyethylene, that can play an important role also in the context of pollution (production of $100*10^9$ t/y) [1]. The focus of this work is also the study of the performance of carbon-based catalysts as g-C_3N_4 and SiC introducing metals or other oxides as co-catalysts to further improve the H_2 formation [2]. The carbon nitride possesses the advantages of low cost, non-toxic, thermodynamic stability, and remarkable optical properties. Whereas the SiC is a widely used semiconductor in the electronic industry and can be used as photocatalyst in the plastics photoreforming due to its high mechanical and chemical resistance. A good production of H_2 was verified from both sacrificial agents (fig.1), however there is an increase of H_2 production in the presence of a metal oxide co-catalyst in the case of glucose PR, and a decrease in the case of polyethylene PR in the presence of the metal co-catalyst.

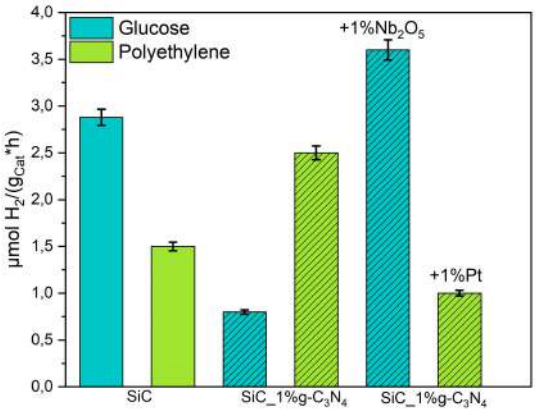

Figure 1: Comparison Glucose and Polyethylene

References:

[1] Muhammad Ashraf,Nisar Ullah, Ibrahim Khan et all., 2023,Chemical Reviews,123,4443-4509
[2] MTA Iapichino,Roberto Fiorenza,Salvatore Scirè et all.,2024,Catalysis Communications, ,187,106850

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IND-OR-030

Innovative Cu-based polymers to recover dissipated heat at low-temperature

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Thermoelectric (TE) materials enable the direct conversion of heat into electricity through the Seebeck effect. Given that approximately 70% of consumed energy is dissipated as low-temperature heat (<200 °C), the development of TE materials is crucial for reducing our carbon footprint.[1] Most TE materials are inorganic (such as Bi_2Te_3); however, they come with significant drawbacks including high thermal conductivity, high fabrication temperatures, high cost, scarcity, brittleness, and toxicity. Recently, coordination polymers such as poly[Kx(Ni-ett)] have emerged as encouraging TE materials for low-temperature energy harvesting.[2] Different materials can be produced by substituting the metal center or the organic ligand. As a result, nickel has been replaced with the greener and less toxic copper to develop innovative thermoelectric materials. Different polymers have been synthesized, processed as dispersion, and deposited as thin-film. Finally, chemical and electrical characterizations have been performed, showing promising properties for applications in low-temperature heat harvesting.

References:

[1] F. Yuan, et al., Small. 2021, 17, 2100505.
[2] S. Yuanhui, et al., Advanced Materials. 2016, 28, 3351–3358.

Acknowledgements:

This research acknowledges support from the Project CH4.0 under the MUR program “Dipartimenti di Eccellenza 2023–2027” (CUP D13C22003520001). S.G. acknowledges the project NODES which has received funding from the MUR - M4C2 1.5 of PNRR funded by the European Union - NextGenerationEU (Grant agreement no. ECS00000036).

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IND-OR-031

New generation of PVDF membranes preparation using γ-Valerolactone (GVL) as a green solvent for Membrane Distillation

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In the framework of sustainability, Membrane Technology can be considered as a green alternative and economically competitive with conventional separation technologies as also confirmed by the European Commission which included it among the Best Available Technologies [1]. Membrane manufacturing is yet to embrace the use of harmful and toxic solvents, such as N-methyl-2-pyrrolidone (NMP), N, N-dimethylacetamide (DMA), and N, N-dimethylformamide (DMF) despite being a sustainable technology with a low environmental footprint [2]. In this work, γ-valerolactone (GVL) was selected as a renewable green solvent for the preparation of poly (vinylidene fluoride) (PVDF) membranes by phase inversion technique that allowed to obtain membranes with controlled morphology, pore-size and physical-chemistry properties for Membrane Distillation (MD) process. A comparison with the performance of PVDF commercial membranes is also included. The results confirmed an asymmetric structure of the membrane and the possibility of obtaining a sponge-like morphology. Generally, the effect of humidity on membrane morphology delays the phase inversion process promoting the formation of porous surfaces and sponge-like structures. The porosity of the membranes was in the range between 84% and 86% with a pore size in the range of 0.2 to 0.8 microns dependent on the composition of the dope solution and the casting conditions. The experimental tests of MD were conducted in Direct Contact Membrane Distillation (DCMD) configuration using deionised water as feed at the following operative conditions: membrane area of 40 cm^2, feed/distillate inlet pressure of 1 atm, feed flow rate (Q_{feed}) of 66 L/h, feed temperature (T_{feed}) around 60°C, distillate flow rate (Q_{dist}) of 42 L/h and distillate temperature (T_{dist}) of 20 °C. The membranes that were tested were very stable in time, with similar flux results to those of commercial membranes.

References:

[1] F. Russo, R. Mazzei, A. Brunetti, A. Criscuoli, A. Figoli, The Status and Perspectives of Sustainable Membrane Materials, Membrane (Bio)reactors, and Membrane Distillation Processes, Membr. Sci. Int. 3 (2024) 1–25.
[2] D. Zou, S.P. Nunes, I.F.J. Vankelecom, A. Figoli, Y.M. Lee, Recent advances in polymer membranes employing non-toxic solvents and materials, Green Chem. 23 (2021) 9815–9843.

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IND-OR-032

Experimental investigation on biomass pyrolysis: a study on devolatilization and speciation

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Pyrolysis of lignocellulosic biomass represents a promising solution to generate liquid biofuels that can help the decarbonization of critical sectors[1]. However, the complex nature of the process has hindered the obtainment of rigorous experimental data. In this study pyrolysis tests are run in a thermogravimetric analyzer (TGA) based setup[2], subjecting biomass samples to a controlled heating ramp (3-100 °C/min) under Helium flow, with the aim of collecting kinetically relevant information. Different analytical techniques and sampling protocols, including commercial sorbing tubes (ORBO 609) for heavy oxygenates collection, an offline GC-MS/FID for heavy and light oxygenates analysis and an online mass spectrometer for gas and H_2O analysis, are employed to obtain a detailed description of volatiles composition and quantification of products. Cellulose and two hemicelluloses – hardwood xylan and softwood glucomannan – have been investigated. Fig.1 shows the peculiar features for both devolatilization trends and product distribution for the three components. More than 45 products are identified and individually quantified, reaching mass balances above 90%, a notable achievement in particular for xylan and glucomannan that are scarcely studied in the literature. In cellulose pyrolysis, the bio-oil yield is maximized, with the prevalence of the C6 anhydrosugar levoglucosan. Xylan products are almost evenly distributed among the solid, liquid and gas streams. Glucomannan, with its hybrid chemical structure, displays a behavior intermediate between cellulose and xylan.

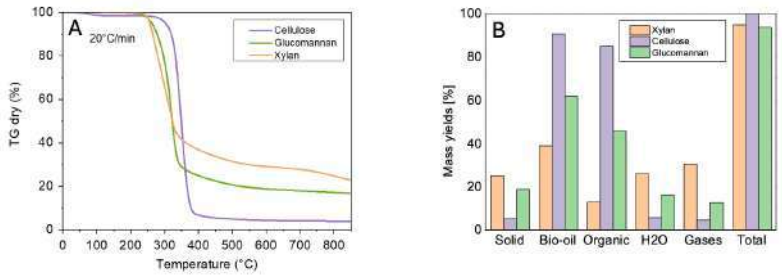

Figure 1: A) TG curves and B) pyrolysis product distribution for cellulose, xylan and glucomannan

References:

[1] D. Mohan, C. U. Pittman, 2006, Pyrolysis of wood/biomass for bio-oil: A critical review, Energy and Fuels, 848–889.
[2] V. Piazza, R. Da Silva JR, A. Frassoldati, L. Lietti, T. Faravelli, A. Beretta, 2023, Detailed speciation of biomass pyrolysis products in a novel TGA-based setup: the case-study of cellulose, Journal of Analytical and Applied Pyrolysis.

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IND-OR-033

Valorization of Char from Chemical Recycling of Plastics

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Nowadays, the production of virgin plastic has reached hundreds of tons per year all over the world, and less than 10% is usually recycled[1]; the remaining is ended in the environment or in landfills. Plastic can be recycled over mechanical or chemical method. Only a certain type of plastic can be subjected to mechanical recycling (i.e. PET, PE), and the process is limited by the number of possible cycles and a lower quality of the products[2]. Chemical recycling is a more advantageous method because it allows to decompose plastic in smaller molecules with the same characteristics of the virgin monomers, and therefore allows to have a closed cycle, following the principles of circular economy[3]. Through the chemical recycle it is possible to use plastic as alternative raw material to fossil sources, with a favourable footprint of greenhouse gases.

HOOP® technology, registered trademark by Versalis S.p.A, is a chemical recycling process based on the pyrolysis of mixed plastic (*plasmix*) that cannot be mechanically recycled. Indeed, pyrolysis is a versatile technique that allows to treat different types of plastics without the need of a previous separation steps. During the pyrolysis, in absence of oxygen, the thermochemical decomposition of the material occurs, obtaining three fractions: liquid, gas and solid. The liquid (oil) is the main fraction, made of a mix of liquid hydrocarbons, that can be used as feedstock for steam cracking plants and reintroduced in the plastic production; the gaseous fraction (fuel gas) is mainly made of N_2, H_2 and C_1-C_5 hydrocarbons, and it can be used as fuel for the heat demand of the pyrolytic plant. Finally, the solid fraction (char:≈ 8% of the plasmix fed to pyrolysis plant) is composed by coke (≈50 wt.%) and inorganic compounds present in the plasmix. Considering the production capacity of the pilot plant HOOP®, over 4875 t/a of oil produced, 870 t/a of char would be by-produced, and this material needs to be reused; furthermore, the char is a by-product always present in the pyrolysis plasmix's processes. At the moment, the applications of char range from reducing agent in foundry, to asphalt component, or as fuel in cement plants. However, these applications are translated in a low-value high-volume business. The aim of this work is therefore to investigate alternatives for the valorization of the char, to reuse it in the chemical production chain, and to increase the yield of the total recycling process. In an optic of circular economy, the recovery of this substantial organic fraction would increase the saving of virgin sources, and it would lower the emission associated to the use of fossil sources.

References:

[1] K. Kumar Jha, T.T.M. Kannan, Materials Today Proceedings 2021, 37, 3718-3720.
[2] Z. O. G. Schyns, M. P. Shaver, Macromolecular Rapid Communications 2021, 42, 2000415.
[3] T. Thiounn, R. C. Smith, Journal of Polymer Science 2020, 58, 1347–1364.

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IND-OR-034

Valorization of Olive Mill Wastewater: From Waste to Biopesticides and Biofertilizers

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The recovery of waste material is the challenge that has been affecting the last decades worldwide. My doctoral work fits into this context, as part of the PNRR project of Agritech, National Center for Technology in Agricolture. The waste in question is olive mill wastewater (OMW), which along with pomace, represents one of the two by-products obtained from olive oil extraction. To date, there is still no real destination/use mode to dispose of/valorize this waste. Currently in Italy, laws still allow for spreading it on the ground, but this is unsustainable as the water has high COD and organic content and presents phytotoxic and antimicrobial properties due to the presence of polyphenols[1]. However, it is possible to valorize this water because it is rich in molecules of interest such as lipids, proteins, carbohydrates, and polyphenols themselves, molecules that are extremely useful due to their high antioxidant power[2]. Hence, the objective of this research is to exploit various innovative technologies to extract/purify and concentrate polyphenols and produce biopesticides and biofertilizers to be applied in the fields. This document outlines a possible work scheme to be applied from the olive harvesting campaign to the formulation of a final bio product, which will be directly tested in future field studies. The first application is a pretreatment involving acidification with concentrated sulfuric acid of the raw OMW. This process promotes the sedimentation rate of suspended solids in the water, which then settle at the bottom, creating a flocculent solid matrix composed of high molecular weight organic constituents and salts (mostly potassium). The clarified solution obtained is then subjected to a series of membrane processes aimed at removing residual solids, high molecular weight organic compounds, and concentrating polyphenols. After membrane processes, the concentrated and purified water still contains high levels of salts, which is a limitation especially for biopesticide production as high salt content can dry out the leaves. To address this issue, an anion exchange resin capable of adsorbing polyphenols (acids) and carbohydrates while allowing salts to pass in an initial fraction can be utilized. At this point, after desorbing the polyphenols (eluting with H_2O:MeOH + 2.5% of acetic acid), it is advisable to lyophilize the samples, obtaining an oil to be used as a reagent for enzymatic esterification to obtain acylated polyphenols, now lipophilic and hence no longer soluble in water but in organic solvents. The future idea is to formulate a pesticide consisting of the active ingredient constituted by acylated polyphenol (lipophilic) suitably dissolved in an organic solvent, partially soluble also in water such as tetrahydrofuran (THF). Once sprayed on the leaf and after the water has evaporated, leaving the dispersed acylated polyphenol, the active ingredient remains adhered to the leaf, without the risk of being washed away by rain, exerting a barrier effect against insect or fungal attacks.

References:

[1] Russo, E.; Spallarossa, A.; Comite, A. et al., Antioxidants 2022, 4, 903.
[2] Bottino, A., Capannelli, G., Comite, A. et al., Membranes 2020, 10, 334.

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IND-OR-035

Optimization of catalyst acidity for the catalytic pyrolysis of plastic wastes

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Plastics are often described as the materials "God forgot to create" and thanks to their extraordinary properties, they have brought countless benefits to our society. According to the Global Plastics Outlook published by OECD, 431Mt (million tons) of new virgin plastics were produced in 2019, 353Mt of which became a waste. Unfortunately, most polymeric wastes are currently disposed in landfills (49%) or incinerated (19%) and only a tiny fraction is recycled (9%). Over the last years, pyrolysis is emerging as a promising and versatile technique to chemically recycle mixed plastic wastes. The implementation of a catalytic system is a key factor to lower the required energy demand and achieve better selectivity towards the desired products. Among all the possible catalysts, zeolites are the most studied systems reported in the literature. H-ZSM5, Y-zeolite, β-zeolite, FCC catalysts etc. are known to promote hydrocarbon cracking, reducing the average molecular weight and improving the quality of the oil produced.[1] Deactivation by fouling and reduction of the oil yield are known problems shown by those types of acid catalysts. In order to mitigate those drawbacks, is of vital importance controlling the acidity and morphology of the catalytic system (Figure 1).[2] Indeed, the lower the acid strength, the less cracking is promoted, but on the other hand, if the acidity is too high, coke-forming reactions are overly favoured. As for the acidity, also the right structure as to be selected. Channels dimensions and morphology play a key role in the shape selectivity toward reactants, transition states and products. Moreover, the diffusion of coke precursors and therefore catalyst deactivation are vastly affected by the shape of the pores. We are currently studying those aspects in order to optimise the catalyst design and process efficiency in both the in-situ, in which the catalyst is directly in contact with the molten plastic, and ex-situ configuration.

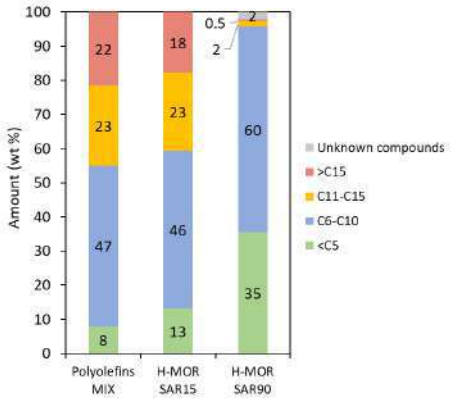

Figure 1: Effect of the SiO_2/Al_2O_3 ratio (SAR) on the oil composition in terms of number of carbon atoms

Acknowledgements:
MUR and Versalis S.p.a. are acknowledged for the Ph.D. granted to M.O. through the PNRR D.M. 352/2022.

References:

[1] Y. Peng, Y. Wang, L. Ke, L. Dai, Q. Wu, K. Cobb, Y. Zeng, R. Zou, Y. Liu, R. Ruan, Energy Conversion and Management 2022, 254, 115243
[2] H. Yuan, C. Li, R. Shan, J. Zhang, Y. Wu, Y. Chen, Fuel Processing Technology 2022, 238, 107531

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IND-OR-036

Adsorption Technologies for Sustainable Reduction of CH_4 and CO_2 from Agricultural Livestock

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Ruminants, mainly dairy cattle, are widely recognized as one of the main contributors to methane emissions in the environment, playing a significant role in the global warming phenomenon. Considering that a cow emits about 500 L/d of methane [1] and in view of the increasing population of cows due to the intensive farming activities, the daily methane emission is considerable. Extensive efforts have been made to reduce methane emissions from ruminants prior to their release into the environment; however, considering that the enteric fermentation process is unavoidable, it is crucial to establish methods for capturing the emitted methane.
Given the common practice of implementing forced ventilation within barns for animal well-being, the discussed process aims to capture methane via adsorption on zeolite through the barn ventilation. The literature review has identified commercial zeolite 13X and Clinoptilolite as suitable materials. The Adsorption isotherms of the gases on the selected adsorbent materials were taken from the literature and are being currently validated through experiments. It is estimated that a cattle (600 kg of body weight) consumes 21 kg DMI /day and due to the enteric fermentation and respiration releases 23 g CH_4 / kg DMI and 647 g CO_2 / kg DMI [2]. Carbon dioxide poses a significant challenge for methane capture on zeolite, because adsorption competition exists between CO_2 and CH_4. Therefore, it is suggested that the adsorption process is dominated by the carbon dioxide adsorption. The design work, performed using Aspen Adsorption® V11 software, revealed the necessity of a two-stage adsorption system, with two beds in series. An initial "guard bed" filled with zeolite 13X is used to adsorb carbon dioxide and other gases from the barn, while efficiently adsorbing methane in the second bed of the same volume filled with Clinoptilolite, a cost-effective natural zeolite with excellent properties for methane adsorption. With the current configuration, the first bed reaches saturation in 210 days whereas the second bed reaches saturation in 40 days; consequently, five replacements need to be executed while keeping the guard bed in operation. The designed plant allows to obtain an exiting flow consisting only of air, therefore mitigating the environmental impact of the agricultural sector.

References:

[1] K. A. Johnson, D. E. Johnson, Journal of Animal Science 1995, Volume 73, 2483 – 2492.
[2] A. Jonker, L. J. Farrell, Animal Production Science 2019, Volume 6, initial 1063 – 1069.

Acknowledgments

This study was carried out within the Agritech National Research Center and received funding from the European Union Next-Generation EU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1032 17/06/2022, CN00000022).

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IND-OR-037

Removal of chromium (VI) from water exploiting maltodextrin-based cationic adsorbents

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Developing polymers obtained from renewable sources, encouraged by the spreading of "Green Chemistry" concepts, has gained scientific and industrial attention. Maltodextrins are water-soluble D-glucose oligomers produced from starch via enzymatical or thermal treatments, widely employed in the food and pharma industry.[1] Furthermore, because of their good water solubility, numerous studies reported the possibility of cross-linking maltodextrins into insoluble polymer networks by exploiting suitable cross-linkers, aiming for application in aqueous media. However, many of these compounds, namely, epichlorohydrin, diphenyl carbonate, and isocyanates, are toxic and require the use of organic solvents. As lower-toxicity alternatives, water-soluble diglycidyl ethers have been studied and reported. In addition, alongside diglycidyl ethers, the introduction of tertiary amines during the synthetic step has been exploited to obtain hydrophilic cationic maltodextrin-based adsorbents, which displayed promising removal performances towards both organic and inorganic contaminants.[2,3]

Chromium, predominantly as Cr(VI), is among the most prevalent water contaminants generated by the metal finishing, textile, electroplating, and leather industries. Cr(VI) is highly soluble in water and can enter the human body through dermal and oral exposure. Moreover, it is extremely toxic and carcinogenic in long-term exposure and therefore must be removed from the effluents before disposal. However, conventional techniques for chromium sequestration, such as filtration, reduction, precipitation, and ion exchange, have still limited applicability.[4]

In this work, cationic bio-derived polymers obtained via a sustainable approach by crosslinking maltodextrins with suitable diglycidyl ethers were studied as adsorbents for removing Cr(VI) from aqueous media.

References:

[1] Y. Yu, M. Shen, Q. Song, J. Xie, Carbohydr. Polym. 2018, 183, 91–101.
[2] C. Cecone, G. Hoti, F. Caldera, M. Ginepro, A. Matencio, F. Trotta, Gels 2024, 10, 232.
[3] C. Cecone, M. Iudici, M. Ginepro, M. Zanetti, F. Trotta, P. Bracco, Nanomaterials 2023, 13, 2805.
[4] R. Garg, R. Garg, M. Sillanpää, A. Zumla, M. A. Khan, N. M. Mubarak, Y. H. Tan, Sci Rep 2023, 13, 6859.

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IND-OR-038

From Waste to Feedstock: BHET-driven Integration for Closing the Loop in Eco-Friendly Polyurethane Resins

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The enormous worldwide employment of single-use plastic materials is leading to ever-increasing waste generation. Therefore, the use of the latter as a feedstock for the production of waste-derived materials has emerged as a hot topic within both the scientific community and the industrial area. However, to accelerate the creation of an effective and reliable market for secondary raw materials, an essential requirement for circular materials is the ease of implementation in current processes and products[1].

In this perspective, we have started to investigate bis(2-hydroxyethyl) terephthalate (BHET), a low molecular weight diol as the main product of the glycolysis of polyethylene terephthalate (PET), as a promising circular component in the formulation of more sustainable ready-to-market polyurethanes[2]. This approach is particularly appealing considering that the end-of-life of a preeminent thermoplastic polymer on a global scale (i.e. PET) would serve as feeding for the most prevalent thermosetting polymer worldwide[3] (i.e. PUs), thereby offering an alternative route for closing the loop on a not negligible portion of PET waste.

In this contribution, we explored an innovative approach to implement BHET as a secondary raw material in the formulation of NCO-terminated prepolymer tailored for thermosetting resins. BHET was seamlessly integrated into the prepolymer formulation, removing the need for modifications to the industrial process, and demonstrating outstanding compatibility with other components within the mixture. The impact of BHET concentrations and its relative ratio with polyether and polyester constituents of the prepolymer on the final resins were systematically evaluated, showcasing the feasibility of fine-tuning the physical, chemical, and mechanical properties of polyurethanes while preserving market-level properties. In conclusion, we proved the successful incorporation of a significant amount of BHET (up to 20% w/w) into novel, eco-friendly prepolymers using a solvent-free methodology, without necessitating additional steps in the industrial workflow.

References:

[1] Bucknall, D.G., Philos. Trans. R. Soc. A (2020) 378, 2176.
[2] Mariotti, N., Viada, G., Galliano, S., Menozzi, A., Tammaro, F., Gianelli, W., Bonomo, M., Barolo, C., J. Clean. Prod. (2023) 408, 137161.
[3] https://plasticseurope.org/knowledge-hub/plastics-the-facts-2022/

Acknowledgements:

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IND-OR-039

Enhancing Safety in Academic Laboratories: A Combined HAZOP and LOPA Approach for Risk Assessment in Fischer-Tropsch Synthesis Experiments

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This study proposes a risk assessment framework for Fischer-Tropsch synthesis experiments in academic laboratories and pilot plants, focusing on addressing the prevalent issues of accidents and incidents due to variable conditions, human error, and inadequate training. By integrating Hazard and Operability Analysis (HAZOP) and Layers of Protection Analysis (LOPA), the work aims to tackle the unique risks in academic environments, including manual operations and transient processes. It emphasizes analyzing operability issues, identifying high-risk deviations, and assessing the effects of manual interventions and laboratory infrastructure on safety. Key areas like the Fischer-Tropsch reactor and feed section were pinpointed as high-risk, revealing inadequately mitigated risks. An in-depth LOPA analysis led to identifying essential preventive and mitigative strategies, recommending automation, safety interlocks, automatic control loops, and redundancy to improve safety. The study highlights the significant impact of manual operations and laboratory infrastructure, such as ventilation and safety equipment, on risk scenarios.

Offering a comprehensive view on safety management in academic settings, the study suggests moving towards automation and strategic safety implementations to boost experimental setup safety. This approach aims to elevate safety standards in academic labs and pilot plants, significantly reducing accidents and injuries.

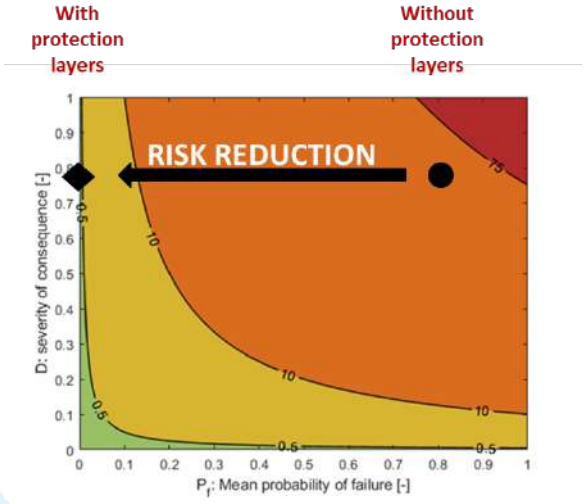

Figure 1: Example of risk class evaluation after implementing protecting layers (failure of Reactor R-01).

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IND-OR-041

Chemical and enzymatic hydrolysis of waste wheat bran to sugars and their simultaneous biocatalytic conversion to valuable carotenoids and lipids

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Defatted wheat bran, an industrial waste of the food chain, represents a strategic renewable material for modern biorefinery schemes. Through a combination of chemical and biological catalysis, a cascade process was developed to produce high-value fine chemicals, such as carotenoids and lipids, from polysaccharide fraction. Due to the low lignin content and suitable particle size of defatted wheat bran, pretreatment steps are unnecessary, allowing the direct enzymatic or chemical hydrolysis of polysaccharide components to give fermentable sugars. Regarding the biocatalytic approach, the optimisation of the main reaction parameters, such as enzyme dosage and biomass loading, was performed to improve the monosaccharide yield. Regarding the chemical route, a microwave-assisted $FeCl_3$-catalysed approach was optimised in terms of catalyst amount and reaction time to maximise the sugar yield, minimizing the formation of furanic derivatives which are strong inhibitors for the subsequent fermentation step. The biological conversion of sugars obtained by both catalytic routes into carotenoids and lipids was performed by the commercial yeast *Rhodosporidium toruloides*. The simultaneous production of carotenoids and lipids was optimised by investigating the effect of the C/N ratio in the fermentation medium. The highest carotenoids cell content achieved in this study (14.8 mg/g) is about 5 times higher than the maximum value reported in the literature to date for this yeast. Moreover, *R. toruloides* achieved the complete conversion of sugars into desired bioproducts for both the biomass hydrolysates demonstrating the effectiveness of the two different catalytic approaches adopted for biomass hydrolysis.

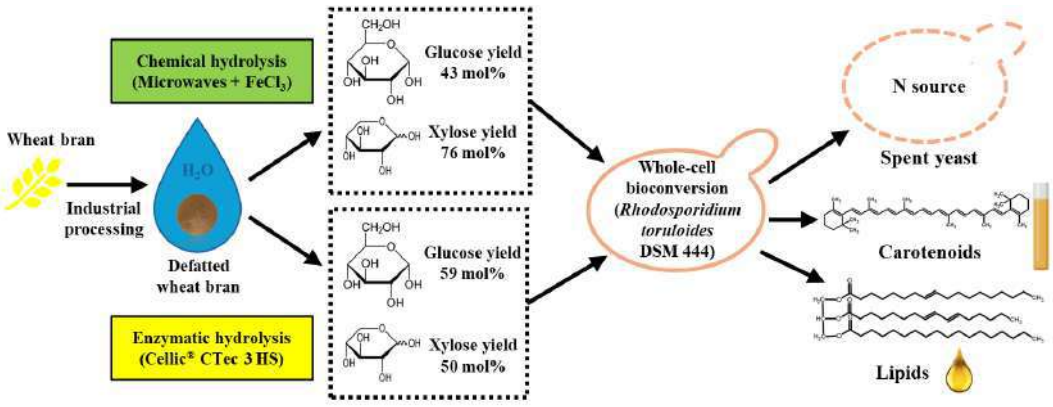

Figure 1: Biorefinery scheme developed for the exploitation of waste wheat bran.

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IND-OR-042

A circular economy approach for the design, synthesis, and utilization of Ni-based heterogenous catalyst.

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Nowadays, the design of more sustainable processes, aiming at the waste prevention, is of crucial importance. Additionally, strategies such as recycling and upcycling are promising tools to contrast the waste disposal. In this context, the definition of suitable methods for the valorization of urban waste is pivotal to promote a circular economy.

We report the upgrading of pine needles urban waste in PiNe,[1,2] a porous carbonaceous material used as support for metal nanoparticles (M/PiNe).[3,4] To meet the future generations needs, the immobilization of low-cost Ni as active site afforded a competitive and performant heterogeneous catalyst. Ni/PiNe proved to be efficient, also for consecutive cycles, in cross-coupling reaction under MW irradiation (Figure 1).

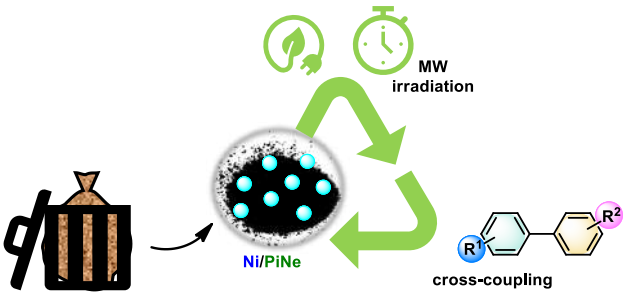

Figure 1: Waste valorization to recyclable Ni/PiNe used in cross-coupling under MW irradiation.

Acknowledgements
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References:
[1] F. Valentini, E. Cerza, F. Campana, A. Marrocchi, L. Vaccaro, Bioresource Technology 2023, 390, 129847.
[2] F. Campana, F. Valentini, A. Marrocchi, L. Vaccaro, Biofuel Research Journal 2023, 40, 1989-1998.
[3] F. Ferlin, F. Valentini, D. Sciosci, M. Calamante, E. Petricci, L. Vaccaro, ACS Sustainable Chem. Eng. 2021, 9, 12196−12204
[4] F. Valentini, B. Di Erasmo, M. Ciani, S. Chen, Y. Gu, L. Vaccaro, Green Chem. 2024, DOI: 10.1039/D4GC00497C

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IND-PO-001

Double-layer off-on mechanochromic systems based on pyrene and perylene bisimide derivatives

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Excessive mechanical stress on polymeric materials can result in the rupture of macromolecular chains, causing degradation and macroscopic failures which can compromise the functionality of devices and even pose relevant safety issues. Reliable rapid and accessible strain monitoring would be a potent preventive measure against premature and potentially debilitating damage. One way to achieve this is by employing mechanochromic probes which, once dispersed or covalently bound to the desired material, make it able to change its optical properties in response to mechanical stimuli, thus providing reliable and direct clues to easily address mechanical stress.[1] This approach also allows to target commodity polymers which are largely available, already find several applications, and can be easily reused/recycled.

In this study, we have developed a novel design for a two-layers mechanochromic device capable of producing a large variation of fluorescence upon stretching thanks to synergic response of the different mechanophoric systems present in the different layers. In particular, the bottom layer comprises a pyrene-based aggregachromic system capable of switching its fluorescence response to lower wavelengths upon mechanical deformation, while the top layer contains a red pigment, based on perylene bisimide dyes, that act as a filter to absorb the radiation coming from the bottom layer in the relaxed state.[2,3] Upon stretching, the combination between the shift of the fluorescence in the bottom layer and the thinning of the filter in the top layer result in large and rapid variation of the intensity.

We investigated the optical response of different dye-filter combinations and tested different host materials to better understand the efficacy of the proposed design. By employing elastomeric matrices, it is possible to obtain reversible off-on systems. This approach provides an affordable and effective method to prepare versatile mechanical stress indicators.

References:

[1] F. Ciardelli et al., Chemical Society Reviews 2013, 42, 857-870.
[2] C. Micheletti et al., ACS Appl. Polym. Mater. 2023, 5, 1545-1555.
[3] F. Muniz-Miranda et al., ACS Omega 2019, 23 (4), 20315-20323.

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IND-PO-002

Ketonization of bio-based hexanoic acid for the synthesis of 6-undecanone: a possible alternative route to produce sustainable aviation fuels (SAFs)

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The ketonization of a bio-based hexanoic acid (BIO-HA) was investigated with the aim of selectively synthesizing 6-undecanone (6U), a symmetric ketone that has various industrial applications, such as serving as a solvent, flavour or could be utilized as a precursor for sustainable aviation fuels (SAFs).[1] This synthetic approach (figure 1), in respect to the traditional fossil-based jet fuel production, would benefit from utilizing bio-based feedstocks. Our raw material was obtained through an effective fermentative process able to produce renewable hexanoic acid from waste grape pomace, which is obtained with high purity by exploiting its immiscibility with acidified water, as recently reported.[2] Moreover, the catalytic tests were carried out in the gas-phase using a continuous-flow fixed-bed reactor at 350 °C. Unreacted reactants and products were quantified by means of GC-TCD (online) and GC-FID (offline). Unknown products were identified by means of GC-MS. The yields and selectivities of various products in the presence of different catalysts such as ZrO_2, TiO_2 and a mixed oxide (Zr/Ti/O) were analysed and compared. The effect of the main impurities contained in the BIO-HA, such as butyric acid, valeric acid and water, on the catalytic activity and performances was also investigated in detail. Long term tests have clearly underlined the negative effect of these impurities on catalyst lifetime compared with commercially available, highly pure, hexanoic acid. Interestingly, the results showed that ZrO_2 is the best catalyst for the ketonisation of anhydrous medium chain acids, however water strongly inhibits its activity even in small quantities. On the other hand, TiO_2 is less active than ZrO_2 when tested with anhydrous acids, but its activity is not strongly influenced by the presence of water in the feed. All in all, the results indicate that BIO-HA can be used as raw materials for the synthesis of bio-6U, nonetheless the presence of unknown impurities lead to catalyst deactivation after around 50 hours of reaction.

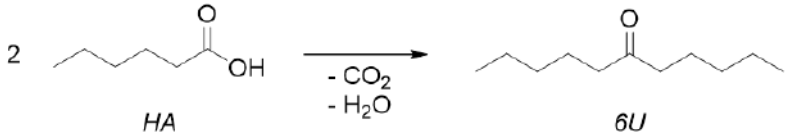

Figure 1: The ketonization reaction of hexanoic acid (HA) to 6-undecanone (6U).

References:

[1] P. Domenech, B. K. Joseph, A. T. Nielsen and A. Riisager, 2023, Ind. Eng. Chem. Res., 62, 44, 18350–18361.

[2] G. A. Martinez, S. Puccio, J. M. B. Domingos, E. Morselli, C. Gioia, P. Marchese, A. M. Raspolli Galletti, A. Celli, F. Fava and L. Bertin, 2022, Green Chem., 24, 2882.

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IND-PO-003

From Waste to Catalyst: Pyrolysis-Based Valorization of Biomass

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A way to valorise agricultural and other organic waste is thermolytic transformation via pyrolysis, resulting in different products: biogas, bio-oil and biochar, corresponding to the gas, liquid and solid fractions, respectively[1]. The solid phase, biochar, is a promising carbon-rich material that can be applied to various fields, such as wastewater treatment, soil remediation, as a material for electrodes, and catalysis, replacing other carbon materials from less sustainable sources[2]. The properties of biochar are influenced by the nature of the biomass and pyrolysis parameters such as temperature, heating rate and residence time. Moreover, its physicochemical features can be enhanced through activation with different agents, such as steam, CO_2, KOH, or ZnCl2. In this study, different biochars have been activated with steam as a more sustainable activating agent to obtain high surface area carbons suitable as supports for metal nanoparticles[3]. Two different biomasses, one of vegetal origin (rice husk) and one of animal origin (leather tanning scraps), were used to produce steam-activated biochars (AR, AL). A 1:1 wt% mixture of the two (ARL) was also investigated. The three samples were employed as a support for Pd nanoparticles using a deposition-precipitation method. The synthesized catalysts (Pd/AR, Pd/AL, Pd/ARL) were characterised with N_2 physisorption, CHNS elemental analysis, SEM, XPS, Raman spectroscopy, CO chemisorption and MP-AES to investigate the physicochemical properties of the carbonaceous supports and their interaction with the metal phase. They were also tested in benzaldehyde hydrogenation, evaluating reactant conversion and hydrogenation product yield. The results of the reaction show that the catalyst supported on the biochar produced from the mixture yields a more active catalyst than the one produced from leather scraps and a more selective catalyst than the one produced from rice husk, showing a synergic interaction between the biomasses constituents during the pyrolysis process. These results will be discussed with respect to the data from characterizations.

Sample	BET surface area (m^2/g)	V_{tot} (cm^3/g)	I_d/I_g	Effective wt% Pd (nominal: 0.7 wt%)	$D_{(Pd)average}$ (nm)	TOF (h^{-1})	Yield (%)
Pd/AL	380	0.12	1,113	0.44	4.6	149	15
Pd/AR	680	0.18	1,086	0.64	4.2	1297	77
Pd/ARL	450	0.24	1,037	0.67	2.0	1084	93

Tab 1: main features of the catalysts and catalytic results.

References:

[1] Salimi, P.; Venezia, E.; Taghavi, S.; Tieuli, S.; Carbone, L.; Prato, M.; Signoretto, M.; Qiu, J.; Proietti Zaccaria, R. *Energy Environ. Mater.* **2023**, *0*.

[2] Longo, L.; Taghavi, S.; Riello, M.; Ghedini E.; Menegazzo F.; Di Michele A.; Cruciani G.; Signoretto, M. *Catal. Today* **2023**, *420*, 114038.

[3] Longo, L.; Taghavi, S.; Ghedini, E.; Menegazzo, F.; Di Michele, A.; Cruciani, G.; Signoretto, M.; *ChemSusChem* **2022**, *15*, e2022004.

IND-PO-004

The HYDREAM project: Tailoring the Hydrophilic-Hydrophobic Reaction Zone for the Electrochemical Nitrogen Reduction Reaction to Ammonia

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The preservation of our planet is the most urgent issue in the world and the scientific community is pushing a lot of researchers to work on technologies for the storage/conversion of CO_2 into chemicals. However, it is easier not to produce CO_2 than setting-up plants to treat it. Therefore, new industrial processes have to be conceived with a new perspective.

In this framework, the HYDREAM project focuses on the development of a gas/liquid/solid three-phase interface (TPI) that endows electrodes with enhanced performance for target electrochemical reactions involving gases, due to its ability to mediate local interfacial environments and inhibit side reactions. Such a TPI concept is starting to be considered by the scientific community due to its promising potentialities in several strategic research fields, e.g. electrocatalyzed reduction of CO_2, O_2 and N_2, fuel cells, sensors for liquid and gas substrates, anti-corrosion systems, etc.

The main goal is to tailor the TPI within a double hydrophilic-hydrophobic reaction zone, bearing a controlled grade of hydrophilicity at the microscale. The achievement of the co-existence of hydrophilic-hydrophobic conditions within the electrocatalyst/electrode will permit a compromise between efficient gas transport to the electrocatalyst and good contact of the electrocatalyst with the electrolyte (i.e., to provide the needed protons for the reduction reaction).

HYDREAM activity is exploring these key experimental points:

- Design of heterogeneous electrocatalysts able to show hydrophobic-hydrophilic conditions in the reaction zone.
- Formulation of non-aqueous liquid electrolytes showing optimal electrode wettability, reactant solubility and mass transport.
- Advanced physico-chemical characterization to assess specific materials features and electrochemical reaction aspects at the nanoscale.
- Exploitation of TPI concept in a highly significant case study, i.e. the electrochemical N_2 reduction reaction (E-NRR) to NH_3 under mild conditions.

Acknowledgements:
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IND-PO-005

A versatile polymer scaffold for the preparation of polymer cathodes for metal ion-organic batteries

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With the energy transition, the energy world is moving toward more sustainable, renewable sources, which offer several advantages such as a reduced CO_2 emissions, an improvement in the general public health, and promotes energy independence and security. However, they also suffer several drawbacks due to their cyclic, seasonal, and regional characteristics. Efficient energy storage technologies, such as batteries, can mitigate this problem and will cover a prominent role in the energy infrastructure of the future.
Currently, Li-ions batteries (LIBs) are among the best performing batteries commercially available, as they offer good stability toward charging-discharging cycles, large power densities and large conversion efficiency. However, they currently rely on the use of specific metals (Li, Ni, Co) the production of which is not sustainable and localized in geopolitically unstable areas of the world. Redox-active polymeric materials as electrode materials can circumvent these issues, as they are obtained from more available resources, they can have a greener footprint, and easily allow for various modifications via chemical synthesis. In addition, thanks to their light weight, organic materials can reach very high specific capacity values compared to the inorganic counterparts.

Materials proposed so far show limited lifetime, due to solubility in the electrolyte, and slow/incomplete discharging. To overcome these limitations, we propose a novel strategy based on processable precursor polymers which can be employed to prepare high molecular weight (disfavouring the solubilisation process), fully conjugated polymers (characterized by a higher charge mobility), comprising either in chain or pendant redox units. In this study, we report an example of such systems consisting in polymeric precursors comprising aromatic moieties separated by 1,4-dicarbonyl fragments which break the conjugation. These units can then be used as scaffold for pyrrole formation in the Paal-Knorr reaction, allowing the insertion of different redox units and, at the same time, making the structure of the polymer flat and conjugated, reducing the solubility.

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IND-PO-006

Advancements in Amino Acid Ionic Liquids for Enhanced CO_2 Capture: Navigating Challenges and Opportunities

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The pressing need to reduce atmospheric CO_2 has spurred the search for carbon capture and sequestration technologies. Ionic Liquids (ILs) have shown promise for CO_2 capture due to their properties such as minimal vapor pressures, high thermal stability and the capacity to dissolve CO_2.. Their tunability enables the enhancement of CO_2 absorption allowing their application in gas separation and industrial capture efforts. Nevertheless, challenges such as high production costs, increased viscosity compared to traditional solvents, and uncertain long-term environmental impacts hinder their widespread. Research efforts are now focused on the realization of more economical ILs with reduced viscosity and improved CO_2 selectivity, alongside evaluating their ecological effects.

Amino Acid Ionic Liquids (AAILs), noted for their superior CO_2 absorption, low vapor pressure, and thermal stability, are being extensively studied. This research traces the development from our initial studies on biobased ILs to recent advancements [1,2], highlighting significant progress in AAILs for industrial CO_2 capture.

Starting from the utilization of choline-based amino acids ([Cho][AA]) in solutions with DMSO to mitigate the intrinsic high viscosity of AAILs throughout the development of other solutions were described emphasized the role of solvents for the improvement of absorption rates while presenting an environmentally benign and economically viable alternative to traditional carbon capture methodologies.

References:

[1] E. Davarpanah, S. Hernández, G. Latini, C. F. Pirri, S. Bocchini, Adv. Sustainable Syst. 2020, 4, 1900067.
[2] G. Latini, M. Signorile, F. Rosso, A. Fin, M. d'Amora, S. Giordani, F. Pirri, V. Crocellà, S. Bordiga, S. Bocchini, J. CO2 Util. Jan. 2022, 55, 101815.

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IND-PO-007

TiO_2-loaded MCM-41 for surface stone protection

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Stone materials have been extensively used in the past as primary materials for construction due to their high strength and good durability. Nevertheless, when exposed outdoors they undergo a gradual decay caused by environmental agents, such as pollutants or microbiological species responsible for the colonization of surfaces [1]. In order to preserve these materials and to prevent their decay, it is common practice to apply protective coatings of various nature, that form a physical barrier on the stone surface making it hydrophobic and inhibiting microbial growth [2]. Current stone surface coatings are often harmful to the environment and to operators, thus innovative solutions are needed.

This work aims to develop a sustainable protective coating for stone surfaces based on a mesoporous silica (SiO_2), MCM-41, loaded with titanium dioxide (TiO_2). In this multifunctional system, the structure of MCM-41 can host antimicrobial products, while TiO_2 gives self-cleaning properties to the surface thanks to its photocatalytic activity [3]. In particular, the photocatalyst will degrade atmospheric pollutants such as VOCs and NOx, which interact with the surface of stone causing chemical degradation and altering its aesthetic appearance. Self-cleaning properties could also help in the degradation of vandalic stains.

Specifically, MCM-41 nanocontainers were synthesized and subsequently enriched with three different types of TiO_2 nanoparticles (*i.e.*, P25, Kronos, Mirkat) to test the photocatalytic activity changes of the materials. The obtained composite materials were characterized through several analytical techniques: N_2 physisorption, FT-IR, SEM-EDS and HRTEM.

To investigate the photocatalytic activity of the synthesized nanomaterials methylene blue was employed as a model stain compound. This test was conducted both in liquid, with subsequent monitoring by UV-visible spectrophotometry, and on plaster mock-ups exposed outdoors to visible light.

In summary, the synthesis and characterization of TiO_2-loaded MCM-41 nanoparticles were pursued to develop a coating for stone surfaces, aiming to extend protection duration and enhance self-cleaning action.

References:

[1] J. Becerra, A. P. Zaderenko, *et al.*, International Journal of Architectural Heritage, 2021, 15, 1320–1335,
[2] S.A. Ruffolo and M. F. La Russa, Frontiers in Materials, 2019, 6, 147
[3] M. Signoretto, E. Ghedini, *et al.*, Applied Catalysis B: Environmental, 2010, 95, 130-136

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IND-PO-008

Feasibility of green mechanochemical synthesis for dual function materials preparation

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A recent approach in mitigating the emissions of CO_2 is the integrated carbon capture and utilisation for the synthesis of CH_4 from waste flue gases by using Dual Function Materials (DFMs).[1] The DFMs are formed by the CO_2 capture component, usually an alkaline oxide, and the catalytic component, usually a transition metal. The two parts must interact in synergy to be able to convert the captured CO_2 efficiently with a spillover mechanism from the adsorbent phase to the catalytic sites.[2]

In this work, we report the preparation and performances of bimetallic RuNi DFMs with CaO and Na_2O as adsorbent phases supported on CeO_2-Al_2O_3. The DFMs have been prepared by a mild-energy solventless mechanochemical process. The materials were tested at 650 °C for the cyclic CO_2 capture, both in lean conditions and with the presence of O_2 in the stream, and the reduction to produce CO by the Reverse Water-Gas Shift reaction (RWGS). Compared to the conventionally impregnated samples,[3] these DFMs show increased CO_2 capture capacity and CO production (Table 1). Yet, undesirable CO production is observed also during the CO_2 capture step due to the strong reducibility of the milled DFMs. The presence of O_2 during the capture step suppressed the formation of CO without negatively affecting the CO production by RWGS and the DFMs stability in cyclic operations, showing good potential in real flue gas applications.

Table 1: CO_2 capture capacity and CO production during the capture and the RWGS steps for selected samples prepared with the mechanochemical method (M) compared to reference impregnated samples (W).[3]

Sample	Synthesis	CO_2 capture capacity mmol/g_{DFM}	CO - capture step µmol/g_{DFM}	CO - RWGS µmol/g_{DFM}	CO - capture step (CO_2+O_2) µmol/g_{DFM}	CO - RWGS (CO_2+O_2) µmol/g_{DFM}
RuNi/CaO/ CeO_2-Al_2O_3	W	0.26	n.a.	58	n.a.	n.a.
RuNi/Na_2O/ CeO_2-Al_2O_3	W	0.16	n.a.	2	n.a.	n.a.
RuNi+CaO/ CeO_2-Al_2O_3	M	0.29	500	185	4.5	30
RuNi/Na_2O/ CeO_2-Al_2O_3	M	0.26	1192	8	2.4	30

References:

1. Omodolor, I. S., Otor, H. O., Andonegui, J. A., Allen, B. J. & Alba-Rubio, A. C. *Ind. Eng. Chem. Res.* **59**, 17612–17631 (2020).
2. Bermejo-López, A., Pereda-Ayo, B., González-Marcos, J. A. & González-Velasco, J. R. *J. CO2 Util.* **42**, 101351 (2020).
3. Merkouri, L. P., Ramirez Reina, T. & Duyar, M. S. *Nanoscale* **14**, 12620–12637 (2022).

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IND-PO-009

Study of promoters for Ni/Al_2O_3 catalyst in Methane Dry Reforming

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Dry Reforming of Methane (DRM) is the process of simultaneous conversion of CH_4 and CO_2 to obtain syngas (CO and H_2). The process enters in the field of green energy transition, since it uses CO_2 to produce hydrogen in a more sustainable way[1]. However, the DRM process is not yet applied at the industrial level, due to the limitations of the catalytic system, that affects the overall economy of the process. Because of the reaction conditions adopted, the catalyst suffers from coke deposition and sintering of active phase[2].
In this work, to enhance the catalytic resistance, is evaluated the introduction of promoters on a Ni-based catalyst, supported on γ-Al_2O_3. In particular, vanadium and calcium are studied as promoters, to determinate the optimal weight percentage to introduce. Different catalysts are synthetized by incipient wetness impregnation method, and tested for the DRM reaction at 650°C in a fixed bed reactor, with a GHSV of 12000 h^{-1}, using different ratios of the reagent gases (CH_4:CO_2:He), under a total flow of 200 mL/min.
Both fresh and spent catalytic materials are characterized using various techniques, such as: TPR, TPO, XRD, CHNS analysis, SEM-EDX, TEM and nitrogen physisorption. From the activity results obtained, it is demonstrated that these promoters are effective in a low amount (about 1 wt.%), showing a good stability and activity over 25 h of reaction. By characterizing exhausted samples, it is proved that these promoters are suitable to enhance the coke resistance.

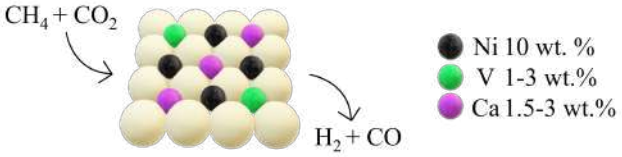

Figure 1: Graphical abstract.

References:

[1] M. Pizzolato, G. Da Pian, E. Ghedini, A. Di Michele, F. Menegazzo, G. Cruciani, and M. Signoretto, Reactions, 2022, 3, 634 – 647.
[2] M. Pizzolato, G. Da Pian, E. Ghedini, A. Di Michele, F. Menegazzo, G. Cruciani, and M. Signoretto, Catalisys Today, 2023, 418, 114041.

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IND-PO-010

Modulation of redox property of Cu complexes based on bipyridine ligands substitution

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We recently reported on a new application for the [Cu(6,6'-dimethyl-2,2'-bipyridine)$_2$][PF_6] (coded CuBPA) system as an active catalyst for allylic oxidation of cyclohexene by tert-Butyl hydroperoxide (TBHP) in dichloromethane[1]. Such a redox cycle was not observed for [Cu(2,2'-bipyridine)$_2$][PF_6] (coded CuBPD) system where the oxidation by TBHP is a fast but irreversible process, and the back-reduction with cyclohexene is not observed. The slow kinetic of the oxidation of CuBPA by TBHP, in contrast with the almost immediate oxidation of CuBPD, prompted us to explore the system [Cu(6-methyl-2,2'-bipyridine)$_2$][PF_6] (coded CuBPAD), aiming at a complex with intermediate redox and catalytic properties: it is known that the backbone substitution is crucial for the properties of these systems[2]. Preliminary computational study showed an encouraging linear correlation between the grade of methyl substitution and the ΔE and ΔG of the two oxidation reactions. Thus, we synthesize the BPAD ligand and prepared the corresponding Cu complex. The good match between computed and experimental Raman spectra confirmed the good quality of the models, corroborating the computational result, cyclic voltammetry confirmed the intermediate redox potential of CuBPAD, while UV-Vis study monitored the oxidation for CuBPAD in the same conditions used for CuBPA, confirming an intermediate behaviour that we expect to be reflected in the catalytic performance[3].

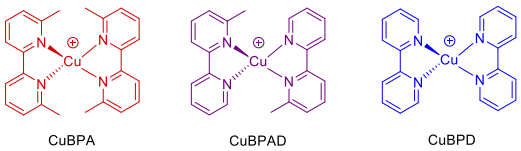

Figure 1: From left to right: CuBPA, CuBPAD, CuBPD.

References:

[1] B. Centrella; G. Deplano; A. Damin; M. Signorile; M. Tortora; C. Barolo; M. Bonomo; S. Bordiga. *Dalton Transactions* **2022**, *51* (38), 14439–14451.

[2] Y. Saygili; M. Söderberg; N. Pellet; F. Giordano; Y. Cao; A.B. Munoz-García; S.M. Zakeeruddin; N. Vlachopoulos; M. Pavone; G. Boschloo; L. Kavan; J.E. Moser; M. Grätzel; A. Hagfeldt; M. Freitag. *J Am Chem Soc* **2016**, *138* (45), 15087–15096

[3] Damin, A.; Bonomo, M.; Centrella, B.; Signorile, M.; Barolo, C.; Bordiga, S. *ACS Omega* **2024**.

IND-PO-011

Physical-Chemical Characterization of Hydrochars from HTL of Waste Polyurethane Foams

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Polyurethanes are one of the most versatile and requested polymers on the market[1]. In particular, rigid polyurethane foams (PUR) are widely used in thermal insulation, furniture and automotive applications. Because of their commercial success, million tons of polyurethane waste are produced every year. Landfilling and incineration are still the most common ways of processing polyurethanes in Europe[2], while mechanical and chemical recycling remain limited due to the thermoset nature of polyurethanes and the high energy demand requested for the processes. According to the 12th goal of the 2030 Agenda for Sustainable Development, it is necessary to identify efficient methods for the recycling of plastic waste. In this study, a promising valorization of PUR by thermochemical recycling was evaluated via hydrothermal liquefaction (HTL), to obtain a solid product, named hydrochar, with high added value. A rigid and thoroughly characterized[3] PUR for model making, was used as feedstock for the tests. Reactions were carried out using a Parr reactor 4576 and ultrapure water in subcritical conditions, with temperature ranging from 250°C to 345 °C and different reaction times (from 20 min to 120 min). Moreover, for the first time in literature an acidic environment was experimented, using a mixture of water and acetic acid, with a volume ratio of 2,5:1 (pH =2,06). The hydrochars thus obtained were characterized by ultimate analysis, ICP-MS, FTIR, porosimetry and SEM to evaluate the influence of the reaction parameters on the hydrochar properties such as elemental composition, degree of functionalization, morphology, and porosity.
This in-depth characterization of the hydrochars will make it possible to evaluate their applicability in different industrial fields according to a circular economy perspective.

References:

[1] J.O. Akindoyo, Md. D.H. Beg, S. Ghazali, M.R. Islam, N. Jeyaratnam and A.R. Yuvaraj, RSC Adv., 2016, 6, 114453-114482.
[2] J. Datta, P. Kopczyńska, D. Simón, J.F. Rodríguez, J. Polym. Environ., 2018, 26, 166–174.
[3] R. Gallorini, B. Ciuffi, F. Real Fernández, C. Carozzini, E. Ravera, A.M. Papini, L. Rosi, ACS Omega, 2022; 7(42): 37757-37763.

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IND-PO-012

Exploring the structure-activity relationship and coke poisoning resistance in Nickel-Lanthanum catalysts for Methane Dry Reforming

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Methane dry reforming (DRM) stands as an innovative catalysed process pivotal in sustainable fuel alternatives development, efficiently transforming CH_4 and CO_2 into syngas ($CO+H_2$), thus reducing greenhouse gases concentration unto the atmosphere.[1] Despite the interest to environmental issues, the reaction faces challenges due to side reactions, such as methane decomposition, Boudouard reaction, and CO reduction, leading to catalyst deactivation due to carbon deposits accumulation.[2] Nickel-based catalysts are commonly used in DRM due to their affordability and robust performance,[3] but they undergo deactivation due to carbon deposition and sintering process at high temperatures. To address these issues, different catalysts compositions and various preparation conditions have been explored, aiming at enhancing structural properties, phase composition, distribution of nickel phases, and overall catalytic activity.

In this study, a comparison of catalytic performances of Ni-La catalysts prepared with microwave-assisted precipitation synthesis (MW) and hydrothermal method (HT) has been performed. The differences in CH_4 and CO_2 conversion over the investigated catalysts have been explained by a comprehensive structural analysis, which suggests differences in Ni-La crystal phases and particle sizes. TGA and HR-TEM have been carried out to evaluate coke formation and the influence of time on the stream on Ni particle size, suggesting for MW catalysts good stability and the possibility to regenerate such samples from carbon deposition with limited Ni sintering.

References:

[1] N.A.K. Aramouni, J.G. Touma, B.A. Tarboush, J. Zeaiter, M.N. Ahmad, Ren. Sust. Energy Rev. 2018, 82, 2570
[2] V. La Parola, L. F. Liotta, G. Pantaleo, M. L. Testa, A. M. Venezia, Applied Catalysis A: General 2022, 642, 118704
[3] J. Huang, Y. Yan, S. Saqline, W. Liu, B. Liu, Applied Catalysis B: Environmental 2020, 275, 119109

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IND-PO-013

Iron Oxide Reduction using Hydrogen as green reducing agent

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The steel industry plays a key role in the world's industry and economy and the yearly production exceeded 1950 mega tons in 2020. Unfortunately, it is also emitter of carbon dioxide reduction is made by coal-based reduction; in fact, 73.7% of the production exploit *Blast Furnace* (BF). In the BF, the reduction is conducted with carbon monoxide obtained from coke. The coke and iron oxide are charged from the top part of the BF, descend through the shaft where they are preheated and react. The partial oxidation of coke produces CO which starts to reduce the iron oxide and liquid iron slag and CO_2 are obtained. In fact, the steel production is responsible approximately 8% of industrially based global CO_2 emissions, which corresponds to around 2 Giga tons yearly. The most accredited candidate for decarbonization of ironmaking is a shaft furnace where the reduction is carried out in solid state by a reducing gas, yielding *direct reduced iron* (DRI). In the DRI, the reduction of iron oxide is carried out at the lower temperature using reformed natural gas with a H_2/CO ratio of 3. They represent the first important step towards the decarbonization of the ironmaking process, but fossil feedstock is used, and CO_2 is still emitted. Recently, hydrogen reduction has attracted increasing attention to reduce the greenhouse emissions, which requires further development of the process. The focus of the present work, then, is to study the reduction kinetics of iron oxide using hydrogen as reductant. The overall reaction displays interestingly complex behaviour, which depends on gas phase, surface and solid phase phenomena. This explains also the very versatile and partly contradictory observations and interpretations found in literature. Therefore, monolayer and bed experiments with pure hematite and commercial samples were performed in various experimental conditions in order to investigate kinetics and mass transfer phenomena. To support the interpretation of the data morphological and chemical-physical characterization has been performed. The collected data lays a strong basis for understanding the overall reduction dynamics. Finally, it provides a strong basis for developing a mathematic model to describe the overall kinetics of the reduction.

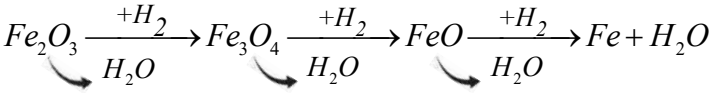

Figure 1: Reaction scheme of hematite reduction

References:

[1] M. Bernasowski, 2014. Theoretical study of the hydrogen influence on iron oxides reduction at the blast furnace process. Steel Research International, 85(4), 670–678.
[2] A. Bonalde, A. Henriquez, & M. Manrique, 2005. Kinetic Analysis of the Iron Oxide Reduction Using Hydrogen-Carbon Monoxide Mixtures as Reducing Agent. ISIJ Int., 45(9), 1255–1260.
[3] A. A. El-geassy, M. I. Nasr, & M. M. Hessien, 1996. Effect lron of Reducing Gas on the Oxide Compacts Volume Change during Reduction of. In ISIJ International 36, 6.

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IND-PO-014

High-added value chemicals production by a photothermo-catalytic CO_2 reduction with modified phyllosilicates

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The Carbon Capture and Utilization (CCU) processes can be efficient solutions for the CO_2 emission mitigation. Here we applied the photothermo-catalysis for the CO_2 conversion into solar fuels[1]. We investigated the performance of modified phyllosilicates (ps) with the incorporation of Ni and Ce ions in their structure and subsequently coated with CeO_2. The modified phyllosilicates were prepared by hydrothermal method at 160 °C and the CeO_2 coating was made by precipitation with KOH. The catalysts were characterized by FT-IR, Raman, XRD, SEM-EDX, XPS, H_2-TPR, CO_2-TPD, UV-DRS and N_2- physisorption. The catalytic activity was determined in the solar photothermal CO_2 reduction both with pure CO_2 and into an integrated approach where the CO_2 was produced from the thermal catalytic oxidation of toluene. The photothermo-catalytic CO_2 reduction was carried out inside a cylindrical batch reactor maintained at 120°C and irradiated with a solar lamp. The results showed that the Ni/Ce-ps@CeO_2 catalyst achieved a CO_2 conversion of 87% after 5 hours of photothermo-catalytic (Fig.1) test using pure CO_2 with a production rate of 15.8 $\mu mol/g_{cat} \cdot h$ of CO and 5.6 of CH_4. In the integrated approach, the CO_2, produced in the thermo-catalytic oxidation of toluene, was converted at a lower extent (50% over Ni/Ce-ps@CeO_2) into CO and CH_4. The peculiar structure of the phyllosilicates permitted to efficiently expose the surface active sites of the deposited CeO_2 to the solar irradiation. The high versatility of the proposed approach paves the way for the use of modified phyllosilicates (montmorillonite, bentonite) with the incorporation of different ions and with the coating of other semiconductor photocatalysts to improve the performance in the photothermo-catalytic CO_2 conversion.

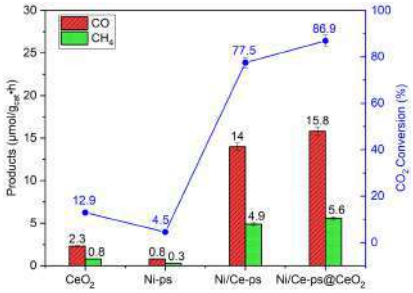

Figure 1:Photothermo-catalytic CO_2 reduction using pure CO_2 at T = 120 °C after 5 h of simulated solar irradiation.

Acknowledgements
This work was funded by SAMOTHRACE, CUP-E63C22000900006.

References

[1] R. Fiorenza, M. Bellardita, S.A. Balsamo, A. Gulino, M. Condorelli, G. Compagnini, S. Scirè, L. Palmisano, Catal Today 2023, 413-415, 113949.

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IND-PO-015

Photoconversion of CO_2 to fuels under high pressure

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Carbon dioxide emissions into the atmosphere are ever increasing due to the massive use of fossil fuels. To overcome this issue, an attractive strategy is photoreduction of CO_2 which has the potential to transform this pollutant into useful and valuable products by leading to circular economy, avoiding the use of net CO_2-producing energy sources and raw materials.

In this work, an innovative high-pressure batch photoreactor was used for the photoreduction of CO_2 at a constant temperature 80°C. It allowed operating pressure up to 20 bar. The reactor was made of AISI 316 stainless with an internal capacity of 1.7 L, allowing semi-pilot scale demonstration and it is completed by a magnetic stirrer and a double-walled thermostatic system. A 250 W medium-pressure Hg vapour lamp was immersed vertically in the reactor axis as an irradiation source. The optimum reaction time was 1.5 hours. Sodium sulphite was used as a hole scavenger, leading to maximum productivity. Somehow lower performance was obtained testing widely different hole scavengers, possibly from renewable sources, such as alcohols, amines and alkanolamines. The reaction was carried out at pH=14 and this favoured 100% selectivity towards HCOOH as product.

Environmentally friendly graphitic carbon nitride (g-CN) was used as a photocatalyst to avoid toxic or rare materials. Different preparation methods were compared and its exfoliation through either thermal, chemical or ultrasound treatment was compared. The semiconductor was also functionalised with different oxides in a Z-scheme fashion, e.g. with ZnO, SnO_2 and Fe_2O_3 with different loadings. Among the best performing examples, the hybrid 8wt% Fe_2O_3/g-CN photocatalyst returned ca. 8 mol/kg_{cat} h of HCOOH, with respect to ca. 6 mol/kg_{cat} h of the bare g-CN. The synthesized catalysts were characterized by XRD, BET, DRS, TEM and SEM. Some interesting materials were also tested by spectrofluorimetry, demonstrating interestingly that exfoliation is an important strategy to improve the lifetime of the photogenerated charges.

Acknowledgements

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IND-PO-016

Indirect valorization of CO_2 by exploitation of $NaHCO_3$ in the mechanochemical synthesis of high value-added compounds

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In the realm of mechanochemistry the integration of gases in solid-gas reactions has been recently unveiled as a viable synthetic strategy.[1] However, storing and handling gases can lead to safety and technical concerns limiting the wide application of potentially attractive methodologies. The utilization of solid surrogates offers several benefits, such as the safe and simple handling of reagents instead of dangerous gases.[2] Furthermore, solid compounds are highly suitable for ball milling conditions, which not only helps reduce the need for solvents but also enables faster reaction times.

Carbon dioxide has been successfully employed for the synthesis of fine and bulk chemicals.[3] Herein, we report $NaHCO_3$ as an extremely cheap, safe, and easy to handle solid surrogate of gaseous CO_2 for carboxylation reactions. In particular, cyclic carbamates and carbonates can be conveniently obtained from the corresponding propargylamines and epoxides, and $NaHCO_3$ under mechanochemical conditions.

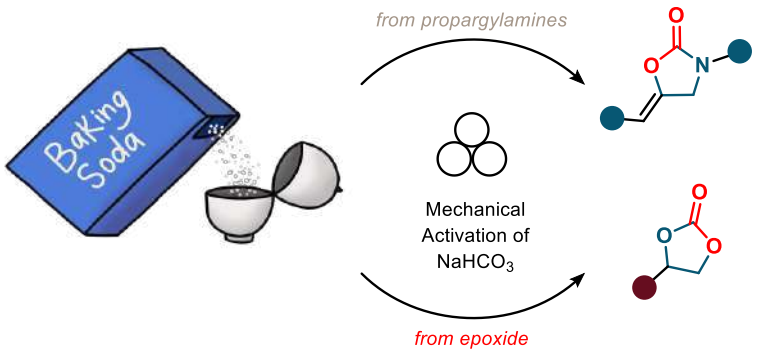

Figure 1: Mechanochemical catalytic synthesis of cyclic carbamates and carbonates from $NaHCO_3$.

References:

[1] C. Bolm and J. G. Hernández, *Angew. Chem. Int. Ed.*, **2019**, *58*, 3285–3299.
[2] M. Turberg, K. J. Ardila-Fierro, C. Bolm and J. G. Hernández, *Angew. Chem. Int. Ed.*, **2018**, *57*, 10718–10722.
[3] M. Aresta, A. Dibenedetto and A. Angelini, *Chem. Rev.*, **2014**, *114*, 1709–1742.

IND-PO-017

Rare Earth Recycling through selective affinity of zeolite X towards Ce, La, Eu and Y

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Rare Earth Elements (REE) are at the core of critical components for the energy transition, from storage batteries to magnets, lasers and efficient electrical applications. Their status of critical resources renders their recovery and recycling a priority for a sustainable circular economy. Individual properties of "light" and "heavy" REE for specific applications set the requirements for high selectivity in their separation in hydrometallurgical and recycling processes.

Zeolites are well-known and unexpensive cation exchangers but their competitivity vs. other REE recovery techniques has been hampered by their poor stability in acid solutions. In this project, effective conditions have been searched for the extraction of Ce, La, Eu and Y cations from pH 4 solutions and their recovery from saturated exchangers by NH_4 solutions [1]. The nature of the REE affected both affinity and loading, with selectivity of exchange controlled by the coordination of the hydration sphere of each cation, The collected data are at the basis of possible procedures of selective separation by proper cycles of controlled loading and recovery.

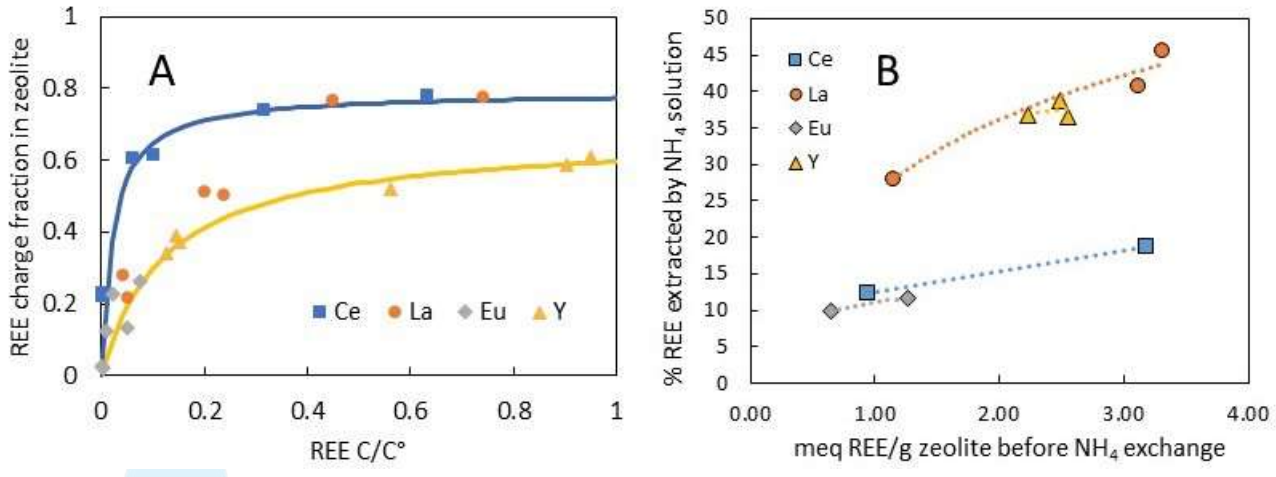

Figure 1: isotherm of NH_4-REE cation exchange on zeolite X (A) and effectiveness of back-exchange of REE by NH_4 solution (B).

References:

[1] F. Colombo, R. Fantini, F. Di Renzo, G. Malavasi, D. Malferrari, R. Arletti, Waste Manag. 2024, 175, 339-347.

IND-PO-018

MICS: Green and sustainable products & materials from non-critical and secondary raw sources

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The Neapolitan Industrial Chemistry Laboratory (NICL) of the Department of Chemical Sciences of the University of Naples Federico II is a player in the MICS (Made in Italy–Circular and Sustainable) Extended Partnership, on the synthesis of green and sustainable products & materials from non-critical and secondary raw sources, with the aim to synthesize non-isocyanate polyurethane foams (NIPUs).

Polyurethane (PU) foams represent a wide class of polymeric materials, having implications in different sectors from automotive, packaging, cushioning/bedding to construction building. However, their synthesis requires the use of oil-based components, mostly harmful and toxic isocyanate components. On this account, NIPUs foams have been indicated as suitable candidates to replace conventional PUs, where foams can be obtained through "non-isocyanate" routes such as aminolysis between 5 or 6 membered ring-cyclic carbonates (5CCs and 6 CCs) and diamines or transurethanization between carbamates and diamines. A sketch of the possible routes is reported in Figure 1 [1].

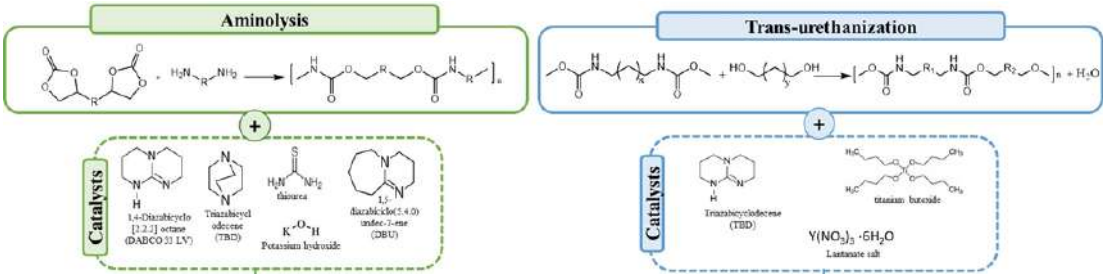

Figure 1: Main polymerization and blowing routes to obtain NIPU foams. Taken from [1].

In the present work, details on the different strategies are provided.

References:

[1] F. Orabona, F. Recupido, F. Taddeo, G.C. Lama, T. Salmi, M. Di Serio, L. Verdolotti, V. Russo, submitted to ACS SusChemEng 2024.

Acknowledgements:

This study was carried out within the MICS (Made in Italy–Circular and Sustainable) Extended Partnership and received funding from the European Union Next-Generation EU (Piano Nazionale Di Ripresa E Resilienza (PNRR) –Missione 4 Componente 2, Investimento 1.3 –D.D. 1551.11-10-2022, PE00000004). This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

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IND-PO-019

Process intensification in acidic wastewater treatment and waste valorization

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Acidic waters often resulting from industrial processes and other activities typically comprise a range of perilous and harmful substances, including organic solvents, heavy metals, pose a significant environmental challenge with adverse effects on aquatic ecosystems, infrastructure, and public health. Traditional treatment methods have limitations in effectively neutralizing acidity and removing pollutants to mitigate these impacts and restore ecological balance. One promising method for treating acidic waters involves the use of lime (CaO), a versatile and cost-effective solution. However, this method generates large amount of sewage sludge presents its own set of threats in terms of disposal and environmental impact [1].

This research presents a general overview of the treatment of acidic waters through lime utilization and explores the potential valorization of sewage sludge in diverse processes (Fig.1). Through a comprehensive analysis of current research and practical applications, it explores underlying mechanisms and highlights the effectiveness of lime in neutralizing acidic waters by adjusting pH levels, and removing pollutants through precipitation heavy metal hydroxides [2]. Furthermore, this investigation delves into diverse methods, including anaerobic digestion and thermal treatment processes for the repurposing of sewage sludge. It considers its potential applications in waste-to-energy and nutrient recycling beyond conventional disposal practices, aiming to reduce landfill waste volume and environmental pollution while promoting resource recovery. The valorization of sewage sludge entails its transformation into valuable resources such as syngas, fertilizers, biofuel, and biogas [3]. This integration presents synergistic benefits, including improved water quality and promoting circular economy principles.

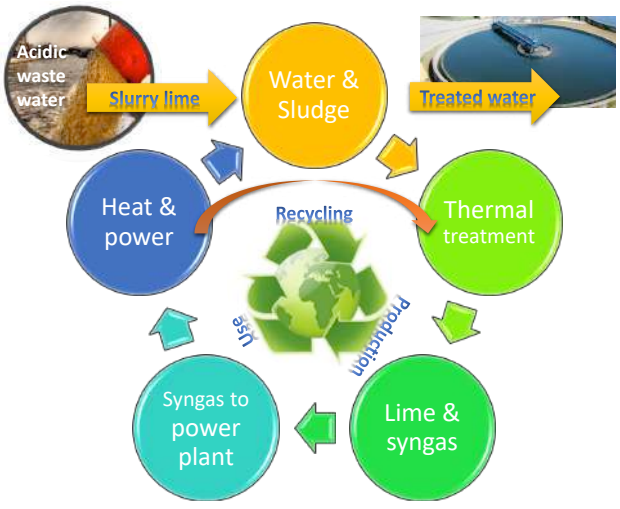

Figure 1: Circular economy of sludge recovery

References:

[1] S. Xia, Z. Song, X. Zhao, J. Li, Journal of Water Process Engineering 2023, 52, 103555.
[2] M. S. Akhtar, Water Conservation Science and Engineering 2022, 7, 683 – 696.
[3] J. Oladejo, K. Shi, X. Luo, G. Yang, T. Wu, Energies 2019, 12, 60.

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IND-PO-020

Pyrene-substituted cyclic triimidazole: an attractive and versatile sensor for the detection of explosives substances

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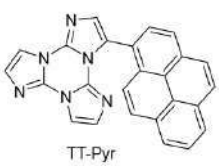
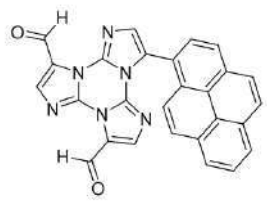
Explosives compounds, like 2,4,6-trinitrotoluene (TNT), are still widely utilized as a blasting agent not only in controlled explosions for peaceful purposes but also in illicit and terrorist activities, such as in improvised explosive devices (IEDs). The development of novel approaches for rapid, specific and sensitive detection of explosives, based on photoluminescent compounds, represents an important tool for mitigating and preventing risks linked to these materials [1]. In the search for low-cost and user-friendly sensors, fluorimetric techniques have emerged as a promising solution thanks to their high sensitivity and selectivity, short response time, very low limit of detection (LOD) and the ability to work both in solution and in solid phase. In this study, two derivatives of cyclic triimidazole and pyrene, namely the blue emitting 3-(pyren-1-yl)triimidazo[1,2-*a*:1′,2′-*c*:1″,2″-*e*] [1,3,5]triazine, TTPyr, and the yellow-orange emitting 11-(pyren-1-yl)triimidazo[1,2-*a*:1′,2′-*c*:1″,2″-*e*][1,3,5]triazine-3,7-dicarbaldehyde, $(CHO)_2$TTPyr, are exploited through fluorescence-quenching titrations experiments with various nitroaromatic energetic hazardous materials and proposed as sensor species for the quantitative detection of explosives. The performances of the two sensors in the fluorimetric detection of the explosives are reported in Tab. 1. $(CHO)_2$TTPyr shows markedly higher sensitivity for nitroaromatic derivatives compared to aliphatic ones, with picric acid (PA) detection showing the most sensitive response, characterized by a Stern-Volmer quenching constant value of 1.25×10^4 M^{-1} and a calculated detection limit of 0.63 ppm. Such selectivity can be associated with the specific formation of dark complexes through π– π interaction between the analytes and the fluorophore, and a static mechanism is recognized as responsible for the observed quenching [2].

Table 1: Detection of nitroaromatic and nitroaliphatic analytes by TT fluorophores (K_{SV}: Stern-Volmer constant).



TT-Pyr

Analyte	K_{SV} (M^{-1})	LOD (ppm)
2NT	1,71E+03	2,49
3NT	1,70E+03	3,00
4NT	9,75E+02	3,90
DNT	1,31E+03	3,36
TNT	2,50E+03	2,39
PA	1,46E+04	0,65
RDX	2,30E+02	25,13
PETN	1,74E+02	36,26
Dynamite	2,00E+02	28,72
NH_4NO_3	1,89E+02	9,59



TT-Pyr-$(CHO)_2$

Analyte	K_{sv} (M^{-1})	LOD (ppm)
2NT	1,74E+03	2,51
3NT	1,99E+03	1,83
4NT	7,38E+02	26,16
DNT	1,06E+03	5,79
TNT	1,76E+03	4,52
PA	1,25E+04	0,63
PETN	-1,15E+01	/
RDX	1,66E+02	36,50
NH_4NO_3	1,54E+02	11,73
Dynamite	1,96E+02	29,70

References:

[1] X. Sun, et al., Chem Soc Rev 2015, 44, 8019 – 8061.
[2] M. Formenti, et al., Dyes and Pigments 2022, 206, 110637 – 110654.

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IND-PO-021

Electrochemical and photocatalytic treatments: an innovative coupled strategy for simultaneous hydrogen production and wastewater remediation

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Nowadays, the transition toward carbon-neutral energy production is imperative to mitigate climate change, ensuring a stable energy supply for the future generation[1]. Hydrogen (H_2) is a promising energy storage medium, whose market is expected to increase exponentially due to its use as an energy vector in the transportation sector. Nevertheless, just 4% its production comes from electrochemical water splitting. In this context, the high potential required for the Oxygen Evolution Reaction (OER) constrains H_2 evolution. Additionally, the use of noble metal-based electrodes complicates the practical application due to high costs and limited availability. In this frame, researchers are moving toward the development of noble metal-free electrodes mainly based on earth-abundant compounds.[2] Regarding the anodic reaction, organic pollutants in wastewaters containing high level of chemical energy are excellent electrons donors and suitable candidates for producing H_2 thanks to lower oxidation potential respect the one required for OER. For this reason, the electrochemical treatment of wastewater can represent a viable solution for hydrogen generation and simultaneous wastewater treatment, even if alone it is not sufficient. So, its coupling with other approaches can represent an interesting and efficient solution. Herein, we propose an innovative coupled process involving electrochemical treatment followed by heterogeneous photocatalysis for H_2 generation using noble-metal free cathode and the simultaneous wastewater treatment. In general, electrochemical treatment alone resulted insufficient for wastewater complete mineralization. So, the photocatalytic step using bismuth oxychloride was exploited.[2] This hybrid approach offers a novel and sustainable solution for energy generation and water purification in the face of increasing global industrialization and water scarcity.

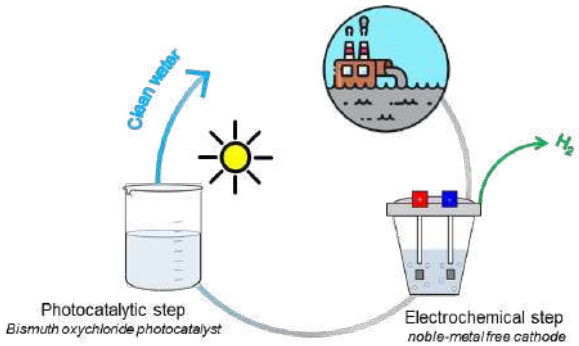

Figure 1: Proposed coupled process.

References:

[1] Bernasconi,R., Khalil,M.I., Cakmakci,D.S., Bektas,Y., Nobili,L., Magagnin,L., J. Mater. Sci., 2022, 57, 9370–9388.
[2] Falletta, E., Bernasconi, R., Fabbrizio, V., Marcolini, E., Giordana, A., Iliev, I. B., Magagnin, L., Bianchi, C.L., J. Env. Chem. Eng., Submitted

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IND-PO-022

VisioNing: valorization of agro-industrial wastewater. From research bench to business.

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The escalating pollution caused by agro-industrial wastewater is an alarming environmental threat. Apart from the obvious water wastage, valuable nutrients within are also lost[1]. Wastewater treatment sector and that of fertilizers' production account for over 3% and 1.2% of world's energy[2]. Moreover, fertilizer costs are continually growing as they are related to the energy cost and population growth. This represents a significant economic damage for companies in the sector. The agro-industrial wastewater treatment market is witnessing a surge in interest towards efficient and sustainable technologies. In fact, technological innovation and the embrace of eco-friendly solutions are driving industry transformation.
In this context, the mission of VisioNing is simple but ambitious: transforming wastewater from a problem to a resource with 100% of circularity and sustainability. VisioNing was conceived after a meticulous examination of the challenges in wastewater treatment. Combining bioelectrochemical and photocatalytic technologies powered by solar energy, our process not only purifies water, but recovers and reuses the nutrients it contains. While numerous wastewater treatment solutions exist, our combined technology offers dual benefits: energy efficiency and recyclability. This empowers us to position ourselves as frontrunners in sustainability and innovation, ensuring a 30% reduction in operational costs compared to traditional systems. Having conducted in-depth research and developed prototypes at the University of Milan, we have now refined an operational and highly-efficient model. A pilot test was conducted with several companies in Lombardy, financed by the "Farming Future" investment fund of CDP Venture Capital SGR and ToSeed & Partners, confirming the preliminary results in terms of nutrients recovery and water purification.

Figure: VisioNing pilot plant.

References:

[1] J. R. Jones, J. A. Downing, Agriculture. Encyclopedia of Inland Waters 2009, Volume, 225 – 223.
[2] https://www.caprari.com/wp-content/uploads/2023/07/Trattamento_acque-reflue.pdf.

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IND-PO-023

Probing the Drug Delivery behaviour of β-Cyclodextrin Nanosponges via classical Molecular Dynamics simulations

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Cyclodextrins (CDs) are cyclic oligosaccharides constituted by α-D-glucopyranose monomeric units connected by α-(1-4) glycosidic bonds, characterized by a truncated hollow cone shape[1]. Thanks to the marked tendency to form inclusion complexes with a large variety of substrates (e.g., pharmacologically active molecules, vitamins, etc.), CDs have been applied as Drug Delivery Systems (DDSs), both alone or in the cross-linked form of nanosponges[2]. These porous materials are obtained through a condensation reaction of a glycosidic monomer and a cross-linking agent and offer several advantages as DDSs with respect to β-cyclodextrin alone. To shed light on the complexation mechanism, computational investigation are increasingly essential, towards a full atomistic representation of nanosponge[3].

The present work relies on previous benchmark Density Functional Theory calculations on monomeric β-CD[4] and inclusion complexes with melatonin (MT) as a guest[5], and then proceeds with classic molecular dynamic simulations both on the inclusion complex with melatonin and on the novel nanosponge model obtained by cross-linking β-CD and citric acid.

These MD simulations carry information on the dynamics of the binding process occurring in both the single host-guest complex and the nanosponge, so as to provide an accurate theoretical model for Drug Delivery applications. Results have shown the presence of D-glucopyranose in two main conformations confirming the high flexibility of β-CD, which disappears both with the complexation and reticulation. Melatonin binding to β-CD is dynamic and not very strong, indeed the guest in some cases escapes from its host but remained enclosed inside the secondary cavities grid.

References:

[1] P. Jansook, N. Ogawa, T. Loftsson, Int. J. Pharm. 2018, 535, 1–2.
[2] F. Trotta, M. Zanetti, R. Cavalli, Belistein J. Org. Chem. 2012, 2091, 8, 2091–2099.
[3] W. Wang, Z. Ye, H. Gao, D. Ouyang, J. Control. Release 2021, 338, 119-136.
[4] S. Pantaleone, C. I. Gho, R. Ferrero, V. Brunella, M. Corno, Int. J. Mol. Sci. 2023, 24(23), 16826.
[5] R. Ferrero, S. Pantaleone, M. Delle Piane, F. Caldera, M. Corno, F. Trotta, V. Brunella, Molecules 2021, 26(19), 5881.

IND-PO-024

Low-carbon hydrogen generation via intensified and electrified biogas reforming

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Hydrogen production from biogas is an interesting option for upgrading the biogas plants that today are incentivized for producing electricity. Hydrogen production can be performed in tubular packed-bed reactors by the well-established steam methane reforming (SMR) process, whose heat demand is satisfied by burners. However, at the small scale of biogas plants, the conventional convective heat transfer is severely limited; we thus propose an innovative reactor layout[1], where the heat transfer is enhanced by a conductive copper structure packed with catalytic pellets, and the endothermic reaction enthalpy can be supplied from renewable electricity, which heats a resistive wire placed inside the reactor by the Joule effect. The removal of the combustion heating cuts 40% of the emissions associated with the conventional methane steam reforming. In addition, i) if biogenic CO_2 is captured downstream of the reactor, the process has negative emissions; ii) with the present electrified technology, the energy required for hydrogen production is only 15 kWh/kg_{H2} compared to 40-55 kWh/kg_{H2} for electrolysers. We will report experimental and modelling results obtained in a single-wire lab-scale prototype eSMR which promise high performance in compact reactors, thanks to excellent heat management. Validated mathematical models successfully predict the temperature (see Figure 1) and composition profiles within the reactor and can be used for the design of a scaled-up unit with multiple wires.

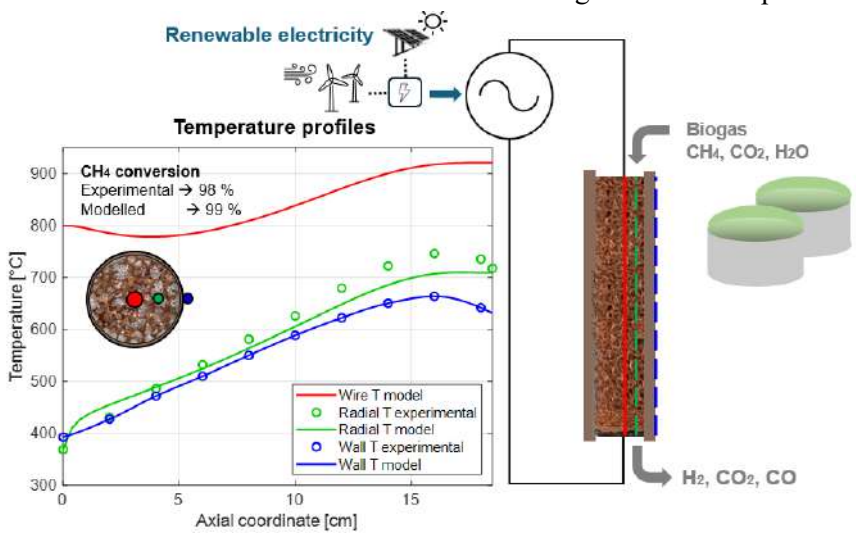

Figure 1: eSMR schematics with experimental and simulated temperature profiles.

References

[1] M. Ambrosetti, A. Beretta, G. Groppi, M.C. Romano, E. Tronconi, 2023, WO/2023/062591.

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IND-PO-025

CO_2 photoreduction under solar light with doped perovskites

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Carbon dioxide is an abundant greenhouse gas accounting for 79% of global warming. Different strategies aiming at achieving its conversion into high value-added products like fuels and chemicals have been proposed to reduce its concentration[1].

Photocatalysis, intended in this case as CO_2 photoreduction in presence of water vapor, is an alternative catalytic approach, which exploits solar energy as an abundant, unlimited, renewable energy source to enable carbon dioxide conversion into different solar fuels[2], without requiring additional energy input to make the reaction take place. Perovskites such as barium titanate ($BaTiO_3$) and calcium titanate ($CaTiO_3$) are promising photocatalytic materials which show good photostability, corrosion resistance in aqueous solutions and band gap necessary to obtain all the products of carbon dioxide reduction. However, they absorb UV radiation, which constitutes only 4% of the solar spectrum.

The goal of this study aimed at designing efficient photocatalytic materials to enable CO_2 photoreduction under solar light. $BaTiO_3$ and $CaTiO_3$ perovskites were prepared via hydrothermal synthesis and doped with non-metal dopants.

The materials were characterized through FT-IR, DRS, SEM-EDX, TEM, N_2 physisorption, and XRD techniques and then tested in the CO_2 photoreduction in a gas phase batch reactor.

Bare barium and calcium titanates were not active under solar irradiation, however doped perovskites showed good photoactivity under the same conditions. Compared to the bare perovskites, doping the materials with heteroatoms, likely led to a narrowing of the band gap, demonstrating their activity in the visible region of the spectra. N-doped $CaTiO_3$ showed the best photocatalytic activity reaching a TON equal to 1,8 $\mu mol/g_{cat}$ relative to methane production.

References:

[1] L. Al-Ghussain, Environ. Prog. Sustain. Energy. 2019, 38, 13-21
[2] L. Sun, Y. Wang, N. Guan, L. Li, Energy Technol. 2020, 8, 1900826

IND-PO-026

Exploring natural phenols for the synthesis of bioactive polymers

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The design of polymers from renewable sources or wastes is one of the most intense field of research in the drive towards a fully sustainable and circular bioeconomy. Substances like phenols, terpenes, vegetable oils, are eligible raw materials for the manufacture of a variety of polymeric materials, including elastomers, plastics, hydrogels, and composites.[1] Herein we present the use of bioactive natural phenols, tyrosol (Ty) and eugenol (EU), as building blocks for the obtainment of bioactive polymers. Ty is an abundant phenol in olive oil mill wastewater while EU is a phenolic monoterpenoid obtained mainly from clove oil and lignin. Both compounds were functionalized with acrylic moieities to obtain polymerizable monomers. In the case of EU, the allyl group was submitted to epoxidation and then reacted with 2-hydroxyethyl methacrylate (HEMA) to obtain EUMA monomer (Figure 1).[2]

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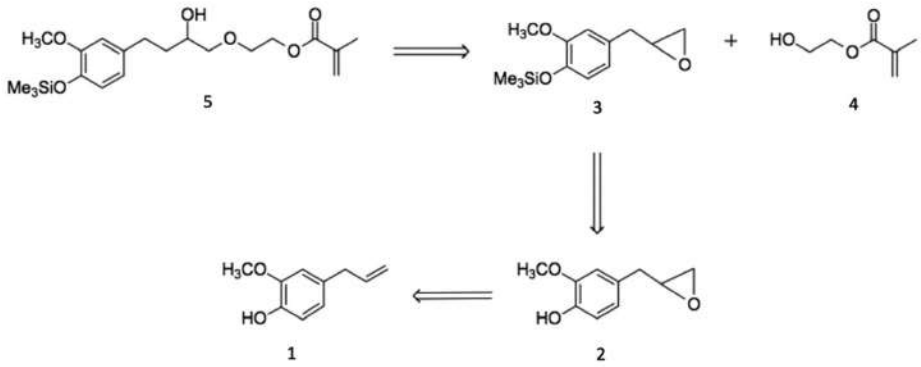

Figure 1: Retrosynthetic pathway for the synthesis of an eugenol-methacrylate monomer

The synthesized copolymers showed significant elastomeric properties and swellability degrees related to the phenol group content. A relationship between polymer composition, structure and biological activity was found. Currently, the synthesised phenol-based acrylic monomers are being tested in additive manufacturing processes to obtain insoluble manufacts with desired geometry and biological features.

References:

[1] R. M. Cywar, N. A. Rorrer, C. B. Hoyt, G. T. Beckham, E. Y-X. Chen, Nat. Rev. Mater. 2022, 7, 83–103.
[2] M. Di Consiglio, E. Sturabotti, B. Brugnoli, A. Piozzi, L. M. Migneco, I. Francolini, Polym. Chem. 2023, 14, 432-442.

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IND-PO-027

Thermochemical Conversion of Biomass for Sustainable Energy and Materials

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The pressing environmental concerns related to fossil fuel consumption and the growing global demand for energy, chemicals and materials greatly encourage the development of technologies to replace oil with renewable carbon sources[1]. In this context, lignocellulosic biomass (i.e., plant-derived feedstock, particularly from non-edible sources) stands out as a promising alternative carbon source due to its high availability and versatility. The conversion of waste biomass not competing with the food industry, in compliance with the RED II Directive, offers an efficient strategy to produce biofuels for the transport sector while also playing a crucial role in generating secondary raw materials, thereby providing a viable alternative to the fossil-based economy. This work focuses on different thermochemical conversion methods (pyrolysis[2], HTL[3] and HTC) in order to evaluate the most suitable strategy to obtain high value-added products and mainly bio-fuels form residual biomass. The use of different processes and reactors (microwave oven and stainless-steel autoclave), as well as the choice of appropriate reaction conditions in terms of temperature, time, and catalysts, promote the synthesis of the target fraction and affect its chemical-physical composition. Characterization of the products (solid, liquid and gas) was essential to assess the difference effects between the strategies and reaction conditions employed. Emphasis was placed on the chemical characterization of liquid fractions to assess the distribution of different classes of organic compounds, in particular aliphatic and aromatic hydrocarbons. Furthermore, the surface characterization of the solid fractions led to evaluate the most suitable conditions for the production of bio-materials. The study explores the possibility to produce biofuels and high value-added products from waste biomass in a circular economy perspective.

Acknowledgements.
Riccardo Gallorini, Luca Rosi and Anna Maria Papini wish to thank the Fondazione Cassa di Risparmio di Firenze for financial support (ENFORCE Project, Ricercatori a Firenze, 2021).

References:

[1] J. Jacquet, and D. Jamieson. Nature Clim Change, 2016, 6, 643–646.
[2] R. Gallorini, S. Aquilia, C. Bello, F. Ciardelli, M. Pinna, A.M. Papini, L. Rosi. J. Anal. Appl. Pyrolysis, 2023, 174, 106138.
[3] R. Gallorini, B. Ciuffi, F. Real Fernandez, C. Carozzini, E. Ravera, A.M. Papini, L. Rosi. ACS omega, 2022, 7, 37757-37763.

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IND-PO-028

Covalent Organic Frameworks: from non-processable powders to plastic materials through a polymer-supporting strategy

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In the last years, the world of microporous materials has seen a major development, given their outstanding chemical and physical features. Among them, Covalent Organic Frameworks (COFs) are flourishing. COFs can be defined as 2 or 3D networks based on covalent bonds and fully organic structures.[1] They are synthesized starting from monomers with multiple complementary functionalities that combine to form highly ordered and crystalline materials. On paper, almost infinite combinations of monomers can be targeted, leading to an incredible variety of different COF structures. As expected, their properties depend on their structure and, in turn, given the great amount of different available motifs, COFs are characterized by a wide array of different chemical and physical properties.[2] This versatility makes these materials widely applicable in many different fields that go from catalysis to electrochemical applications, through gas and energy storage, just to name a few. Despite the great interest in the field, a possible industrial applicability of COFs has been hindered by some drawbacks, amongst which an inherent lack of processability is one of the most significant. COFs are usually obtained as powders and it is almost impossible to process them in complex shapes with good control.[3] This work aims at solving this shortcoming through a polymer-supporting strategy. Different COFs have been synthesized and then exploited as active components in the synthesis of different polymers. This approach allowed the direct growth of polymeric chains on the COF backbone. These polymeric chains are expected to arrange between the COFs' layers, resulting in an improved processability, possibly close to the one of more classical thermoplastic materials. The covalent bond between the COFs and the polymeric chains has been assessed as well as the thermal and morphological properties of the resulting materials. Processability tests were also carried out, with the successful preparation of films through solvent casting.

References:

[1] F. Haase, B. Lotsch, *Chem. Soc. Rev.*, 2020, 49, 8469.
[2] H.R. Abuzeid, A.F.M. EL-Mahdy, S.W. Kuo, *Giant*, 2021, 6, 100054.
[3] D. Rodrìguez-San-Miguel, F. Zamora, *Chem. Soc. Rev.*, 2019, 48, 4375.

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IND-PO-029

Synthesis and Solid State NMR Characterisation of new Polyketone-based Anion Exchange Membranes

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The need of a green transition requires new ways to produce and store energy. Among different possibilities, green hydrogen produced from anion exchange membrane water electrolysers (AEM-WE) is one of the most appealing. However, AEMs need substantial improvements to reach longer life cycles and higher efficiencies. Because of this issue, different polymeric backbones and charged groups can be tried to tune properties up to a satisfying level.

In this abstract, we present our research concerning AEMs for water electrolysers based on a functionalised low molecular weight polyketone (PK). We report the functionalisation of PK through a Paal-Knorr reaction using a diamine that can then be quaternised with an alkyl iodide during the casting process to obtain an AEM[1] (Figure 1). Different diiodides, ranging from diiododecane to diiodobutane, have been used together with iodobutane in various ratios to explore thermal and mechanical properties of the resulting membranes.

Membranes have been characterised with common techniques coupled with Solid State NMR (SSNMR) spectroscopy and relaxometry. ^{1}H, ^{13}C and ^{2}H spectra and proton spin lattice relaxation times have been used to get information on possible phase segregation and to monitor the degree of cross-linking achieved in the membranes. Moreover, SSNMR techniques were applied to membranes hydrated with either normal or deuterated water to study water mobility and the formation of ionic channels.

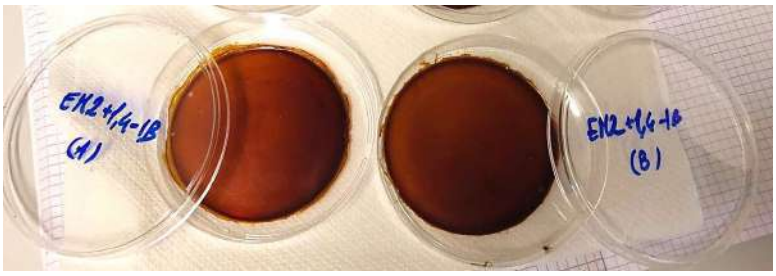

Figure 1: AEMs based on functionalised polyketone obtained through a one-step casting-quaternisation procedure.

References:

[1] O. Racchi, R. Baldassari, E. Araya-Hermosilla, V. Mattoli, P. Minei, A. Pozio, A. Pucci, *Polymers* **2023**, *15*, 2027.

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IND-PO-030

High-rate electrosynthesis of liquid chemicals from CO_2 and CO

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Electrochemical CO_2 and CO reduction reactions (CO_2RR and CORR) with renewable electricity enable the recycling of CO_2 waste into energy-rich chemicals conventionally produced from fossil resources.[1] Liquid hydrocarbons (e.g. formate, ethanol, acetate, and propanol) are widely employed commodity chemicals and can be produced via CO_2RR and CORR. Therefore, we sought to develop electrocatalysts with high selectivity (Faradaic Efficiency, FE) to formate,[2] acetate,[3] and ethanol operating at reaction rates (current densities) of industrial interest.[4]

Upgrade of CO to hydrocarbons favors high selectivity toward long hydrocarbon (C_{2+}) products. Additionally, the low solubility of CO in aqueous electrolytes results in increased energy efficiencies when CO_2RR-to-CO is followed by CORR-to-hydrocarbons.

In one of our recent works, to exploit the advantages of CORR, we developed a carbon reservoir catalyst (CRC architecture, Figure 1) where nitrogen-doped carbon nanoparticles increase CO availability close to Cu catalytic nanoparticles, enabling electrosynthesis of ethanol with high selectivity, energy efficiency, and disfavouring hydrogen evolution from water-based electrolytes. With this CRC catalyst, we achieve ethanol FE and CE of 50% and 93% (CE*Faradaic efficiency [FE] = 47%) at 200 mA cm^{-2}.

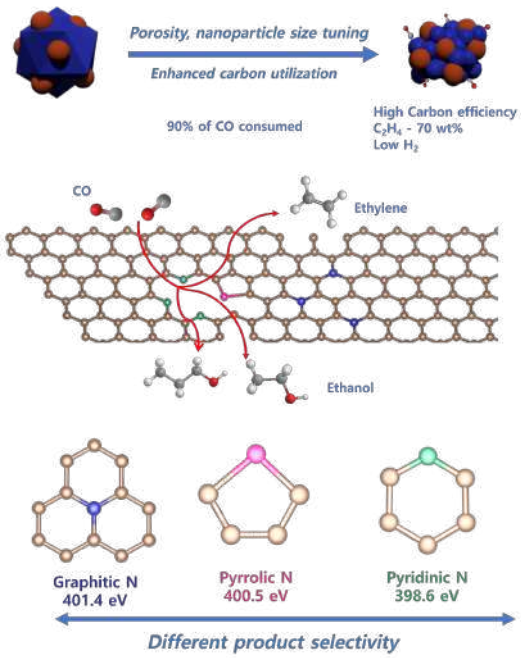

Figure 1: the CRC electrocatalyst architecture from the nano to the atomic scale.

References:
[1] D. T. Whipple et. Al., JPCL 24 (2010) 3451
[2] I. Grigioni et al., ACS Energy Lett. 6 (2021) 79
[3] R. Dorakhan et al., Nature Synt. 3 (2023) 1307
[4] S. Park et al., Joule 10 (2023) 2335

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IND-PO-031

Up-cycling of waste Sulfur by inverse vulcanization: novel materials for advanced photonics

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The recently emerged Inverse Vulcanization (IV) process enables the up-cycling of elemental Sulfur, the main by-product of oil and gas refining, and leads to a new class of amorphous polymers consisting of polysulfide chains cross-linked by organic divinyl moieties.[1] Due to their peculiar nature, inverse vulcanized polymers (IVPs) exhibit unique functional properties, such as dynamic covalent behaviour and self-healing capability. IVPs also boast very high refractive index and excellent transparency in the near infrared region, which make them appealing building blocks for functional photonic structures.[2] All-polymer photonic crystals are indeed technologically interesting for materials affordability, fabrication simplicity and scalability. However, their application in the field of light confinement is still limited by low and similar refractive indices typical of most processable polymers in their transparency range.

Here, novel IVPs with a very high refractive index were synthetized using specifically designed vinyl aromatic derivatives as cross-linking monomers, which were obtained from the corresponding bromide substrates by a single step Suzuky-Miyaura cross-coupling reaction. Comonomers type and amount were varied to enhance both the optical behaviour and filmability. The achieved IVPs were then successfully used to fabricate all-polymer distributed Bragg reflectors (DBRs), see Fig. 1.

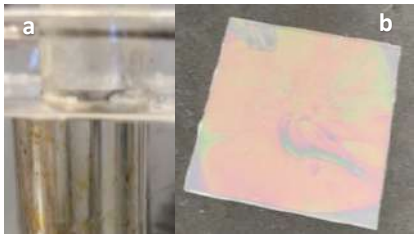

Figure 1: a) Reaction vessel during the IV process; b) a DBR fabricated with a synthesized IVP.

Acknowledgement:
Project PRIN 2020 "PETALS Polymer mETamateriALs for nanophotonicS" (prot. 2020TS9LXS) funded by Italian Ministry for Universities and Research (MUR).

References:
[1] W. J. Chung, J. J. Griebel, E. T. Kim, et al., Nat. Chem. 2013, 5, 518 – 524.
[2] C. Tavella, G. Luciano, P. Lova, M. Patrini, C. D'Arrigo, D. Comoretto, P. Stagnaro, RSC Adv. 2022, 12, 8924 – 8935 and references therein.

IND-PO-032

Synthesis of a new heterogenous photocatalyst for the valorizaztion of biomass residues by photoreforming

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The generation of spent lithium-ion batteries (s-LIBs) worldwide amounts to millions of tons annually. While current recycling methods focus on extracting valuable metals like Ni, Co, and Li, they suffer from poor selectivity, high energy requirements, and expensive by-product management. Consequently, there's growing interest in exploring alternative methods for the direct reuse of s-LIBs [1]. At the same time, lignocellulosic and agro-industrial waste and residues represent a central feedstock for modern biorefineries aimed to the sustainable production of renewable energy and biobased materials and chemicals [2]. Technologies such as hydrothermal carbonization (HTC) have been proposed to upgrade orange peel waste (OPW), yielding hydrochar (OPW-HC) and liquid bio-oil (OPW-OIL), rich in furans derivatives like furfural and 5-HMF, pivotal in modern biorefineries [3]. OPW-OIL can be very rich in furans derivatives (furfural and 5-HMF) that represent one of the most important classes of intermediates in modern biorefineries.

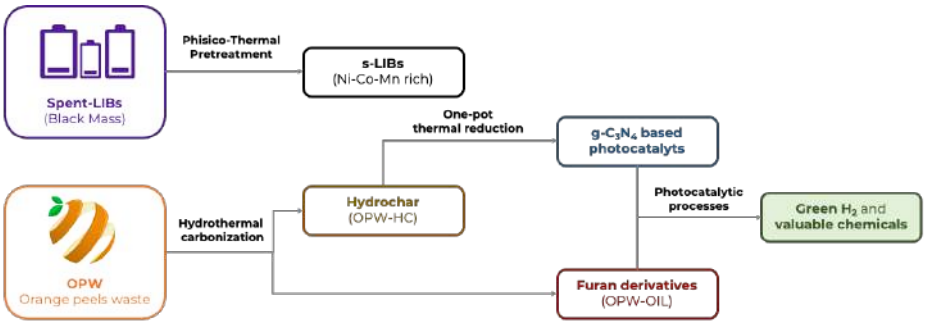

Figure 1: Development of low-cost and robust heterogeneous photocatalyst.

Starting from these two abundant wastes, we propose a simple direct approach to transform s-LIBs into a lithium (Li)-Co-Ni-Mn doped graphitic carbon nitride composites through one-pot in situ thermal process by using hydrochar as co-catalysts to improve the photocatalytic activity in H_2 production and value-added chemicals.

References:

[1] E. Paone, M. Miceli, *et al.*, ACS Sustain. Chem. Eng. 2022, 10 (7), 2275-2281.
[2] C. Xu, E. Paone, *et al.,* Chem. Soc. Rev. 2020,49, 4273-4306.
[2] A. Satira, E. Paone, *et al.,* Applied Sciences 2021, 11 (22), 10983.

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IND-PO-033

Innovative Photoelectrocatalytic filter for Recirculating Aquaculture Systems

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Ammonia poses a threat to biodiversity in aquatic environments, having toxic effects on fish living in freshwater and seawater.[1] In this work, we have designed a photoelectrochemical reactor and tested in a recirculating aquaculture system (RAS, Fig.1a). This technology exploits the UV-electrochlorine advanced oxidation process to improve water quality and fish welfare, performance and sustainability. The photoanode is prepared by anodization of a metal titanium mesh in a ethylene glycol, water and hydrofluoric acid electrolyte solution at 30 V for 6 h in order to obtain a self assembled titania nanotube arrays film (Fig.1b). The illuminated semiconductor film promotes the oxidation of chloride ions naturally present in fresh- (or sea-) water, to chlorine radical which is highly reactive and selective in ammonia oxidation yielding N_2 or nitrate. [2] Preliminary ammonia degradation tests were performed in 5·mM KCl cotaining 100 ppm NH_3 solutions at 4 V potential bias. A stable photocurrent up to 550 mA under UV- irradiation was obtained during the test (Fig.1c).[3] An almost full ammonia conversion was reached after 6 h-long test with a selectivity towards N_2 and NO_3^- of 80% and 20%, respectively. The setup has been shown to be biocompatible in a real rainbow trout farming plant[4] showing a lower nitrate accumulation in water with respect to a traditional bio-filter.

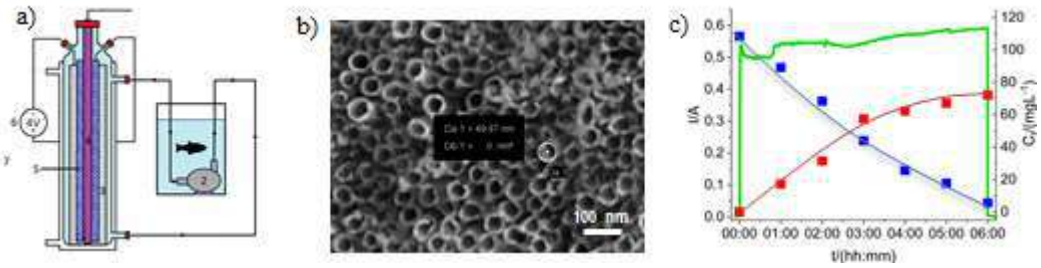

Figure 1: a) Titania Nanotubular film; b) Schematic of the PEC reactor and experimental setup; c) Ammonia degradation and photocurrent performance: Current (green), NH_4^+ concentration (blue), NO_3^- concentration (red)

Acknowledgements

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References:

[1] R. Crab, et Al., Aquaculture 2007, 270, 1–14
[2] S. Livolsi et al. Catal. Today 2023, 113996, 413-415
[3] G. L. Chiarello et al., ACS Catal 2016, 6, 1345–1353
[4] E. Buoio, el al. Sustainability, 2022, 14, 9067

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IND-PO-034

Lead-free piezoelectric polymer-ceramics composites for sustainable energy harvesting

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Energetically autonomous systems based on lead-free smart materials and energy harvesting devices that reduce consumption of fossil energy resources (no need for battery replacement or recharging) while significantly lowering overall materials and processing costs, operation times and hazardous waste production fully meet the increasingly pressing global environmental challenges. In this framework, polymer-matrix composites embedding ceramic fillers with different functionalities are attracting a great deal of interest for a range of applications, including high-storage-efficiency capacitors, flexible piezoelectric harvesters and portable devices, also exploitable for self-powered electronics, such as wearable or implantable medical devices, safety-monitoring IoT systems, consumable electronics. Polymer-ceramics composites indeed combine typical properties of polymers, as easy processing at low temperature, flexibility and high breakdown strength (BDS), with the dielectric and piezoelectric properties of ceramics, typically ferroelectric perovskites, such as $BaTiO_3$ (BT) and $Ba_{1-y}Ca_yZr_xTi_{1-x}O_3$ (BCTZ). Among polymer matrices, poly(vinylidene difluoride) (PVDF) is largely investigated because it exhibit relatively high dielectric constant, low dielectric losses, ferroelectric character and remarkable BDS, besides being non-toxic and biocompatible.

Here, based on previously achieved results,[1,2] PVDF-BT composite films at 30 vol% of ceramic particles were prepared exploiting and comparing different preparation techniques: namely, solvent casting, melt blending and microwaves heating all followed by a compression moulding step, or directly by hot pressing.

A multi-level characterization of the prepared composites was performed to investigate morphology, mechanical performance and functional properties, thus gaining an insight into the comprehension of process-structure-properties relationships required for the optimization of the envisaged final harvesters based on these flexible piezoelectric composite films.

Acknowledgements:
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References:
[1] L. Padurariu, E. Brunengo et al. ACS Appl. Mater. Interfaces 2023, 15, 13535.
[2] F. Craciun, F. Cordero et al, Composites Part B 2023, 263, 110835.

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IND-PO-035

Two-photon polymerization of reactive mesogens for micrometric smart devices

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The use of light in polymer science opens up to multiple opportunities. Among them, exploiting photopolymerization processes, specifically designed materials can be printed allowing for 3D structure preparation at different scales. In this communication, the use of Direct Laser Writing, a technique based on two-photon polymerization, will be presented to realize 3D micrometric objects by shape-changing Liquid Crystalline Networks (LCNs). Such materials are crosslinked polymers prepared by a mixture of reactive mesogens (Figure 1a) able to convert energy from external stimuli (as light) into mechanical motion. Their chemical composition can be tailored to achieve different mechanical properties and to modulate force production during actuation. With this materials, we demonstrated different synthetic micrometric robots entirely powered by light and able to reproduce diverse animal behaviour. Developed microrobots are able to perform humanoid tasks, as walking and swimming, but also to grab and manipulate objects.[1]

In the last year, we have also demonstrated more complex smart microdevices useful for photonic or information encryption systems. In both cases, material shape, birefringence (Figure 1B) and their variation under stimuli have been carefully engineered to demonstrate 3D photonic crystals able to work as tuneable filters for telecommunication wavelenght[2] or an array of responsive pixels able to show or hidden basic information.[3] These examples demonstrate how to introduce enhanced functionalities in smart microsystems spanning from storage devices with physical encryption to complex motion actuators.

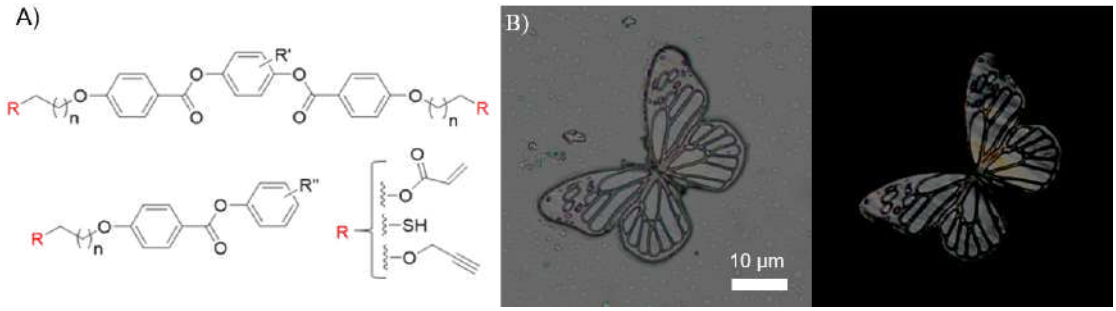

Figure 1: Examples of reactive mesogens (A) and a 3D printed butterfly observed without or with polarized light (B).

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 952166 (REPAIR) and from MUR (PRIN 2022 WATERONIC).

References:

[1] S. Nocentini, et al. Adv. Optical Mater. 2018, 6, 1800207.
[2] I. De Bellis, et al. Adv. Funct. Mater. 2023, 2213162.
[3] S. Donato, et al. Small 2023, 2306802.

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IND-PO-036

Continuos Flow Production of γ-Valerolactone from methyl-levulinate promoted by MOF-derived Al_2O_3-ZrO_2/C catalysts

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The growing demand for sustainable energy, fuels, materials, and chemicals production has led to the exploration of alternative biobased feedstocks that can be processed by modern biorefineries. Among these, levulinic acid and alkyl levulinates obtained from lignocellulosic biomass are particularly interesting, as they can be used to synthesize various value-added chemicals, including γ-valerolactone (GVL). GVL is a fully degradable, non-toxic green solvent, a precursor for valuable chemicals, and a potential fuel additive [1-3].

Currently, most published studies on the hydrogenation of levulinic acid and its esters utilize ZrO2-based catalysts under batch conditions with pressurized molecular hydrogen. However, these catalytic processes often lack selectivity and are challenging to scale up. In contrast, catalytic transfer hydrogenation (CTH) offers a more suitable and sustainable alternative to traditional hydrogenation methods, as it utilizes organic molecules like alcohols that act as hydrogen donors toward the carbonyl group in the presence of a catalyst containing both acid and base Lewis sites. In this study, the catalytic conversion of methyl levulinate (ML) into γ-valerolactone (GVL) through catalytic transfer hydrogenation (CTH) [4] using 2-propanol as the hydrogen donor/solvent is presented under both batch and continuous flow conditions. A series of Al_2O_3-ZrO_2/C catalysts with varying Al/Zr ratios were synthesized using Metal-Organic-Frameworks (MOFs) as sacrificial templates. The reactions conducted under continuous flow conditions were significantly more efficient compared to those carried out under batch conditions, yielding excellent GVL yields. Furthermore, the activity results showed that the addition of Al2O3 improved the catalytic performance in terms of both ML conversion and selectivity towards γ-valerolactone (GVL) by increasing the content of both Lewis acid and base sites.

The achieved results represent significant progress in the selective production of GVL from methyl levulinate, as it combines the preparation of highly active non-noble metal catalysts with the use of a more sustainable catalytic process under continuous flow conditions.

References:

[1] T. Tabanelli, E. Paone, P. Blair Vásquez, R. Pietropaolo, F. Cavani, F. Mauriello, 2019, ACS Sustainable Chem. Eng., 7(11), 9937–9947.
[2] L. Negahdar, M. G. Al-Shaal, F. J. Holzhäuser, R. Palkovits, 2017, Chem. Eng. Sci., 158, 545−551.
[3] B. Cai, X.-C. Zhou, Y.-C. Miao, J.-Y. Luo, H. Pan, Y.-B Huang, 2017, ACS Sustainable Chem. Eng., 5, 1322−1331.
[4] M. Ronda-Leal, S. M. Osman, H. W. Jang, M. Shokouhimehr, A. Romero, R. Luque, 2023, Fuel, 333, 126221

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IND-PO-037

Immobilizing lytic polysaccharide monooxygenases on carbon nanotubes to increase stability and prevent oxidative damage

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Thanks to their excellent functional properties, enzymes can catalyse several complex chemical processes under mild conditions and are potentially excellent catalysts for a more sustainable chemical industry. However, low stability and tendency to be inhibited by substrates, products or solvents, limit their application for nonbiological purposes. A promising and successful strategy to improve enzyme stability in industrial settings is the enzyme immobilization onto a suitable carrier, following simple and cost-effective protocols.

Lytic polysaccharide monooxygenases (LPMOs) are mononuclear copper-containing enzymes found in the majority of cellulolytic fungi and actinomycete bacteria that are able to oxidize C–H bonds of the glycoside linkages in polysaccharides[1–3]. However, LPMOs are prone to oxidative damage, particularly in the absence of an adequate substrate[2]. The aim of this contribution is to develop a possible bio-catalyst for C-H activation reactions, based on bioconjugation of LPMOs to Carbon Nanotubes (CNTs), in order to stabilize the biological partner without jeopardizing its catalytic ability. CNTs have been selected since they are conductive, thus allowing the electron transfer processes fundamental to optimize the LPMO activity. Two LPMOs, *Ls*AA9A and *Sc*AA10C, containing lysine residues close to the substrate binding surface, were selected encouraging immobilisation in the desired orientation. Moreover, to increase the chances of successful immobilisation, these enzymes were engineered, introducing two lysine residues on two different loops on the LPMO surface.

Using a two-step carbodiimide activation/immobilization reaction, enzymes were immobilised on multi-walled COOH-CNTs. After the reaction, the oxidase[4] and peroxidase[5] activities of the LPMO bioconjugates was assessed, demonstrating a successful immobilization just for the engineered enzymes. The results on oxidative damage showed that the inactivation of both free LPMOs is already evident after only 10 minutes with less than 20% residual activity, while the bioconjugates retained around 70% residual activity under the same conditions, indicating that the CNT is successful in protecting the LPMO against oxidative damage.

The stability of the enzymes was finally assessed by using circular dichroism, incubating the bioconjugates at different temperatures and in presence of different organic solvents.

References:

[1] Forsberg, Z. et al. Proc. Natl. Acad. Sci. U. S. A., 2014, **111**, 8446–8451.
[2] Bissaro, B. et al.. Nat. Chem. Biol. 2017, **13**, 1123–1128.
[3] Vaaje-Kolstad, G. et al. Science 2010, **330**, 219–222.
[4] Kittl, R., Kracher, D., Burgstaller, D., Haltrich, D. & Ludwig, R. Biotechnol. Biofuels 2012, **5**.
[5] Breslmayr, E. et al. Biotechnol. Biofuels 2018, **11**, 1–13.

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IND-PO-038

Two birds with one stone: green NH_3 production from stationary NO_x emissions

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Green ammonia is expected to play a crucial role in the energy transition as it serves as a sustainable base chemical and a versatile energy carrier. With its potential to store and transport hydrogen, it will facilitate the integration of renewable energy sources into various sectors, thus accelerating the shift towards a cleaner and more resilient energy infrastructure[1]. Nowadays, NH_3 production is energy intensive, as the energy required to sever the N-N bond is significant. NO_x is a waste toxic compound present in combustion flue gases, which is nowadays abated using NH_3 as a reactant according to the well-established SCR process to comply with environmental regulations. In this scenario, the production of green ammonia using NO_x as N source is very appealing[2], as it could turn emission abatement from a cost to a potential resource, allowing for a decentralized production of green NH_3.

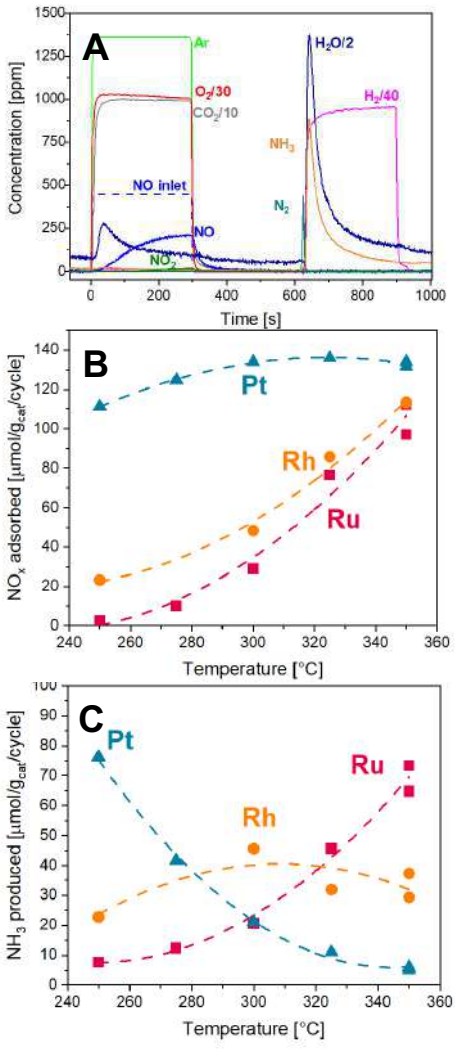

Figure 1: A: cycle at 250 °C with 1% CO_2, 3% O_2 and 500 ppm NO (adsorption) and 4% H_2 during (reduction) on Pt-DFM; **B:** Stored NOx as a function of T; **C:** NH_3 productivity as a function of T

A possible way to abate NO_x while producing NH_3 is to use Lean NO_x Traps (LNTs) materials for NO_x abatement from mobile sources. These catalysts rely on a cyclic process: they can adsorb NO_x when exposed to flue gases; once the trap is saturated the atmosphere is switched to reducing conditions to convert NO_x to N_2 while regenerating the trap. By twisting the formulation and process conditions of LNTs it should be possible to steer the selectivity of the process towards NH_3 rather than N_2.

We have effectively demonstrated this using three home-made catalysts based on 1% Pt, 0.5% Ru or 0.5% Rh, each supported on Al_2O_3 and promoted with Ba. By working at 250°C on a Pt-based catalyst, we managed to obtain a significant NO_x adsorption and a complete regeneration of the adsorbent when exposed to H_2 (Fig. 1A), with a selectivity to NH_3 in excess of 75%, yielding a production of 80 µmol/g/cycle of NH_3. At higher temperatures the amount of adsorbed NO_x increases slightly (Fig 1B), but the NH_3 selectivity drops due to the faster kinetics of N_2 formation causing an overall decrease in NH_3 production (Fig 1C). Ru and Rh show 100% NH_3 selectivity below 300°C, but are unable to store significant amount of NO_x at these temperatures. Operando FT-IR tests are currently ongoing to disclose mechanistic aspects of the reaction.

References

1. Macfarlane et al., *Joule* 4 (6), 2020, 1186-1205
2. Kobayashi et al., *Catal Sci Technol* 13, 2023, 297-300

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IND-PO-039

Blending or bonding? Benzothioxanthene derivatives as emitters in Luminescent Solar Concentrators based on poly(methyl methacrylate) from recycled sources

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Many conjugated planar fluorophore structures utilized for the preparation of poly(methyl methacrylate) (PMMA) Luminescent Solar Concentrators (LSC) face concentration quenching due to the presence of free dye molecules that phase separate from the host polymer matrix, even at relatively low concentrations.[1] One potential strategy to mitigate this effect without diminishing the fluorophore quantity is the covalent integration dye into the polymer chain through co-polymerization with a monomeric unit functionalized with the fluorophore molecule. Benzothioxanthene (BTX) imides have shown promising emitting properties in solution[2] and comparable to commonly used perylene diimides (PDIs). Also, considering the mono-substitution, they are the best candidate since they prevent cross-linking during the polymerization process. Notably, two BTX derivatives were synthesized as fluorophores: i) BTX-EH, which was dispersed within the PMMA matrix; ii) BTX-MA, containing a methacrylic group suitable for co-polymerization with MMA. All devices were based on PMMA manufactured through free-radical polymerization of chemically recycled methyl methacrylate (r-MMA), which exhibits similar properties to virgin methyl methacrylate, but with a lower environmental impact. LSCs with varying fluorophore concentrations (100, 200, 300 ppm) were characterized by determining internal (η_{int}) and external (η_{ext}) photon efficiencies, as well as the fluorophore quantum yield (QY),[3] and the properties compared to define the best (blending or bonding) formulation strategy.

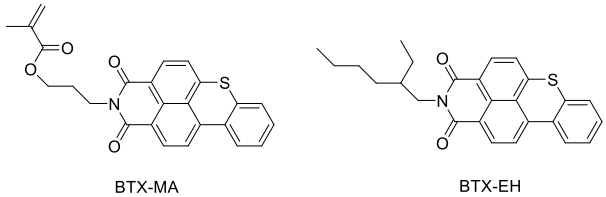

Figure 1: BTX imidic derivatives structure.

References:

[1] Micheletti, C.; Wang, Q.; Ventura, F.; Turelli, M.; Ciofini, I.; Adamo, C.; Pucci, A., Aggregate, 2022, 3, e188.
[2] Galán, L. A.; Andrés Castán, J. M.; Dalinot, C.; Marqués, P. S.; Blanchard, P.; Maury, O.; Cabanetos, C.; Le Bahers, T.; Monnereau, C., Physical Chemistry Chemical Physic, 2020, 22, 12373-12381.
[3] Debije, M. G.; Evans, R. C.; Griffini, G., Energy & Environmental Science, 2021, 14, 293-301.

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IND-PO-040

Kinetic investigation of Ammonia Decomposition over Ru-based Catalysts for Hydrogen Production

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Hydrogen (H_2) is considered as one of the most prospective energy carriers for the future energy systems[1]. Ammonia (NH_3) as a promising H_2 carrier, has attracted increasing attention, due to its well established production and distribution infrastructure, zero carbon emissions during dehydrogenation and no side reactions[2]. Ru is the most active metal for NH_3 decomposition[3]. In this work, a kinetic investigation of NH_3 decomposition was performed over Ru-based catalysts, with a systematic experimental and modelling work.

Ru/γ-Al_2O_3, Ru/MgO and Ru/$MgAl_2O_4$ catalysts were prepared via an incipient wetness impregnation. Catalysts were characterized by BET, ICP-MS, H_2-chemisorption and NH_3-TPD. NH_3 decomposition was tested in a micro fixed bed reactor with diluted NH3-feeds, in order to guarantee isothermal conditions. Tests were thus simulated by a an isothermal 1D pseudo-homogeneous reactor model. Gas composition was analysed by an on-line MS. In all the test, GHSV=20000 Nl/h/Kg_{cat}.

Catalytic tests showed the activity order: Ru/$MgAl_2O4$ > Ru/MgO > Ru/γ-Al_2O_3 (Figure 1). The kinetic investigation indicated an apparent negative order with respect to NH_3 (Figure 2), but H2 cofeed tests (Figure 3) revealed that the reaction is strongly inhibited by H_2, such that first order dependence on NH_3 is recovered at large H_2 feed content.

A simple power-law expression $r = \mathrm{k(T)} * \frac{P_{NH_3}}{P_{H_2}^{1.5}}$ could well explain the data, suggesting that the rate-determining step is within the NH_3 dehydrogenation pathway. The same dependencies were found over all the catalysts despite the different activity.

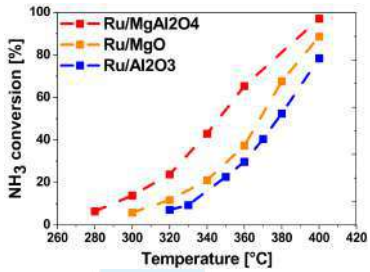

Figure 1. Effect of supports, 2.55% NH_3 in He

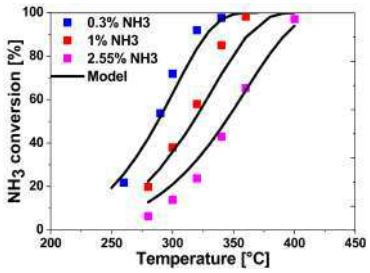

Figure 2. Effect of NH_3-inlet concentration over Ru/$MgAl_2O_4$

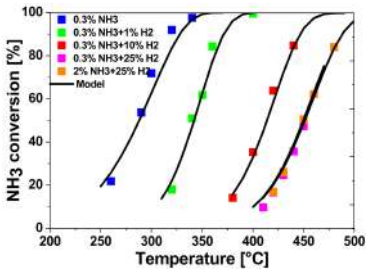

Figure 3. Effect of H_2 cofeed over Ru/$MgAl_2O_4$

References:

[1] K.E. Lamb, M.D. Dolan, D.F. Kennedy, Int J Hydrogen Energy, 2019, 44, 3580–3593.
[2] S. Sayas, N. Morlanés, S.P. Katikaneni, et al, Catal Sci Technol, 2020, 10, 5027–5035.
[3] S.R. Kulkarni, N. Realpe, A. Yerrayya, et al, Catal Sci Technol, 2023, 13, 2026–2037.

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IND-PO-041

Integrated valorization of paper mill wastes for the sustainable production of chemicals and energy

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The great world production of paper and paperboard (more than 400 Mt/a) involves the production of significant amounts of waste streams[1]. A cellulose-rich waste (CRW) and the inorganic-rich waste (IRW), supplied by the company Lucart Group, resulted particularly interesting for chemical and energy valorisation as an alternative to costly disposal. CRW, deriving from the converting step, has a content of glucan of 75 wt % but cannot be reused within the paper mill process, while IRW contains 70 wt % of $CaCO_3$ and about 25 wt % of cellulose. Due to its high cellulose content, CRW was employed as substrate for the one pot acid-catalyzed conversion to ethyl levulinate (EL) using ethanol as reagent and reaction medium. The increasing interest towards EL is related to its outstanding characteristics: EL is a promising versatile biofuel which can be employed as bio-blendstock in both diesel and gasoline engines, and also an intermediate for the production of plasticizers, solvents and pharmaceuticals.[2] The optimization of the ethanolysis process, performed in the presence of 1% sulphuric acid, allowed to reach EL yields of 45 mol%, an important achievement given the simplicity of the process involved.

On the other hand, the IRW was employed in a oxy co-gasification process for energy recovery through the production of syngas adopting a downdraft fixed bed reactor with O_2/H_2O as gasifying agents. A blend of IRW and wood pellets in 1/5 wt/wt ratio was adopted as substrate. Notably, the co-gasification in the presence of IRW produced a syngas characterized by high hydrogen content (40 mol %) and CO (21 mol %). Moreover, tar compositional analysis revealed the presence of long-chain (C_{19}-C_{39}) and polyaromatic hydrocarbons. Finally, the ash characterisation evidenced the formation of good quality CaO deriving from $CaCO_3$ decarbonisation, which can be exploited in the paper mill process itself in a circular economy perspective.

References:

[1] T. Turner, R. Wheeler, I.W. Oliver, Journal of Environmental Management, 2022, 115439.
[2] A. M. Raspolli Galletti, C. Antonetti, S. Fulignati, D. Licursi, Catalysts, 2020, 10, 1221.

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IND-PO-043

A unified approach for the synthesis of heteroaromatics by combining decatungstate photocatalysis and Paal-Knorr reaction in flow

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Heteroaromatics are coveted scaffolds in pharmaceuticals, agrochemicals and material science: their expedite synthesis is therefore of prime importance. A privileged access point to these precious motifs is the Paal-Knorr approach, especially for the synthesis of five- and six-membered heterocyclic compounds including furans, thiophenes, pyrroles and pyridazines. This approach demands for the wide availability of 1,4-diketones. Consequently, substantial efforts have been directed towards to developing efficient methodologies for preparation of such compounds[1,2]. A very convenient method consists in the decatungstate (DT)-photocatalyzed hydrogen atom transfer (HAT) acylation of electrophilic olefins, which starts from readily available raw materials such as aldehyde and α,β-unsaturated carbonyl compounds[3].

In this study, we present a unified strategy for a streamlined two-step synthesis of heteroaromatics, combining decatungstate photocatalysis and the Paal-Knorr reaction in flow conditions (Figure 1). The first photocatalytic step involves the reaction between an aldehyde and a vinyl ketone to obtain 1,4-diketone via DT-photocatalyzed HAT, which occurs in 5 minutes. Without isolating the intermediate, the diketone enters a second reactor and is reacted with amines, Bronsted acid, Lawesson's reagent, and hydrazine to afford pyrroles, furans, thiophenes and pyridazines, respectively. For example, the modular nature of our method allowed for the tailored, on-demand synthesis of pyrroles in 6 minutes residence time with a Space-Time Yield (STY) of 47 kg h^{-1} m^{-3}, thus offering an operationally simple and scalable route to these commercially relevant scaffolds.

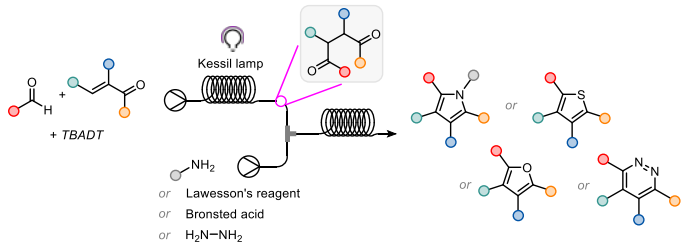

Figure 1: A unified telescoped approach for the synthesis of heteroaromatics.

References:

[1] M. Lemmerer, M. Schupp, D. Kaiser, N. Maulide, Nat. Synth, 2022, 1, 923–935.
[2] A. Balakrishna, A. Aguiar, P. J. M. Sobral, A. J. F. N. Sobral, Catalysis Reviews, 2019, 61, 84-110
[3] S. Esposti, D. Dondi, M. Fagnoni, A. Albini, Angew. Chem. Int. Ed. 2007, 46, 2531–2534

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IND-PO-044

New materials from lignocellulosic biomasses valorisation

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Lignocellulosic biomass is very widespread in nature and its use as a raw material has the advantage of not being in competition with its use in the food and feed supplies[1]. There are also numerous types of waste lignocellulosic biomasses whose valorisation represents an advantage not only for the use of renewable raw material but also for the possibility of reducing the environmental impact of their elimination as waste. Furthermore, in recent years the exploitation of renewable materials from biomass represents a strategic objective for the chemical industry to reduce the depletion of fossil resources while solving waste disposal problems at the same time.

Based on this, the study of new materials with high added value, that can be obtained from the valorisation of waste biomass, is extremely interesting. In particular, cellulose and other polysaccharides can be recovered from biomass waste using specific protocols optimized based on the different composition of the biomass[2]. The mechanical, physical and chemical treatments must be optimized based on the type of biomass studied.

However, to obtain sustainable production processes, even starting from waste materials, it is essential to limit transformation stages with high energy consumption or with the use of high quantities of reagents and solvents, trying to optimize the complete recovery of the biomass.

The objective of this research was therefore a protocol for a low environmental impact biorefinery process for the extraction and/or valorization of cellulose from fibres of a lignocellulosic biomass, aimed at subsequent use in the production of biobased products such as gels, films and panels insulators, intended for processes of interest to various sectors such as the construction one. The main biomass used in this study is *Posidonia Oceanica* Sea Balls (eagropili), a biomass of photosynthetic origin widely present on the coasts of the Mediterranean Sea, often destined for disposal but with the aim of extending the optimized procedures also to other types of waste lignocellulosic material.

References:

[1] P. Ning, G Yang, L. Hu, J. Sun, L. Shi, Y. Zhou, Z. Wang, J. Yang, Biotechnol Biofuels 2021, 14:102, 1-22.
[2] O.F. Restaino, C.V.L. Giosafatto, S.F. Mirpoor, M. Cammarota, S. Hejazi, L. Mariniello, C. Schiraldi, R. Porta, Int. J. Mol. Sci. 2023, 24, 7301, 1-18

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IND-PO-045

Novel approach to produce green aromatics from ethanol and furfural

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Aromatic compounds, in particular benzene, toluene and xylenes (BTX) have very broad applications in chemical industry. Production of aromatic hydrocarbons is based only on petrol-based feedstock. Therefore the manufacturing of green BTX from renewable raw materials would widely increase their sustainability.[1] In a very innovative work Gancedo et al.[2] proposed an alternative route for the production of aromatics starting from furfural (FFL) and ethanol (EtOH), both coming from renewable feedstock. The reaction network involves the decarbonylation of FFL to form furan and the dehydration of EtOH to form ethylene and the condensation via Diels-Alder cyclization to form BTX. All these steps are acid catalysed reactions and the catalyst used is a commercial HZSM-5 zeolite. In the present work this novel approach for the production of aromatics is more deeply investigated, focusing on the effect of experimental conditions, such as reaction temperature and composition of the feed, as well as the physico-chemical features of the catalysts such as aluminium content and the metal-doping of the catalyst with acid metals (mainly Zn and Ga).

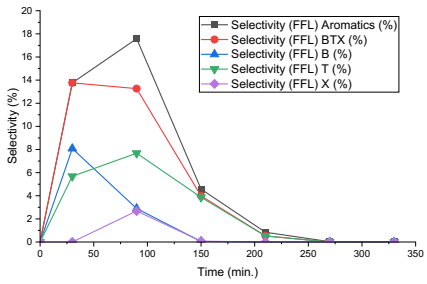

Figure 1: Results of catalytic experiment with H-ZSM-5 40, Selectivity of furfural towards aromatics.

Preliminary studies demonstrated that the H-ZSM-5 zeolite catalyst with Si/Al ratio of 40 is the most active in the production of aromatics (Figure 1), while lower or higher Si/Al ratios are leading to fast catalyst deactivation or absence of production of aromatics, respectively. With all catalysts the production of aromatics stops after 4 hours TOS, whereas the reaction rate of dehydration of EtOH and decarbonylation of FFL are 10% when compared to first 3 hours TOS. This suggests the presence of the catalytic sites of different nature, with only a part of these active in aromatization that suffer from deactivation. With experiments using the single reagents it can be demonstrated that benzene and toluene are mainly produced from EtOH, while xylenes and heavier aromatics are deriving from FFL as well as benzofuran, which is likely the cause of poisoning of the catalytic sites active in the aromatization. Results with metal-doped zeolites will be also presented.

References:

[1] L. Zao, Y. Jiang, Y. Li, H. Zhang, H. Li, S. Yang, Catal. Sci. Technol. 2022, 12, 1902-1921
[2] J. Gancedo, L. Faba, S. Ordóñez, ACS Sustain. Chem. Eng. 2022, 10, 7752-7758

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IND-PO-046

A green chemistry approach for the functionalization of oxidized cellulose nanofilms for the improvement of hydrophobic properties

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Due to the constant increase in society's interest in the realization of ecological transition highlighted by EU Directive 2019/904, the scientific community has increased the focus on the valorization of biomass. Thanks to its abundance in nature and its biodegradability, cellulose is one of the most studied biopolymers, however it also has some disadvantages, which limit its potential: it is insoluble in water, hydrophilic and the defibrillation process are energy intensive. For these reasons, the scientific community has focused attention on the possibility of obtaining more processable nanoscale cellulose derivatives Among others, Isogai et al. in 2011 proposed a method to obtain a stable suspension of C6-oxidated cellulose nanofibers by treatment of cellulose in the presence of the TEMPO/NaBr/NaClO system (TEMPO-oxidized-cellulose nanofibrils TEMPO-ox-CNF)[1]. TEMPO-ox-CNF has carboxyl groups on its surface which can be modified into ester or amide groups to improve its properties[2] or impart new ones[3]. In this contribution, the chemical grafting of TEMPO-ox-CNF by amidation with amines and diamines is proposed using 4-(4,6-Dimethoxy-1,3,5-triazin-2-yl)-4-methylmorpholinium chloride (DMTMM) as a condensing agent. The amidation reaction promoted by DMTMM has various advantages such as the use of water as a solvent and low temperatures. Its effectiveness has already been successfully demonstrated for obtaining high performance films[4]. The material obtained has been characterized by spectroscopic, thermal, and physical-mechanical investigations. Chemical grafting impacts various properties such as hydrophobicity with a significative improvement of contact angle from 40° to 90°.

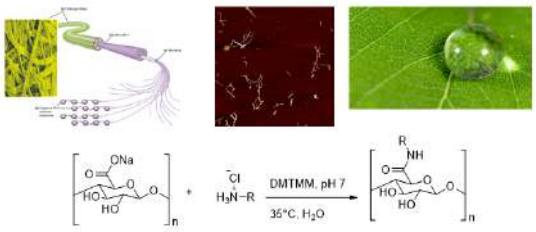

Fig. 1: TEMPO-ox-CNF grafting by amidation

References:
[1]A. Isogai,T. Saito, H. Fukuzumi, Nanoscale 2011, 3, 71-85.
[2]N. Lavoine, J. Bras, T. Saito, A. Isogai, Macromol. Rapid Comunn. 2016, 37, 1033-1039.
[3]D.O. Castro, N. Tabary, B. Martel, A. Gandini, N. Belgacem, J. Bras, Materials Science and Engineering C 2016, 69, 1018-1025.
[4]Beghetto V., Gatto V., Conca S., Bardella N., Buranello C., Gasparetto G., Sole R., Carbohydrate Polymers 2020, 249, 116810.

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IND-PO-047

Enzymatic hydrolysis of protein-rich biomass waste for the production of biostimulants

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Rice and soybeans are among the crops that generate the largest amounts of protein-rich waste, *e.g.* the protein content of rice bran and soy meal are 13-19% and 44-49%, respectively. Thus, they have high potential to be used as starting materials to produce value-added products.[1] To this aim, proteins contained in these agri-food waste must be extracted and separated from the other constituents of biomass, and then hydrolyzed. Enzymatic hydrolysis is an easily scalable, green and cost-efficient strategy which involves the use of proteases, eventually in combination with carbohydrases, to produce mixtures of peptides known as protein hydrolysates (PH), for which a number of applications have been reported. Among them, PH can be used as biostimulans in horticulture.[2] Studies show benefits of biostimulants on growth, yield, product quality, resource use efficiency and tolerance to environmental and chemical soil stresses of several horticultural crops[3,4]. In this work an in-depth investigation of different commercially available enzymatic formulations, experimental conditions (T, pH) and time of hydrolysis was performed to obtain soy PHs with biostimulant activity. A scale-up of the enzymatic reaction was also performed, using a 15L reactor. Five different prototypes of soy PHs were prepared, characterized by elemental analysis and subjected to ultrafiltration through increasing molecular weight cut-off membranes to get different peptide size fractions. Moreover, total and free amino acids in soy PHs were determined with RP-HPLC. Moreover, the biostimulant effect of soy PHs was evaluated on growth and quality of *Lactuca sativa* L. var. longifolia, both under nutritive stress and no stress conditions.

References:

[1] M. Del Mar Contreras, A. Lama-Muñoz, J.M. Gutiérrez-Pérez, M. Moya, E. Castro, Bioresource Technology 2019, 280, 459-477.
[2] C. Fabian, Y. Ju, Reviews in Food Science and Nutrition 2011, 51 (9), 816-827.
[3] G. Colla, S. Nardi, M. Cardarelli, A. Ertani, L. Lucini, R. Canaguier, Y. Rouphael, Scientia Horticulturae 2015, 196, 28-38
[4] A. Ertani, L. Cavani, D. Pizzeghello, E. Brandellero, A. Altissimo, C. Ciavatta, S. Nardi, Journal of Plant Nutrition and Soil Science 2009, 172 (2), 237–244.

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IND-PO-048

Mechanistic insights into r-WGS reaction on Rh and Pt via a combined experimental and structure-dependent microkinetic analysis

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The Reverse Water-Gas Shift (r-WGS) reaction is pivotal among CO_2 utilization approaches since it produces CO, a fundamental block of the chemical industry. However, there are still a lot of debates concerning the precise mechanism of this reaction. We thus combined both theoretical and experimental methodologies to investigate how the reaction mechanism changes according to the oxygen-affinity of the surface, employing two catalyst materials with different oxophilicities, i.e., 4wt.% Rh/α-Al_2O_3 and 4wt.% Pt/α-Al_2O_3.

The reaction rate exhibited a direct proportionality on CO_2 concentrations for both catalysts but showed a significant dependency on H_2 only on Pt. Therefore, we proposed that, on Rh, CO_2 is activated through dissociation into CO^* and O^* (Fig.1a), while, on Pt, CO_2 activation occurs *via* a H-mediated route forming a $COOH^*$ intermediate (Fig.1b), in agreement with previous theoretical investigations from our group[1].

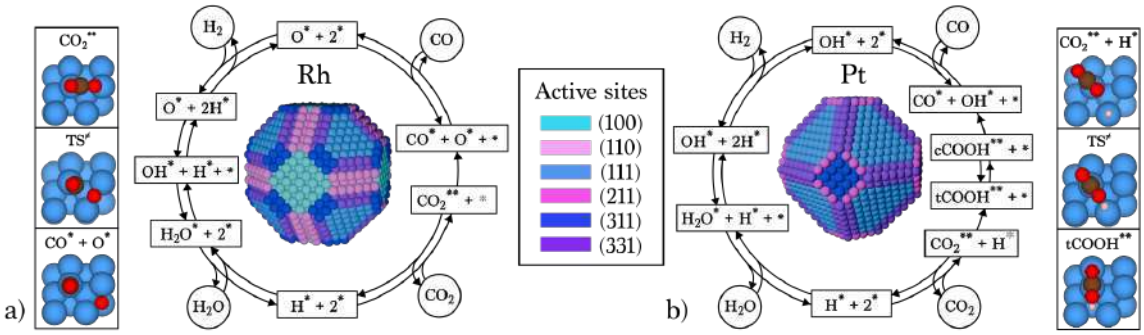

Figure 1: CO_2 activation and reaction mechanisms for r-WGS on Rh (a) and Pt (b).

To elucidate this mechanistic interpretation, we conducted a structure-dependent microkinetic analysis on both materials based on DFT calculations[2]. We found that CO_2 activation is the rate determining step on both catalysts and proceeds *via* dissociation into CO^* and O^* on Rh, while it follows a H-mediated route on Pt, in agreement with experiments. The microkinetic model accounts for both the activity and the abundance of a set of active sites exposed by catalyst nanoparticles. This structure-dependency inclusion was essential to identify the kinetically dominant active sites, i.e., Rh(100) and Pt(111) on Rh and Pt respectively, thus paving the way to derive fundamental rate equations for catalyst design and optimization. Project funded under PNRR-NextGenerationEU "Network 4 Energy Sustainable Transition – NEST".

References:

[1] L. Dietz, S. Piccinin, M. Maestri, J. Phys. Chem. C 2015, 119, 4959.
[2] R. Cheula and M. Maestri, Catalysis Today, 2022, 387, 159.

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IND-PO-049

Development of photoelectrodes based on different perovskite material for energy applications

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Perovskite materials (ABX3) due to their optical and electronic properties have been exploited for energy and environmental applications, such as hydrogen production, CO2 reduction reactions and solar cells[1,2]. Recently, perovskites have been also considered to photo-electrochemically store hydrogen into ammonia molecule. Different types of perovskite materials, moving from halide inorganic perovskites to oxidic systems with single or double perovskite structure were considered as suitable and functional materials for this purpose. In this work, inorganic perovskites were produced considering different chemical approaches and structurally, optically and morphologically characterized. Chemical deposition techniques were optimized to create thin film for photo-electrode with suitable properties (characterized by FE-SEM and UV-Vis spectroscopy). The obtained photo-electrodes were tested electrochemically and photoelectrochemically in different conditions (suitable for ammonia production) using cyclic and linear sweep voltammetry and electrochemical impedance spectroscopy. The obtained results show the influence of perovskite composition and morphology on photoelectrochemical properties of the related photoelectrode.

References:

[1] W. Song, J. Mater. Chem. A 2023, *22*, 12482-12498.
[2] H.S. Kushwaha, Sci. Rep. 2016**,** *6*, 18557-18567.

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IND-PO-050

Innovative and recyclable magnetic catalyst for the development of a sustainable reductive catalytic fractionation process of raw poplar wood sawdust

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Fractionation of 2nd generation lignocellulosic biomasses is an essential step for biorefinery strategies to isolate and fully exploit cellulose, hemicellulose and lignin for the production of materials, fuels and chemicals. One of the most promising strategies aimed to lignin valorisation is based on the extraction, depolymerisation and simultaneous stabilisation of this fraction towards the production of low molecular weight lignin oil through the so called Reductive Catalytic Fractionation (RCF).[1] RCF is a catalyst dependent process capable of producing phenolic compounds and hemicellulose-derived polyols while preserving the carbohydrate cellulose pulp in the presence of a reducing agent, generally hydrogen. Supported noble metal catalysts over carbons or Al_2O_3 were found to be active;[1] however, one major issue, often underestimated, is represented by the inefficient catalyst recovery from the fibrous cellulose pulp which limits catalyst recyclability thus dramatically impacting the economic sustainability of the entire process at larger scale.[2]

For this reason, we developed a novel magnetic catalyst based on supported ruthenium oxide over maghemite (RuO_2/γ-Fe_2O_3), which behave as suitable precursor of the actual, *in situ* obtained, 5%wt Ru/Fe_3O_4 active phase for the RCF. The performances of this system, in terms of delignification of cellulose, lignin oil yield and catalyst recovery, were compared with the one obtained with a commercial 5 wt% Ru/C, considered as a benchmark. A simple, lab-scale, magnetic recovery procedure allows to obtain around 94% of recovery efficiency after the first reaction cycle (while the liquid-liquid extraction reported in literature to recover the Ru/C catalyst only led to 10% of recovery). Ru/Fe_3O_4 allows to obtain excellent delignification efficiency, with the concomitant formation of a highly pure cellulose pulp. On the other hand, both the lower surface area and bigger Ru nanoparticles compared to Ru/C, limit lignin depolymerisation efficiency to phenolic monomers. Preliminary recyclability tests have proven the stability of our catalyst for at least 3 RCF cycles. This innovative approach through the implementation of an active, magnetic, catalyst, never reported in literature in a RCF processes, shows great potential thanks to its good recyclability and its ability to produce very high-quality cellulose pulp together with relatively low MW lignin oil, therefore it was patented.

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References:

[1] E. Paone, T. Tabanelli, F. Mauriello, Curr. Opin. Green Sustain. Chem., 2020, 24, 1-6.

[2] T. Renders E. Cooreman, S. Van den Bosch, W. Schutyser, S.-F. Koelewijn, T. Vangeel, A. Deneyer, G. Van den Bossche, C. M. Courtin and B. F. Sels, Green Chemistry, 2018, 20, 4607-4619.

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IND-PO-051

Determination of Vapor Pressures of FAME Industrial Mixtures by Ebullioscopic and Thermogravimetric Experimental Methods

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The quest for sustainable energy sources has led to biodiesel (BD) emerging as an environmentally friendly alternative to traditional fossil fuels. Fatty Acid Methyl Esters (FAME) constitute the primary components of these biofuels and meeting specific standards, such as ASTM D6751 and EN 14214[1], is essential for their direct use in the fuel market. Vapor pressure (VP) is a crucial characteristic related to the volatility of BD, impacting both safety and engine combustion efficiency, but the experimental determination is challenging due to its composition variability, low vapor pressures, and susceptibility to degradation during experiments[2]. Furthermore, the definition and the measurement of vapor pressure for mixtures is strongly dependent on the possible variation of the composition during experiments, due to the different volatility of the single compounds. It is also possible to calculate the vapor pressure of the mixture starting from its composition, but the different thermodynamic scenario (ideal or not ideal mixture as first) must be considered. Moreover, for industrial samples possible effect due to the presence of impurities[3] must be considered.
The study[4] employed two distinct experimental methods to determine the vapor pressure of certain acetate esters and two industrial blends of Fatty Acid Methyl Esters (FAME) from Sabio Fuels srl. The first method used a direct ebullioscopic approach, whereas the second involved an indirect thermogravimetric analysis (TGA). The impact of impurities on accuracy was investigated, and TGA methodology was optimized for ambient pressure operation. An error function was employed to compare the experimental vapor pressure results obtained through both methodologies with theoretical values. Ebullioscopic measurements proved effective only for acetate esters, as FAME mixtures displayed too low vapor pressures for an accurate quantification using this technique. In contrast, the TGA methodology demonstrated greater accuracy for FAME compared to acetates and it allowed a rapid collection of numerous vapor pressure values through a swift analysis. While this method may be less accurate than others, it can be useful for fast screening FAME mixtures, even when contaminated with light impurities, and determining the temperature at which the vapor pressure equals or exceeds a predefined value.

References:

[1] S.V.D. Freitas, M.B. Oliveira, Á.S. Lima, J.A.P. Coutinho, Energy & Fuels 2012, 26,3048-3053.
[2] T.-Y. Wang, X.-Z. Meng, M. Jia, X.-C. Song, Fuel Process. Technol. 2015, 131, 223–229.
[3] A. Chatzifragkou, S. Papanikolaou, Appl. Microbiol. Biotechnol. 2012, 95, 13–27
[4] G. Tonsi, E. Zanella, A. Grainca, G. Tondelli, S. Capelli, S. Albertini, C. Pirola, In press, Can. J. Chem. Eng. 2024, 1.

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IND-PO-052

Valorization of Polyolefin Plastic Waste into Liquid Hydrocarbons via Catalytic Upcycling

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Every year, millions of tons of poorly managed plastic waste accumulate in the environment, posing significant challenges to ecosystems. This is particularly evident with polyolefins (POs), where 95% of post-consumer POs become waste, constituting over 60% of municipal solid waste plastic content[1-3]. The limited recycling of POs represents a significant gap in the plastic market loop, contradicting the goals of the "European Strategy for Plastics in a Circular Economy." Despite EU legislation suggesting strategies for upcycling plastic waste, the upcycling of POs remains in its early stages.

This project aims to raise awareness and advance the catalytic upcycling of POs waste into value-added liquid alkanes. The process involves thorough characterization using a multi-technique approach to identify crucial catalyst properties and process variables driving the selective cleavage of C-C bonds inPOs.[4,5]. Two types of catalysts will be developed, utilizing acid sites and ruthenium nanoparticles as active phases, with variations in acidity and support porosity. These catalysts will be compared to a commercial Ru/C catalyst. Various types of polyolefins, ranging from high purity to real waste, will undergo reductive conditions such as hydrocracking or hydrogenolysis, as well as transfer reductive conditions using aliphatic alcohols as green H-donor molecules.

References:

[1] R. Geyer, et al., Production, use, and fate of all plastics ever made, Sci. Adv., 3 (2017) e1700782.
[2] European Commission, "A circular economy for plastics," can be found under https://publications.europa.eu/en/publicationdetail/-/publication/33251cf9-3b0b-11e9-8d04-01aa75ed71a1/language-en, 2019.
[3] Jambeck J.R., Geyer R., Wilcox C., Siegler T.R., Perryman M., Andrady A., Narayan R., Law K.L., Science, 347 (2015) 768.
[4] C. Wang, Han H., Wu Y., Astruc D., Coord. Chem. Rev., 458 (2022) 214422.
[5] J. Huang, Veksha A., Chan W.P., Giannis A., Lisak G., Renew. Sust. Energ. Rev., 154 (2022) 111866.

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IND-PO-053

NH_3 catalytic cracking with direct Joule heating in packed POCS

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Due to the current need for more environmentally friendly solutions in every aspect of life, the development of a hydrogen economy[1] is gaining interest as a solution to abandon fossil fuels. To overcome the challenge of hydrogen storage and transportation, one possible solution is NH_3, a commodity whose global production is in the range of 150 Mton/year[2] that can be easily liquefied under moderate pressure (10 bar-a @ 25°C). For its use as a hydrogen carrier, however, a substantial development of the ammonia decomposition process is needed. NH_3 decomposition is an endothermic reaction ($NH_3 \rightarrow 3/2\ H_2 + 1/2\ N_2$, $\Delta H°_r = 45.9$ kJ/mol$_{NH3}$) and efficient heat management in the catalytic reactor is of key importance to optimize system performances.

At the industrial scale, high temperature heat of reaction for highly endothermic processes is provided through furnaces, with associated CO_2 emissions. While this solution is a proved and widely used technology, it is only optimal for large scale operations and not suitable for compact, distributed systems; a promising solution to this problem can be the use of cellular SiSiC internals as ohmic heating elements to supply the required reaction heat[3]. In this view, experimental tests were conducted by packing a SiSiC open cell foam (32 mm diameter, 100 mm length, porosity = 0.88) with a commercial Ru-based catalyst (Heraeus, 2% Ru/Al_2O_3) and a variable voltage DC power supply was used to provide the required power. Pure NH_3 was fed to the system at spatial velocities between 1250 Ncc/h/g_{cat} and 10'000 Ncc/h/g_{cat} while recording conversion and energy efficiency for different outlet temperatures. As demonstrated with the experimental tests, conversion in excess of 95% can be reached at GHSV of 3750 Ncc/h/g_{cat} and lower with thermal efficiency in excess of 60%; moreover, as highlighted by a 2D heterogeneous model, significantly higher thermally efficiency can be achieved with the scale-up of the system.

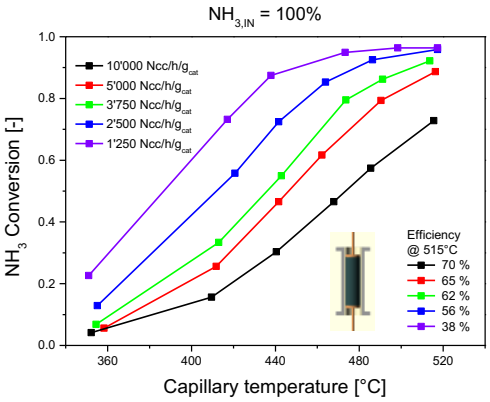

Figure 1: Electrified SiSiC reactor, NH_3 conversion and energy efficiency vs outlet temperature.

References:

[1] C. Tang, Y. Zheng, M. Jaroniec, S.Z. Qiao, Angew Chem., 2021, 60, 19572
[2] U.S. Geological Survey, Mineral Commodity Summaries, January 2023
[3] L. Zheng, et al., AIChE J., 2023, 69, e17620

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IND-PO-055

The flow of materials during the plastic processing; an uncharted and underestimated field in the carbon footprint analysis of plastic working process

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Researchers have recently outlined that the impact of plastics on climate and environment is bigger than originally thought. In a study published in 2021 in Nature Sustainability, it has been pointed out as the global carbon footprint of plastics has doubled since 1995, reaching 2.2 billion tons of CO_2 equivalent (CO_2eq) in 2015[1]. In this context, studies on the global environmental impact of plastics have mainly focused primarily on the disposal phase, whereas there are few studies about the manufacture and in particular processing of plastics, which also remarkably affect the carbon emission and air quality. This produces a knowledge gap about the environmental impact of processing of the plastic, where most companies underestimate the environmental impact of their processes.

The calculation of the LCA, specifically of Carbon Footprint (CF) can assess the industrial environmental impact of a supply chain, but to do so, the study of materials and energy flow must be performed (LCI), where all the input and output in the chain must be identified, quantified, and studied their possible impact in the environment to produce greenhouse gases is concerned. The aim of this work within the PNRR Grins project is to carry out a critical survey in the plastic manufacturing steps, in particular about the most common plastic processing (extrusion and injection molding, mainly) of different polymers in different Italian ad European companies. As initial step the flow of material in input and output (the processed material, the waste and the discarded material) must be assessed. For specific case studies, the use of gas chromatography or total carbon analysis could be considered. The last step of the work is to calculate the carbon footprint of the processes and quantifying the emission of every single steps. These results would support the development of strategies to reduce the environmental impact of the plastic manufacturing process.

References:

(1) Cabernard, L.; Pfister, S.; Oberschelp, C.; Hellweg, S. Growing Environmental Footprint of Plastics Driven by Coal Combustion. *Nat. Sustain.* **2021**, *5* (2), 139–148. https://doi.org/10.1038/s41893-021-00807-2.
(2) Mannheim, V.; Simenfalvi, Z. Total Life Cycle of Polypropylene Products: Reducing Environmental Impacts in the Manufacturing Phase. *Polymers* **2020**, *12* (9), 1901. https://doi.org/10.3390/polym12091901.

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IND-PO-056

Biocatalysis for the Regio- and Stereo-selective Production of Enhanced Pharmaceuticals

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Natural enzymes have revolutionized chemistry through biocatalysis, blending molecular precision with environmental care. This approach has provided sustainable methods for producing fine chemicals and a greener alternative to conventional synthesis, moving from harmful solvents to eco-friendly, regio- and stereospecific biocatalysts[1]. Biocatalysis has enabled the production of complex, water-soluble derivatives by combining pharmaceutical knowledge with biobased molecules, leading to safer prodrugs that mitigate the side effects of traditional active ingredients[2]. Herein, we highlight the synthesis of compounds with significant market presence, like ursodeoxycholic acid, utilized in treating gallstones[3], and a range of cinnamic acid derivatives, such as ferulic and caffeic acids, which are biobased molecules celebrated for their antioxidant and anti-inflammatory properties, as well as ibuprofen, one of the most used anti-inflammatories in the world. Centered on the molecular dynamics of biocatalysts for optimized reuse and stability, these advancements not only showcase the effectiveness of prodrugs over traditional compounds but also reflect a commitment to the principles of sustainability and the circular economy. This journey illustrates a harmonious blend of chemical innovation and environmental responsibility, marking a future where chemistry continues to evolve in alignment with sustainability and health protection.

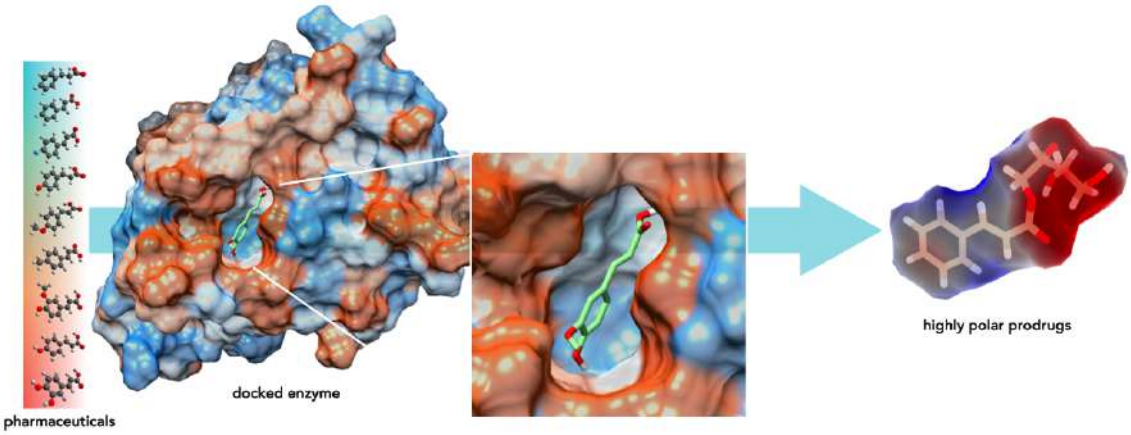

Figure 1: Docking and experimental optimization of enzymatic processes for the green synthesis of enhanced biobased prodrugs.

References:

[1] Zappaterra, F.; Presini, F.; Venturi, V.; Lerin, L. A.; Giovannini, P. P.; Costa, S. 2023, 13 (17), 9852.
[2] Zappaterra, F.; Costa, S.; Summa, D.; Semeraro, B.; Cristofori, V.; Trapella, C.; Tamburini, E. 2021, 25 (5966), 1–15.
[3] Venturi, V.; Marchesi, E.; Perrone, D.; Costa, V.; Catani, M.; Aprile, S.; Lerin, L. A.; Zappaterra, F.; Giovannini, P. P.; Preti, L. 2024, 29 (6), 1305.

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IND-PO-058

Carbon-dots-conjugated semiconductors for enhanced solar-driven photocatalysis

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In the last decades, the rising levels of carbon dioxide (CO_2) in the atmosphere have been increasingly attributed to the global warming effect[1]. Photocatalysis, which exploits the energy of light and abundant semiconductor materials, may represent a promising method to enable more sustainable catalytic reactions[2]. However, the applicability is currently mainly hindered by design of materials able to efficiently harvest solar light to carry out photo-catalytic reactions.

In this context, the conjugation of carbon dots with semiconductor materials was studied as tool to increase the visible-light sensitivity of titanium oxide (TiO_2) and barium titanate ($BaTiO_3$). The hybrid materials were tested for their photo-activity in two distinct reactions and upon the irradiation of either UV or solar light. Two different deposition methods were studied as to provide a scalable strategy to the design of versatile photocatalyst.

As results, only carbon-modified semiconductors were able to convert CO_2 into methane upon solar light excitation. In addition, carbon-dots-$BaTiO_3$ conjugates were proposed for the first time as valid alternative to TiO_2-based photocatalysts, especially in the CO_2 photo-reduction reactions.

If properly designed, carbon dots may represent a way to overcome some of the current limitations to the application of photocatalytic processes for the development solar-powered technologies.

References:

[1] T. M. Gür, Progr. Energy Combust. Sci. 2022, vol. 9, pp. 1–56.
[2] H. Shen, T. Peppel, J. Strunk, Z. Sun, Sol. RRL 2020, vol. 4, pp. 1 – 41.

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INO-MD-01

Biological properties of "inorganic" phosphorus dendrimers

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Dendrimers are hyper-branched macromolecules, synthesized step by step from a multifunctional core. Different types of dendrimers are known, depending on their chemical constituents. Among them, dendrimers having a phosphorus atom at each branching point have particular properties, compared to purely organic dendrimers. Indeed, the internal structure of dendrimers cannot be considered as an "innocent" scaffold.[1]

Depending on the type of their terminal functions, phosphorus-containing dendrimers display different properties, in particular as potential drugs in biology/nanomedicine. Dendrimers bearing phosphonate terminal functions (Figure 1, left) display anti-inflammatory properties, against rheumatoid arthritis,[2] multiple sclerosis, or psoriasis. Diverse dendritic architectures functionalized with metal complexes (Figure 1, right) display anti-cancer properties by themselves,[3] whereas others, functionalized with ammonium terminal functions, act as carriers of drugs against cancers.[4] In addition, phosphorus dendrimers largely enhance the detection accuracy of biochips, enabling the accurate and rapid detection of several diseases.[5]

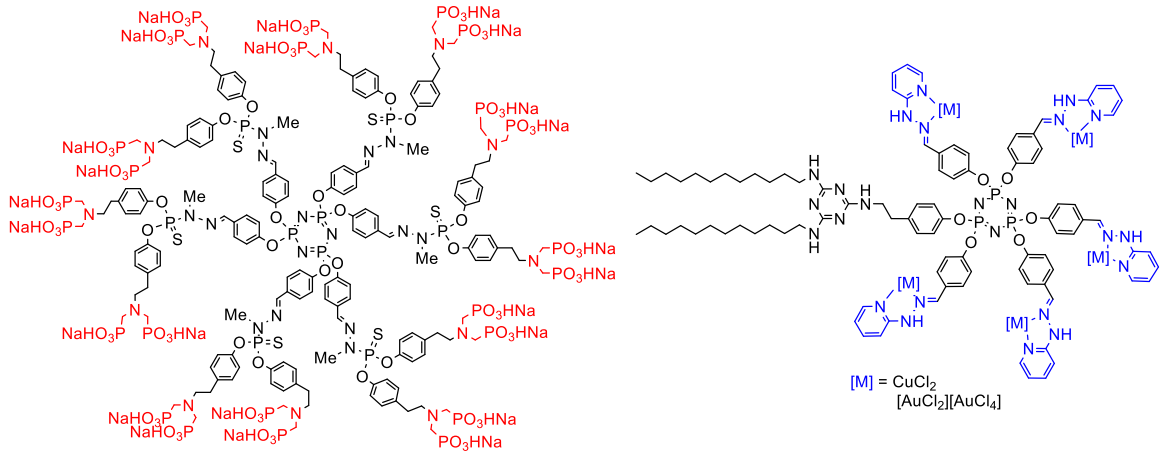

Figure 1: Two examples of phosphorus dendritic structures having biological properties.

References:
[1] A.M. Caminade et al., Nature Comm. 2015, 6, 7722.
[2] M. Hayder et al., Science Transl. Med. 2011, 3, 81ra35.
[3] E. Apartsin, N. Knauer, U.D. Kahlert, A.M. Caminade, Pharmaceutics 2022, 14, 393.
[4] Y. Zou et al., Biomacromolecules 2024, 25, 1171 – 1179.
[5] J.P. Majoral, J.M. François, R. Fabre, A. Senescau, A.M. Caminade, Science China Mater. 2018, 61, 1454 – 1461.

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INO-MD-02

Modeling Materials and Processes in Hybrid/Organic Photovoltaics: From Dye-sensitized to Perovskite Solar Cells

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Over the last two decades, researchers have invested enormous research effort into hybrid/organic photovoltaics, leading to the recent launch of the first commercial products that use this technology. Dye-sensitized solar cells (DSCs) have shown clear advantages over competing technologies. The top certified efficiency of DSCs exceeds 11% and the lab-cell efficiency is greater than 13%.

In 2012, the first reports of high efficiency solid-state solar cells based on organohalide lead perovskites completely revolutionized the field. These materials are used as light-absorbers in DSCs and as light-harvesting and electron conductor in meso-superstructured and flat heterojunction perovskite solar cells (PSCs) and show certified efficiencies that currently exceed 26%.

To effectively compete with conventional photovoltaics, emerging technologies need to achieve higher efficiency and stability, while maintaining low production costs.

Many of the advances in the DSCs and PSCs field have relied on the computational design and screening of new materials. Suitable modeling strategies further allow researchers to observe the otherwise inaccessible but crucial hetero-interfaces that control the solar cell operation, allowing researchers the opportunity to develop new and more efficient materials and optimize processes.

We illustrate the basic device architectures and operating principles of both DSCs and PSCs highlighting the fundamental modeling strategies and revealing fundamental aspects of the device's operational mechanism. Although the modeling of DSCs is relatively mature, the "perovskite storm" has presented new problems and casted new modeling challenges, such as understanding defect activity, interface functioning and carrier recombination in these materials. Solving these issues may contribute to further optimize materials and processes towards the wide uptake of perovskite solar cells.

References:

1. De Angelis, F. *Acc. Chem. Res.* **2014**, 47, 3349.
2. Azpiroz, J. M.; Mosconi, E.; Bisquert, J.; De Angelis, F. *Energy Environ. Sci.* **2015**, *8*, 2118.
3. De Angelis, F.; Petrozza, A. *Nat. Mater.,* **2018**, 17, 377–384.
4. Yang S.; Chen S.; Mosconi E.; Fang Y.; Xiao X.; Wang C.; Zhou Y.; Yu Z.; Zhao J.; Gao Y.; De Angelis F.; Huang J. *Science*, **2019**, 365, 473–478.
5. Motti S. G.; Meggiolaro D.; Barker A. J.; Mosconi E.; Perini C. A. R.; Ball J. M.; Gandini M.; Kim M.; De Angelis F.; Petrozza A. *Nat. Photonics*, **2019**, 15, 532–539.
6. De Angelis F. *ACS Energy Lett.* **2024**, 9, 4, 1759–1760.

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INO-MD-03

Sodium: the journey of a "diffusion catalyst" from the surface to the bulk of $Cu(In,Ga)Se_2$

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$Cu(In,Ga)Se_2$ (CIGS) is the commercially viable thin film semiconductor that is currently most efficient at converting sunlight to electricity through the photovoltaic (PV) effect.

This outstanding achievement is a seeming paradox because the thin film is polycrystalline, thus it displays extended defects potentially acting as recombination centres for photogenerated carriers. Moreover, CIGS contains a high density of oppositely charged point defects: a condition known as compensation. Compensated semiconductors give rise to a photoluminescence emission that is red shifted with respect to the relevant optical absorption onset. The red shift is due to charge carrier thermalization, a source of performance losses that results from an electronic band structure affected by electrostatic potential fluctuations.

Within this context, the success of CIGS technology would simply be impossible in the absence of sodium. The effect of sodium is so powerful that traces of it are enough to boost CIGS solar cell efficiency from few percent to over 23 %, along with other strategies[1]. But what is the exact role played by sodium in CIGS?

The dramatic improvements of optoelectronic properties associated with sodium are accompanied by a multitude of complex effects impacting the whole of CIGS thin films from the surface and grain boundaries to the core of the grains. Disentangling these effects is far from trivial, as confirmed by 30+ years of R&D.

The research I present here solves crucial fundamental puzzles by revealing the ability of sodium to (i) catalyse the diffusivity of matrix atoms within the bulk of the material[2,3,4], and (ii) catalyse oxygen absorption and desorption at surfaces and grain boundaries[5,6]. Both features contribute to the reduction of electrostatic potential fluctuations and -through an interplay between composition and microstructure- abate parasitic recombination of charge carriers[7]. The findings confirm that sodium in CIGS is not a simple dopant. I define it as a "diffusion catalyst": a new concept worth exploring in other chalcogenide materials.

This "sodium journey" started at the University of Luxembourg, it passed through the International Iberian Nanotechnology Laboratory in Portugal and reached the University of Genova. Along the way, numerous researchers based in Europe and USA enriched it enormously; I am indebted to all of them.

References:

[1] J. Keller, et al. Nature Energy 2024, 9, 467-478
[2] D. Colombara, et al. Nature Communications 2018, 9, 826.
[3] D. Colombara. Physical Review Materials 2019, 3, 054602.
[4] D. Colombara, et al. Journal of Materials Chemistry A 2020, 8, 6471-6479.
[5] D. Colombara, et al. Nature Communications 2020, 11, 3634.
[6] F. Babbe, et al. Advanced Energy Materials 2023, 13, 2204183.
[7] D. Colombara, B. J. Stanbery, and G. Sozzi. Journal of Materials Chemistry A 2023, 11, 26426–26434.

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Ziegler-Natta Catalysis: a Journey in the Land of Serendipity

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There are areas of chemistry where the contribution of serendipitous discoveries to the overall progress is overwhelming, because the variables hyperspace is too complex for rational design. One such area is heterogeneous catalysis, and the breakthrough invention of isotactic polypropylene by Giulio Natta in March 1954[1] represents a paradigmatic case. On the other hand, the subsequent progress in Ziegler-Natta polymerization is described in the books[2] as the result of a robust mechanistic underpinning based on crystallochemical models. In fact, the field is currently perceived as fully mature, and academic research has been almost completely discontinued.

Polypropylene industry, on the other hand, is a giant constantly in demand of scientific support, and throughout the last decades in our laboratory we have always been running R&D projects aiming to improve catalysts and products. To our surprise, day after day we accumulated a growing body of experimental and computational data indicating that the popular narration of a smooth, logical evolution from first generation $TiCl_3$ catalysts to $MgCl_2$-supported 'High-Yield' (HY) homologs is –in reality– wishful thinking. This lecture illustrates how serendipity, again and again, contributed to the implementation of HY systems, and popular hypotheses seemingly in line with common sense represented a mind trap rather than a thought accelerator.

References:

[1] G. Natta et al., J. Am. Chem. Soc. 1955, 77, 1708-1710.
[2] G. Cecchin, G. Morini, F. Piemontesi, Kirk-Othmer Encyclopedia of Chemical Technology 2007, 26.

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Bonding and Reactivity in Heterobimetallic Bridging Hydrides Across the Transition Series

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The establishment of donor/acceptor interactions has important implications in organometallic chemistry and its application in homogeneous catalysis.[1] In this context, heterobimetallic bridging hydride complexes are an interesting class of compounds,[2] which have been found as products in several H_2 activation reactions.[3,4] These species are an interesting platform to study, owing to the possibility of activating the hydride moiety and trigger potential bimetallic cooperation.[5]

The present work set to investigate the structure, bonding and reactivity of different classes of heterobimetallic bridging hydride complexes along with potential metal-based FLP cooperativity for the development of novel metal-metal reactivity at the metallic interface (Figure 1).

The new bimetallic compounds obtained were mainly analysed by means of NMR spectroscopy, X-Ray diffraction and DFT analysis. The metal chosen span over the periodic series, to underline the versatility of such approach in organometallic chemistry. The different bimetallic combinations have been exploited to investigate different reactions such as hydride transfer, olefin and alkene insertions, hydrogenation and C-H activation, paving the way for a much better understanding of the potential role of bimetallic complexes in catalytic reactions.

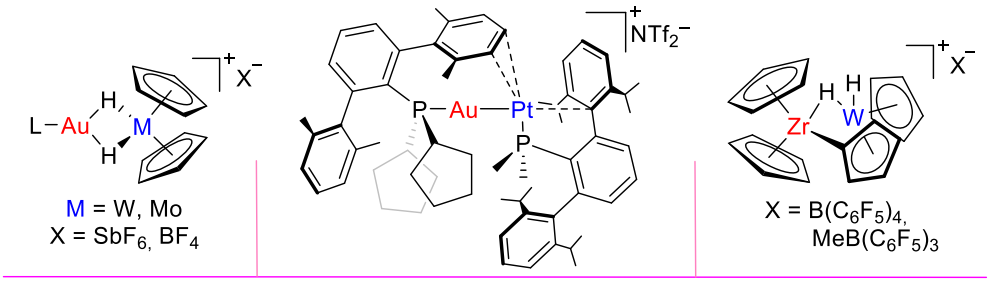

Figure 1: Three main bimetallic cores studied in this work.

References:
[1] J. Campos, Nature Review Chemistry 2020, 4, 696 – 702.
[2] A. Albinati, L. Venanzi, Coordination Chemistry Reviews 2000, 200-202, 687 – 715.
[3] L. Rocchigiani, P. H. M. Budzelaar, M. Bochmann, Chemical Science 2019, 10, 2633–2642.
[4] J. Campos, Journal of the American Chemical Society 2017, 139, 2944 – 2947.
[5] R. Perutz, B. Procacci, Chemical Reviews 2016, 116, 8506 – 8544.

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INO-PZ-03

Metal oxide photocatalysts: the role of surface and nanostructure

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In the field of heterogeneous photocatalysis, the present work explores the design and development of novel metal oxide-based nanostructured materials as efficient photocatalysts for organic contaminants photodegradation[1] and H_2 production through photoelectrochemical water splitting (PEC WS)[2] and alcohol photoreforming.[3] Focusing on titanium dioxide (TiO_2),[4] known as the benchmark photocatalyst, several strategies have been investigated to tailor and improve its optical and electronic properties, using smart and cost-effective synthetic routes to boost both the overall photoresponse and catalytic activity. A direct correlation among morphological, structural, optical, and electronic properties and the photoactivity of the synthesized nanomaterials has been established by critically discussing the experimental results obtained by using advanced experimental techniques. Overall, the research findings provided by the nanostructured systems designed and investigated in this work aim to significantly contribute to the development of new and sustainable solar-driven technologies for future large-scale applications in the field of heterogeneous photocatalysis.[3,5,6]

References:

[1] D. Ma, H. Yi, C. Lai, X. Liu, X. Huo, Z. An, L. Li, Y. Fu, B. Li, M. Zhang, L. Qin, S. Liu, L. Yang, *Chemosphere* 2021, *275*, 130104.
[2] L. Liccardo, E. Lushaj, L. Dal Compare, E. Moretti, A. Vomiero, *Small Science* 2022, *2*, 2100104.
[3] L. Liccardo, P. Moras, P. M. Sheverdyaeva, A. Vomiero, A. Caballero, G. Colón, E. Moretti, *Adv Sustain Syst* 2023, 8 (3), 2300418.
[4] R. Katal, S. Masudy-Panah, M. Tanhaei, M. H. D. A. Farahani, H. Jiangyong, *Chemical Engineering Journal* 2020, *384*, 123384.
[5] N. Spigariol, L. Liccardo, E. Lushaj, E. Rodríguez-Castellón, I. Barroso Martin, F. Polo, A. Vomiero, E. Cattaruzza, E. Moretti, *Catal Today* 2023, *419*, 114134.
[6] L. Liccardo, M. Bordin, P. M. Sheverdyaeva, M. Belli, P. Moras, A. Vomiero, E. Moretti, *Adv Funct Mater* 2023, 2212486.

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Discovery of antibacterial manganese(I) tricarbonyl complexes through combinatorial chemistry

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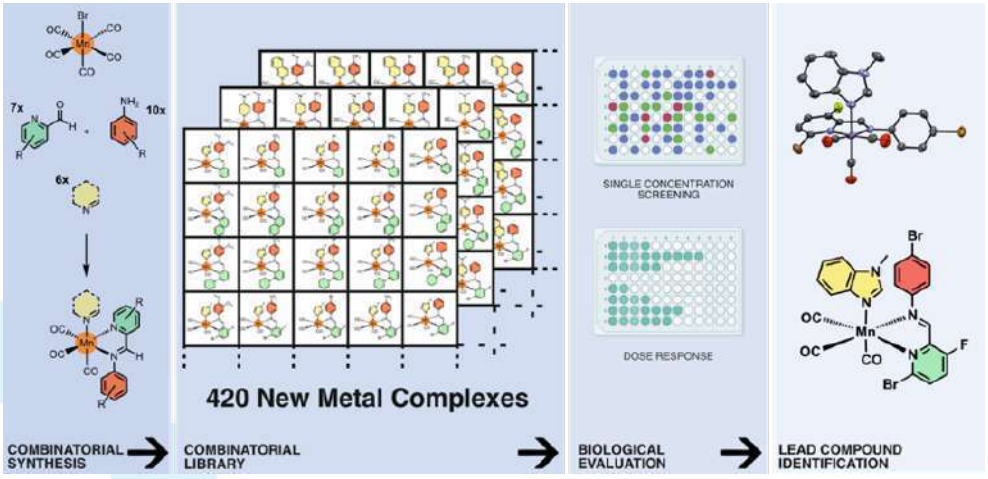
The continuous rise of antimicrobial resistance is a serious threat to human health and already causing hundreds of thousands of deaths each year. Metal complexes have recently shown promising results as antimicrobial agents, but the number of studied compounds is still vanishingly small, making it difficult to identify promising compound classes or elucidate structure-activity relationships. To accelerate the pace of discovery we have applied a combinatorial chemistry approach to the synthesis of metalloantibiotics. Utilizing robust Schiff-base chemistry, we have prepared a library of 420 novel manganese tricarbonyl complexes. All compounds were evaluated for their antibacterial properties and 10 lead compounds were identified, re-synthesised and fully characterised. All 10 compounds showed high and broad activity against Gram-positive bacteria. The best manganese complex displayed low toxicity against human cells with a therapeutic index of >100. In initial mode of action studies, we show that it targets the bacterial membrane without inducing pore formation or depolarisation. Instead, it releases its carbon monoxide ligands around the membrane and inhibits the bacterial respiratory chain. This work demonstrates that large numbers of metal complexes can be accessed through combinatorial synthesis and evaluated for their antibacterial potential, allowing for the rapid identification of promising metalloantibiotic lead compounds.[1]



Reference:

[1] M. Scaccaglia, M. P. Birbaumer, S. Pinelli, G. Pelosi, A. Frei, Chemical Science, 2024, 15, 3907-3919

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H_2 production by ethanol dehydrogenation on metal doped $ZnIn_2S_4$ photocatalysts

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Hydrogen is potential candidate in supporting the energy transition to a more sustainable economy. Its production from ethanol (obtained by fermentation of second-generation biomasses) through photocatalytic processes allow to exploit two renewable sources. In this context, the development of innovative photocatalysts active under solar and visible irradiation represents an important technological advancement to the large scale diffusion of this technology.

In the present work, the effect of metal doping of $ZnIn_2S_4$ (ZIS) photocatalysts on their photocatalytic activity in the photocatalytic production of H_2 from ethanol was studied. The photocatalysts, obtained by hydrothermal synthesis, were active in producing H_2 under irradiation with simulated sunlight or visible light, with an important dependence of the performance on the nature of the dopant metal (Figure 1). The main by-products detected was acetaldehyde while minor amounts of CH_4, CO_2 and ethylene were detected by on-line GC-FID analysis. The photocatalysts have been deeply characterized by complementary techniques, such as XRD, physisorption, ICP-OES and SEM, confirming effective doping of the ZIS structure. Photoluminescence spectra revealed that metal dopants affect the recombination process of photogenerated electron/hole pairs. Insight into the reaction mechanism have been obtained by in-situ ATR-IR spectroscopy, revealing the formation of formates, acetates and carbonaceous C = C species as intermediates or the reaction.

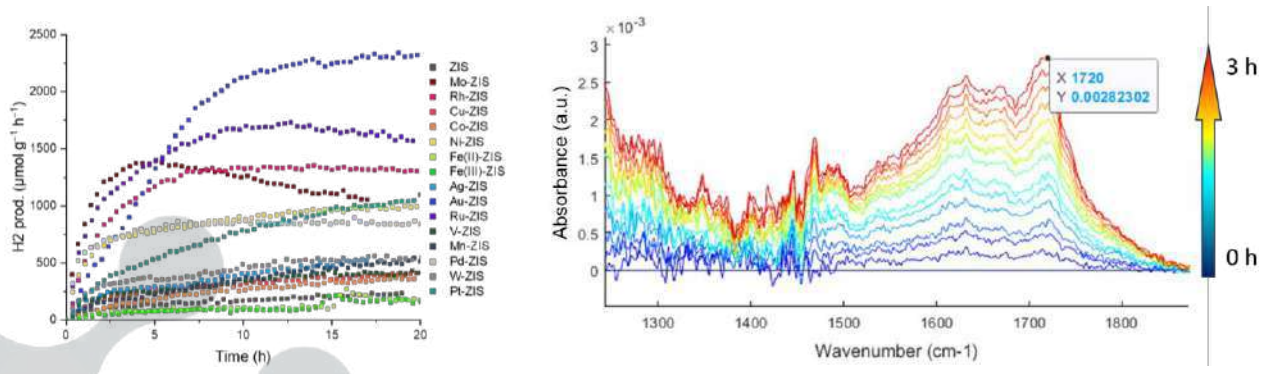

Figure 1: H_2 production rates for metal doped ZIS under simulated sunlight (right) and evolution of ATR-IR spectra in the range 1250 – 1900 cm^{-1} on Au-ZIS under simulated sunlight (left).

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INO-OR-002

Enhancing Antitumor Activity of Platinum-Based Organometallic Compounds: Investigating the Effects of Ligand Substitution and Hydrophobicity. A Study of Novel Water-Soluble Monofunctional Organometallic Pt(II) Complexes $[PtL(\eta^1\text{-}C_2H_4OEt)(phen)]^+$ (L = DMSO, NH_3, 1-hexyl-1H-imidazole, 1-hexyl-1H-benzo[d]imidazole)

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Since the discovery of cisplatin's ability to inhibit tumor growth, numerous studies have focused on understanding the relationship between the structure of platinum compounds and their antitumor activity[1]. It has been found that substituting the chlorido and ammonia ligands with other ligands can greatly enhance the effectiveness of these compounds, leading to the development of 2nd (e.g. carboplatin, nedaplatin, etc.) and 3rd (e.g. oxaliplatin, heptaplatin, etc.) generation platinum drugs[1]. However, there is still a need to better understand the factors that determine the antitumor activity of platinum-based organometallic compounds[2]. In this study, we investigated a series of new organometallic compounds containing phenanthroline (phen) and σ-C_2H_4OEt groups bonded to the central Pt(II) ion, along with a variable L ligand (DMSO, NH_3, 1-hexyl-1H-imidazole, or 1-hexyl-1H-benzo[d]imidazole). These complexes were synthesized from the precursor complex of the type $[PtCl(\sigma\text{-}C_2H_4OEt)(phen)]$ (**1**), which was then reacted with an entering ligand to replace the coordinated halide[3]. The resulting complexes, $[Pt(DMSO)(\eta^1\text{-}C_2H_4OEt)(phen)]^+$ (**2**), $[Pt(NH_3)(\eta^1\text{-}C_2H_4OEt)(phen)]^+$ (**3**), $[Pt(1\text{-hexyl-1H-imidazole})(\eta^1\text{-}C_2H_4OEt)(phen)]^+$ (**4**), and $[Pt(1\text{-hexyl-1H-benzo[d]imidazole})(\eta^1\text{-}C_2H_4OEt)(phen)]^+$ (**5**), were then tested for their anticancer activity on various tumor and healthy immortalized cell lines[4,5]. The cytotoxic activity of these complexes was compared to that of cisplatin. Initial results showed that the cytotoxic activity increased in the order **3** < **2** < **4** < **5**, which can be attributed to the increasing hydrophobicity and intercalating ability of the L ligand, leading to different mechanisms of action. Complex **5** exhibited the highest level of cytotoxicity against the HeLa cell line, while complex **4** showed the highest selectivity for malignant cells (Caki-1). Furthermore, the effects of these new compounds on cell migration and invasion processes were evaluated, indicating their potential to prevent the induction of metastasis.

References:

[1] T.C. Johnstone, K. Suntharalingam, *et al*., Chem. Rev. 2016, 116, 3436–3486, and references therein.
[2] K. Peng, Y. Zheng, *et al*., Chem. Soc. Rev. 2023, 52, 2790 – 2832, and references therein.
[3] F. De Castro, E. Stefàno, *et al*., Pharmaceutics 2021, 13, 642.
[4] E. Stefàno, L.G. Cossa, *et al*., Bioinorg. Chem. and Appl. 2023, 2023, e5564624.
[5] E. Stefàno, F. De Castro, *et al*., Inorg. Chim. Acta 2023, 546, 121321.

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INO-OR-003

Design of Cu-based Electro-Catalysts for Renewable Fuels Production through CO_2 Reduction

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Electrochemistry is a very promising and appealing technology able to accomplish the conversion of renewable sources into fuels for energy applications in a green way, alternative to the traditional fossil fuels, such as the CO_2 reduction reaction (CO_2RR) into valuable C_1-C_{2+} products. However, the possibility of exploiting these catalytic routes to produce fuels at large scale is still strongly affected by the selection of the best catalysts and the optimization of the process parameters.

In this context, different Cu oxides (selected for their strong coordination ability with CO intermediates)[2] and Cu-containing mixed Ni-Co-Zn ferrites were synthesized following different soft-chemistry approaches (i.e., co-precipitation, hydro/solvothermal, sol-gel routes), by varying the Cu oxidation state, the chemical surrounding, and the final morphology (i.e., size/shape, aspect ratio, crystal planes orientation). In particular, in the case of the mixed ferrites, different degrees of Cu-substitution were investigated.[3]

The most promising Cu-containing compounds were deeply characterized, evidencing their morphological and physicochemical properties, and compared with reference substrates. This way, an effective screening of the fundamental properties necessary for maximizing their catalytic performances in electro-CO_2RR was achieved, monitoring how changes at the catalyst and process parameters level might enhance the yield of conversion and selectivity towards final products.

References:

[1] A.R. Woldu, Z. Huang, P. Zhao, L. Hu, D. Astruc, Coord. Chem. Rev. 2022, 454, 214340.
[2] R.-Z. Zhang, B.-Y. Wu, Q. Li, L.-L. Lu, W. Shi, P. Cheng, Coord. Chem. Rev. 2020, 422, 213436.
[3] R. Nisticò, R. Mantovan, M. Cantoni, C. Rinaldi, M. Malandrino, S. Mostoni, M. D'Arienzo, B. Di Credico, R. Scotti, J. Alloys. Compd. 2024, 981, 173628.

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INO-OR-004

Ternary Lanthanide (III) complexes with Fluoride ion: solution structures and dynamics investigated with ^{19}F-CEST

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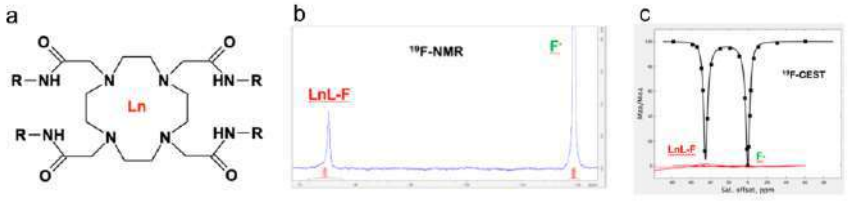
Chemical exchange saturation transfer (CEST) is a powerful NMR technique that enables the investigation of dynamic processes between two (or more) chemicals in which a given nuclear spin displays a different chemical shift in the mutually exchanging species. CEST has found relevant applications in the field of ^{1}H-MRI, where it can reveal the presence of low-concentration solutes via the transfer of their saturated magnetization to a bulk nucleus, from which the MRI signal is detected. Moreover, heteronuclear CEST has an important advantage in terms of detection sensitivity because the response is directly dependent on the molar fraction of the saturated spins over the bulk ones, which is several orders of magnitude higher when the bulk signal is different from water protons. ^{19}F nucleus is well suitable for this purpose due to the high NMR receptivity and null biological background. However, the development of ^{19}F-CEST is still in its infancy with few literature reports.[1-2] In this contribution, ^{19}F-based CEST was assessed to investigate, for the first time, the dynamics of the metal-binding of fluoride ions in a series of tri-positively charged lanthanide(III) complexes formed by tetra-amide derivatives of DOTA ligands (Fig. 1a). In an aqueous solution of the metal complex added with an excess of fluoride ions, the halide distributes between the bulk F- ion and the metal-bound fluoride (LnL-F, Fig. 1b). By analysing the dependence of the bulk F- NMR signal over the saturation frequency (Fig. 1c), it is possible to measure the exchange rate of the metal-bound fluoride and assess how it is affected by the structure of the metal complex. In addition, as the metal complexes themselves possess amidic protons in exchange with water, ^{1}H-CEST experiments were performed to evaluate whether their exchange is affected by the fluoride coordination to the metal center.



References:
[2] Peng Q, Yuan Y, Zhang H, Bo S, Li Y, Chen S, Yang Z, Zhou X, Jiang ZX. Org Biomol Chem. 2017 Aug 2;15(30):6441-6446.
[3] Shusterman-Krush R, Tirukoti ND, Bandela AK, Avram L, Allouche-Arnon H, Cai X, Gibb BC, Bar-Shir A Angew Chem Int Ed Engl. 2021 Jul 5;60(28):15405-15411.

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INO-OR-005

Hybrid Ag+/TiO2 nanocomposite coatings via Aerosol assisted atmospheric pressure plasma deposition for environmental remediation

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Nanocomposites have been a topic of increasing interest in the last decades because of their superior properties when compared to their single components. Metal oxide nanocomposites are largely studied for environmental remediation applications (such as wastewater treatment, photodegradation of organic pollutants or antimicrobial activity). In particular, NPs of TiO_2, an n-type semiconductor, show valuable photocatalytic properties, although affected by several drawbacks, such as a wide band gap of 3.2 eV that leads to a strong absorption in the UV region, thus requiring a high energy irradiation, and a fast electron-hole recombination rate. Noble metals nanoparticles, e.g. AgNPs, are often used as co-catalyst together with TiO_2 in order to reduce the electron-hole recombination time. On the other hand, there are very few examples in the literature on the applicability of Ag^+/TiO_2 composites in photocatalytic technologies, as they are more renowned for their antibacterial properties. Furthermore, the immobilization of photocatalysts onto a solid support can make them suitable and technologically viable for environmental applications, as they can be more easily retrieved and recycled.

In this work, the deposition of TiO_2-based nanocomposites coatings with the addition of $AgNO_3$ in a hybrid siloxane matrix by Aerosol Assisted Plasma Deposition (AAPD) will be presented. The versatility of AAPD has been well demonstrated by this research group in the past by depositing TiO_2, TiO_2/rGO and TiO_2/C_{60} nanocomposite coatings. Indeed, this technique allows to deposit thermodegradable or scarcely volatile species, hence also NPs, in nanocomposite coatings, keeping the activity and structure of the additive, e.g. enzyme, drugs, and so on.

In the present study the coatings are deposited in a dielectric barrier discharge reactor, feeding the plasma with two aerosol generators: one is fed with TiO_2 NPs dispersed in a HMDSO/isopropyl alcohol mixture, and the other with a $AgNO_3$ solution. The chemical composition and the morphology of the coatings have been characterized by means of FT-IR, EDX, profilometry, XPS, SEM and TEM analyses, evidencing the complex nature of the structure of these materials. The photocatalytic activity towards the degradation of methylene blue has been evaluated under UV light irradiation and rationalized. The recyclability of the photocatalysts was assessed over 3 cycles and even an improvement of the performances was found upon reuse; a post-operational characterization via XPS and ICP was carried out to better understand this result.

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Light-Activated Therapeutics: Designing Photoresponsive Bioactive Compounds with Ruthenium(II) Polypyridyl Complexes

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The quest for more precise and controlled photodynamic therapy (PDT) modalities has directed substantial interest towards the development of innovative photosensitizers (PSs) capable of targeting both tumorous and bacterial afflictions with high specificity. In this scenario, Ru(II)-polypyridyl complexes (RPCs) emerge as a promising class of compounds, attributed to their rich chemical-physical repertoire, which makes them ideal candidates as PSs for PDT. Their versatile chemistry allows for the fine-tuning of some important photophysical properties that can maximise their behaviour as PS.

The work explores the significant impact that strategic ligand design has on the photochemical and photobiological performance of RPCs, highlighting the potential for improved spatiotemporal control of drug activation. Our investigation begins with the employment of bis-heteroleptic RPCs decorated with extensive aromatic polypyridyl ligands, such as the popular benzo[i]dipyrido[3,2-a:2',3'-c]phenazine (dppn) ligand. In this arrangement, π-expansive chelate ligands into Ru(II)-scaffolds can change the lowest-lying excited state from ^{3}MLCT to long-lived intraligand ^{3}IL states, efficiently enhancing the crucial production of harmful cytotoxic oxygen species.[1] Secondly, to further extend the ^{3}MLCT emission and further improve the $^1O_2$ photosensitization, we investigate the incorporation of distinct organic chromophores on Ru(II)-scaffolds to form bichromophoric systems where the ^{3}IL states serve as an excited state energy reservoirs. Finally, extending the scope of our research, we introduce the principle of photoactivated chemotherapy (PACT) to the antibacterial field, introducing the term *photorelease antimicrobial therapy – PAT,* by exploiting the unique photophysical properties of RPCs to trigger the release of Metronidazole-derivatives in a controlled manner, offering a chance to specifically activate the drug and thus reduce the development of antibiotic resistance.[2,3]

Our findings highlight the critical role of ligand architecture in dictating the efficiency and versatility of RPCs as PSs. By advancing our understanding of these mechanisms, we are paving the way for the development of next-generation phototherapeutic agents capable of addressing the complexities of tumour and bacterial disease treatment through enhanced precision and efficacy.

References:

[1] G. E. Giacomazzo, M. Schlich, L. Casula, L. Galantini, A. Del Giudice, G. Pietraperzia, C. Sinico, F. Cencetti, S. Pecchioli, B. Valtancoli, L. Conti, S. Murgia, C. Giorgi, Inorg. Chem. Front. 2023, 10, 3025.
[2] G. E. Giacomazzo, L. Conti, A. Guerri, M. Pagliai, C. Fagorzi, P. S. Sfragano, I. Palchetti, G. Pietraperzia, A. Mengoni, B. Valtancoli, C. Giorgi, Inorg. Chem. 2022, 61 (18), 6689-6694
[3] G. E. Giacomazzo, L. Conti, C. Fagorzi, M. Pagliai, C. Andreini, A. Guerri, B. Perito, A. Mengoni, B. Valtancoli, C. Giorgi, Inorg. Chem. 2023, 62, 7716-7727.

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INO-OR-007

Gold-Catalyzed Cycloisomerization and Hydration/Homocoupling Reactions of Terminal Alkynes

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Over the last few decades, due to their π-affinity, gold(I) and gold(III) complexes have been mostly applied in the activation of terminal alkynes toward inter- and intramolecular nucleophilic attack.[1] Within this domain, cycloisomerization and hydration/homocoupling reactions have emerged as robust methodologies for the production of cyclic and acyclic organic compounds, respectively.[2] Following ongoing investigations into the influence of counterions and oxidation state[3] at the metal centre of N-heterocyclic carbene (NHC) gold catalysts towards the cycloisomerization reaction of N-propargyl amides, this study has been broadened to include the hydration/homocoupling reaction of terminal alkynes.

In this work, starting from the homologues series of NHC-gold(I)X and NHC-gold(III)X_3 (X = Cl, Br or I) complexes applied as catalysts in the cycloisomerization reaction, these catalysts were employed in the hydration/homocoupling of the phenylacetylene, chosen as the benchmark reaction for this work. The reactions were performed by using water under additive-, silver- and acid-free conditions,[4] at 110°C, with a catalysts load of 0.5% molar. Methanol was chosen as the solvent and the reactions were performed under both solvent and solvent-free conditions. Interestingly, under solvent-free condition, an homocoupling reactions occurred and 1,4-diphenylbuta-1,3-diyne was selectively obtained as sole product (on the left, Figure 1). Conversely, acetophenone and small amount of phenylacetaldehyde were obtained when methanol was present in the system (on the right, Figure 1).

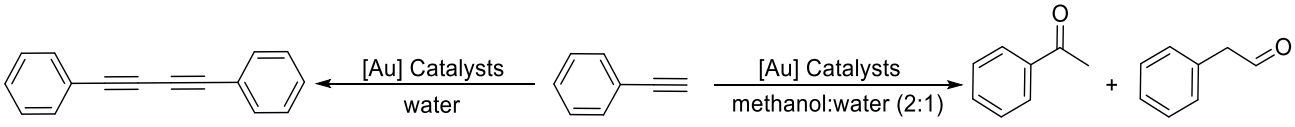

Figure 1: Selective solvent-controlled hydration/homocoupling of phenylacetylene NHC-gold-catalyzed.

References:

[1] R. Dorel, A. M. Echavarren, *Chemical Reviews*, **2015**, *115*, 17, 9028–9072
[2] A. S. K. Hashmi, *Chemical Reviews*, **2007**, *107*, 7, 3180–3211
[3] R. Galassi, N. Sargentoni, L. Luciani, G. Manca, A. Ienco, *Inorganica Chimica Acta*, **2024**, *560*, 1218101 - 1218109
[4] M. Gatto, A. Del Zotto, J. Segato, D. Zuccaccia, *Organometallics* **2018**, *37*, 24, 4685–4691

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TARGETING MCT1: FROM FLUORINE TO COPPER IN NUCLEAR MEDICINE

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MCT1 is a membrane protein responsible for the transport of lactate normally expressed in healthy tissues. However, in some cancer lines its expression results dysregulated and allows the establishment of the "Warburg effect". This mechanism explains the aggressive character of specific tumoral types and allows MCT1 to be a potential target for theranostic applications in oncological field[1]. To date, only few molecules acting as inhibitors for MCT1 are known[2], and the interaction of some of them with MCT1's pocket has been elucidated by Xray crystal data[3]. Some of these are Diclofenac and 7ACC2, a Coumarin derivative.

Coumarins are natural phyto-compounds known since the 19th century, their scaffold has attracted the attention of synthetic and medicinal chemists for decades and showed a large variety of biological activities[4]. One of the recently developed MCT1 inhibitor (7ACC2), that reached clinical trials, is a coumarin derivative[2].

Starting with preliminary docking calculations, the structure of 3-carboxy,7-hydroxycoumarin and Diclofenac was modified to retain a high affinity for the protein structure and to insert an additional specific moiety that allows the radiolabelling with 18-Fluorine.

18-Fluorine was the first radionuclide considered because of its wide presence in the everyday reality of nuclear medicine departments and because of the small structural modification that it induces on the radiolabelled molecule. However, it is a pure positron emitting isotope. For this reason, its application is limited to diagnosis. Our intention is to shift to the use of a bifunctional chelator (BFC) approach to envision Copper (II) isotopes radiolabelling. This would indeed permit to reach the so called "theranostic-pair approach" exploiting different copper isotopes (61-Cu, 64-Cu and 67-Cu). To exploit a radio-metal such as copper, a suitable chelating system must be grafted on the targeting vector trying to reduce the impact on the interaction with the target protein as much as possible. For such goal, a known bifunctional polyazamacrocycle, namely no3py[5] was conjugated on the targeting vector using a PEG chain as a spacer.

References:

[1] V. L. Payen, E. Mina, V. F.Van Hée, P. E. Porporato, P.Sonveaux, Mol. Metab., 2020, 33, 48.
[2] S. Puri, K. Juvale, Eur. J. Med. Chem., 2020, 199, 112393.
[3] V.L. Payen, E. Mina, V. F. V. Hée, P. E. Porporato, P. Sonveaux, Mol. Metab., 2020, 33, 48-66.
[4] N. Wang, et al., Cell, 2021, 184, 370-383.
[5] A. Guillou et al., Eur., J. Inorg. Chem., 2017, vol. 18, 2435–2443

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INO-OR-009

Disclosing the role of catalyst-substrate interaction and surface dynamics in liquid-phase heterogeneous catalysis

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NMR relaxometry can be used to guide the understanding of a catalytic reaction considering that the molecule-catalyst interaction is one of the fundamental parameters of a catalytic cycle. By high-field liquid state ^{13}C NMR analyses (400 MHz) the relaxation time (T1) of organic molecules in the presence of a solvent can be measured [1]. Precisely, the T1bulk is measured for the molecule in solution and the T1ads in the presence of the catalyst; a decrease of the T1ads is expected when the molecule interacts with the catalyst surface, so NMR experiments in high-field allow collecting information of local molecular dynamics, where the variation in T1 is essentially a proof of a preferred orientation. However, the absence of a preferred orientation does not always imply the absence of interactions. For this reason, similar adsorption measurements at low field (20 MHz) can be critical to prove the reality of the surface dynamics [2]. As consequence, ^{1}H Low-Field NMR and ^{13}C High-Field NMR could be considered as complementary analyses to collect information on local molecular dynamics and on surface dynamics, returning a complete picture of the interaction between a molecule and a catalyst.

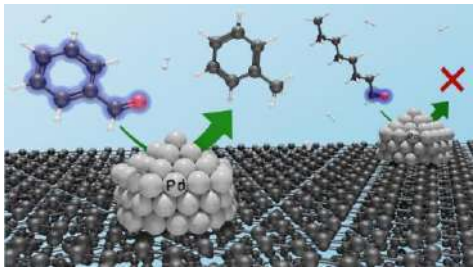

Fig. 1 Aromatic and aliphatic aldehydes hydrogenation on Pd/C catalystss

The hydrogenation of an aliphatic (n-octanal) and aromatic (benzaldehyde) aldehyde in p-xylene has been selected as case-study reaction by Pd/C catalyst (Fig. 1). Pd/C showed a very different activity towards the two substrates, which was correlated with the different T1ads/T1bulk ratio. In particular, by NMR we demonstrated the fundamental role of the solvent and by parallel low-field NMR experiments we were able also to qualify and quantify the affinity of the substrates with the catalytic surface.

References:

[1] M. Stucchi, F. Vasile, S. Cattaneo, A. Villa, A. Chieregato, B.D. Vandegehuchte, L. Prati, Nanomaterials 2022, 12(6), 208.
[2] M. Stucchi, J.P. Korb, O. Serve, V. Livadaris, B.D. Vandegehuchte, L. Prati, Journal of Catalysis 2023, 428, 115168.

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Paddlewheel diruthenium complexes: potent inhibitors of amyloid-beta aggregation

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Metallodrugs have attracted a great deal of interest in the field of neurological disorders due to their potential to effectively modulate the aggregation of amyloid proteins, a prominent feature of many neurodegenerative diseases. These conditions are characterized by the build-up of misfolded proteins, like amyloid-beta (Aβ) in Alzheimer's disease and the subsequent formation of toxic amyloid fibrils[1]. Due to their unique properties, metal complexes can inhibit the formation of large oligomers through direct and indirect interactions with amyloid peptides. Several studies have shown that ruthenium (Ru)-based complexes are an excellent choice due to their capability to inhibit the aggregation and toxicity of Aβ. Within the group of Ru-compounds, paddlewheel diruthenium complexes (Ru_2^{5+}) have emerged as source of inspiration for drug design, because they offer a novel plethora of valuable molecular scaffolds that are not possible with mononuclear compounds[2-3]. Herein, we report on the ability of two paddlewheel diruthenium compounds to act as aggregation modulators of $A\beta_{1-42}$ and its peculiar fragments $A\beta_{1-16}$ and $A\beta_{21-40}$ (Figure 1)[4]. By means of different spectroscopic (e.g., fluorescence assays, UV-vis absorption, and electrospray ionization mass spectrometry) and microscopic (scanning electron microscopy and confocal microscopy) techniques and cellular assays, their Mechanisms Of Action (MOAs) have been elucidated. The overall data may open new perspectives for the use of Ru_2-based compounds as novel neurodegenerative therapeutics.

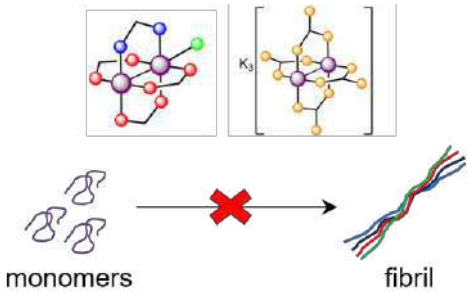

Figure 1: schematic representation of MOAs of diruthenium complexes targeting Aβ peptide.

References:

[1] E. J. Anthony, E. M. Bolitho, H. E. Bridgewater, O. W. Carter, J. M. Donnelly, C. Imberti, E. C. Lant, F. Lermyte, R. J. Needham, M. Palau, Chemical Science 2020, 11, 12888-12917.
[2] I. Tolbatov, E. Barresi, S. Taliani, D. La Mendola, T. Marzo, A. Marrone, Inorganic Chemistry Frontiers 2023, 10, 2226-2238.
[3] A. Terán, G Ferraro, A.E. Sánchez-Peláez, S. Herrero, A. Merlino, Inorganic Chemistry 2023, 62, 670–674.
[4] S. La Manna, C. Di Natale, V. Panzetta, M. Leone, F. A. Mercurio, I. Cipollone, M. Monti, P. A. Netti, G. Ferraro, A. Terán, A. E. Sánchez-Peláez, S. Herrero, A. Merlino, D. Marasco, Inorganic Chemistry, 2023, 63, 564–575.

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INO-OR-011

Copper(II) Salben Complexes as Efficient Catalysts in C-N Coupling Reactions

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H_2salben (Figure 1a, X = H) is a tetradentate Schiff base derived from the condensation of salicylaldehyde (salH) with phenylmethanediamine. This N_2O_2 ligand can coordinate various metal ions, including copper,[1] cobalt,[1] iron and manganese,[2,3] and the presence of only one carbon atom bridging the two iminic groups leads to the selective formation of oligonuclear complexes.[1-3] In particular, the complexation of copper(II) and H_2salben results in the dinuclear [Cu_2(μ-salben)$_2$] (Figure 1b, X = H).[1] The copper(II) ions in this complex exhibits a coordination geometry between tetrahedral and square planar, which confers the possibility to stabilize also copper(I). Therefore, this species is highly suitable for catalytic applications, as it can be easily handled in air while being readily activated *in situ*. In this contribution, a series of different substituted sal(X)ben copper(II) complexes have been synthesized and tested in catalysis. The steric and electronic effects of the substituent X have been explored on a prototype C-N cross coupling reaction (Figure 1c). The best performing catalyst has demonstrated high reactivity and selectivity and afforded the coupling product in high yields at low catalytic loadings and under relatively mild conditions. The reaction's scope has been then explored, highlighting the catalyst activity toward a broad range of substrates.

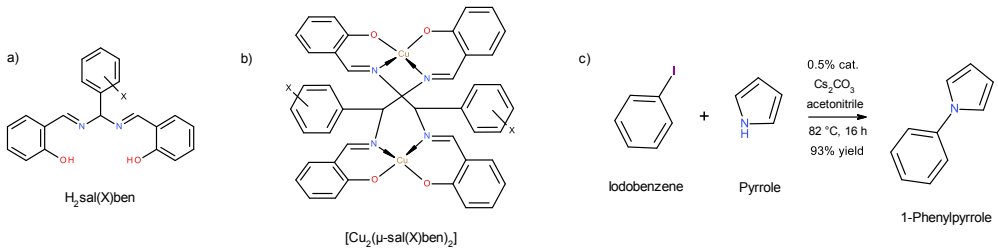

Figure 1: Molecular scheme of a) H_2sal(X)ben and b) [Cu_2(μ-sal(X)ben)$_2$]; c) prototype catalytic reaction.

Acknowledgments: Dipartimento di Scienze Chimiche e Geologiche of the Università degli Studi di Modena e Reggio Emilia through the Fondo Dipartimentale per la Ricerca year 2021 (FDR2021 linea dottorato).

References:

[1] A. Pasini et al., *J. Chem. Soc., Dalton Trans.*, **2000**, 3467–3472; **2001**, 3611–3616; **2002**, 4672–4677.
[2] L. Rigamonti et al., *Int. J. Mol. Sci.*, **2020**, *21*, 7882.
[3] L. Marchi et al., *Int. J. Mol. Sci.*, **2023**, *24*, 5808.

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Towards Atomically Precise Gold Nanoclusters Application in Nanomedicine

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Despite the late appearance of molecular gold nanoclusters (AuNCs) stabilized by N-heterocyclic carbene (NHC) ligands,[1] we have successfully reported a new synthetic methodology to obtain three new classes of mixed PPh_3 and NHC ligated AuNCs through a controllable reaction sequence.[2]

Exploiting the strict stoichiometric control on the ligand sphere, a precise structural regulation at atomic level of these nanometric supramolecules is derived, also reflected in their chemical physical properties.

Relying on a robust synthetic approach, a systematic study in complex biological media is accessible, aimed at assessing their stability, optical properties, and possible interactions with biomacromolecules, up to clarify the impact of NHC ligated AuNCs on cellular recognition and response.

Supported by the promising results of gold-based species as potential anticancer agents and their actual involvement in medicine as anti-inflammatory drugs, we describe here AuNCs as novel engineerable vectors for the target delivery of gold units. More in-depth, their size in the nanometric region joined with their controlled biodegradability to gold complexes under physiological conditions can be a powerful tool for unlocking anticancer agents with an unprecedented selectivity and effectiveness.[3]

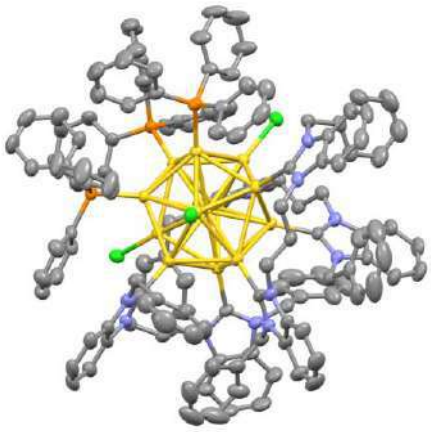

Figure 1*:* Crystal structure of a type **3** cluster $[Au_{13}(di\text{-}NHC)_3(PPh_3)_3Cl_3]^{2+}$

References:
[1] C. M. Crudden et al., Nat. Chem. 2019, 11 (5), 419-425.
[2] M. Bevilacqua, M. Roverso, S. Bogialli, C. Graiff, A. Biffis, Inorg. Chem. 2023, 62, 1383-1393.
[3] T. Bürgi et al., ACS Appl. Mater. Interfaces 2022, 14 (26), 29521-29536.

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High-Throughput Experimentation (HTE) in Catalytic Olefin Polymerization: a Powerful Tool to Investigate Complex Materials

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In this study, a state-of-the-art high-throughput experimentation (HTE) workflow for catalytic olefin polymerization,[1,2] covering an unprecedented wide part of the polymer knowledge and value chains from catalytic synthesis all the way down to "engineering" microrheology, was thoroughly assessed with respect to its ability to prepare new materials and produce large and accurate databases for the investigation of quantitative structure−property relationships (QSPRs).

Olefin block copolymers (OBCs) produced under chain-shuttling polymerization conditions were used as a demonstration case. The strategy was to integrate offline a 48-cell PPR platform with a debottlenecked array of high-end characterizations that were compatible with the low yields (100−300 mg, generally) of PPR cells, namely R-GPC, ^{13}C NMR spectroscopy with high-temperature cryoprobe technology, analytical crystallization elution fractionation (A-CEF), and microcapillary rheometry.[3]

The results of a thorough microstructural, structural, mechanical, morphological, and rheological characterization of OBC replicas prepared with the HTE synthetic platform and a commercial sample, chosen as a benchmark, demonstrate the robustness of the approach.[4] The proposed workflow can become a paradigm for the high-throughput synthesis and investigation of novel materials, thus reducing the time to market of new products. In our opinion, this opens the door to integrated HTE and artificial intelligence approaches to QSPR problem solving in the numerous cases for which a thorough understanding of the theory is not sufficient to deterministically unravel the complexity of practical applications.

References:

[1] Vittoria, A.; Busico, V.; Cannavacciuolo, F. D.; Cipullo, R. Molecular Kinetic Study of ″chain Shuttling″ Olefin Copolymerization. *ACS Catal*. **2018**, *8*, 5051−5061.

[2] Ehm, C.; Mingione, A.; Vittoria, A.; Zaccaria, F.; Cipullo, R.; Busico, V. High-Throughput Experimentation in Olefin Polymerization Catalysis: Facing the Challenges of Miniaturization. *Ind. Eng. Chem. Res*. **2020**, *59*, 13940−13947.

[3] Tammaro, D.; D'Avino, G.; Costanzo, S.; Di Maio, E.; Grizzuti, N.; Maffettone, P. L. A Microcapillary Rheometer for Microliter Sized Polymer Characterization. *Polym. Test.* **2021**, *102*, 107332.

[4] Vittoria, A.; Urciuoli, G.; Costanzo, S.; Tammaro, D.; Cannavacciuolo, F. D.; Pasquino, R.; Cipullo, R.; Auriemma, F.; Grizzuti, N.; Maffettone, P. L.; Busico, V. Extending the highthroughput experimentation (HTE) approach to catalytic olefin polymerizations: From catalysts to materials. *Macromolecules* **2022**, *55*, 5017−5026

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Selective oxidation of halogenated phenols catalyzed by a miniaturized heme-enzyme: insight into the mechanism of action

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Metalloprotein design is currently aimed at reproducing, enhancing or even expanding the properties of natural metalloenzymes by means of artificial biocatalysts.[1] Miniaturization represents one of the strategies employed for this purpose. This approach seeks to identify the minimal peptide scaffold bearing the necessary information to reconstruct the coordination environment of a metal binding site, thus preserving its catalytic function. Our research group has employed this strategy for the development of heme-containing synthetic biocatalysts, known as Mimochromes (MCs).[1] The latest and most promising member of this family, MC6*a, demonstrated to act as an exceptional and versatile catalyst, enabling a wide range of functionalities after metal ion replacement.[2-4] Herein, we have further expanded the catalytic potential of Fe-MC6*a by investigating its ability to catalyze the oxidation reaction of 4-halogenated phenols.[5] Unlike all natural and artificial metalloenzymes tested thus far in the same reaction, Fe-MC6*a induces substrate-dependent chemo-divergent transformations, selectively producing oxidative dehalogenation or oligomerization products, depending on the nature of the halogen atom in the substrates. Mechanistic studies have been performed to elucidate this peculiar reactivity. This investigation not only underlines the unique role of Fe-MC6*a in oxidative catalysis but also suggests the use of this biocatalyst for future applications, such as bioremediation and the synthesis of complex halophenol-derived building blocks.

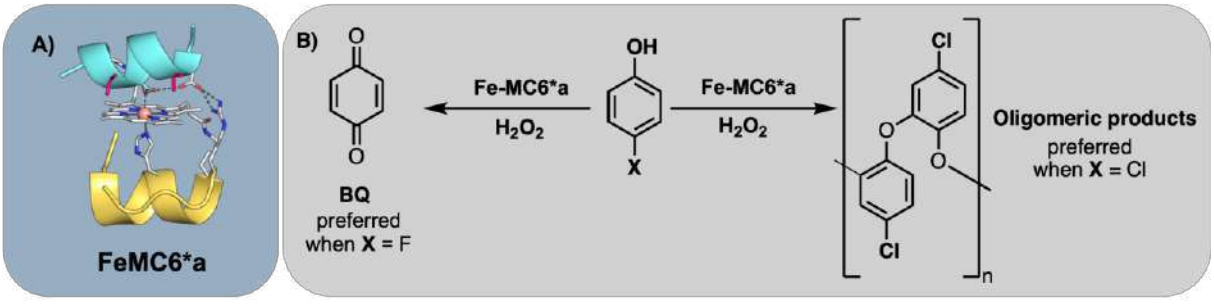

Figure 1: Selective oxidative dehalogenation of 4-XP catalyzed by FeMC6*a.

References:

[1] F. Nastri *et al. Trends Biochem. Sci.* 2019, 44, 1022–1040 and references therein.
[2] G. Caserta *et al. ChemBioChem.* 2018, 19, 1832-1826
[3] L. Leone *et al. ACS Catal.* 2021, 11, 9407–9417.
[4] V. Firpo *et al. Chem. Sci.* 2018, 9, 8582-8589.
[5] D. D'Alonzo *et al. Int. J. Mol. Sci.* 2023, *24*, 8058.

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Zinc(II) Complexes with Schiff bases of 5-pyrazolones acting as Zinc Metallochaperones for Mutant p53 Reactivation

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Schiff bases are a significant category of N,O-chelating ligands known for their notable biological properties, related to the azomethine (-CH=N-) or imine (-C=N-) group, as the imino nitrogen provides a binding site in drug activity, that can be enhanced through complexation with various transition metals.[1] In the context of Zn-based anticancer drugs, Zn(II) complexes with Schiff bases can serve as Zn suppliers in the reactivation of mutant p53, one of the most studied proteins as a cancer target. The p53 suppressor is a transcription factor that contains a single Zn^{+} near its binding interface. Insufficient or excess zinc causes p53 to misfold, inducing the loss of its tumour suppression.[3] Here we present a series of 4-aminoalkylidene-5-pyrazolone molecules, their Zn(II) derivative homoleptic complexes (figure 1), and correlation studies on their structural, photophysical and anticancer properties. Both Zn(II) complexes and their corresponding ligands underwent testing on U373 glioblastoma multiforme cell lines. Preliminary findings concerning the downregulation of p53 by some zinc derivatives are outlined. Additionally, a comprehensive theoretical examination is provided, focusing on the potential dissociation mechanism of the ligands in Zn(II) derivatives, paying specific attention to the impact of various substituents on the aromatic segment of the pyrazolone-based Schiff base ligands.

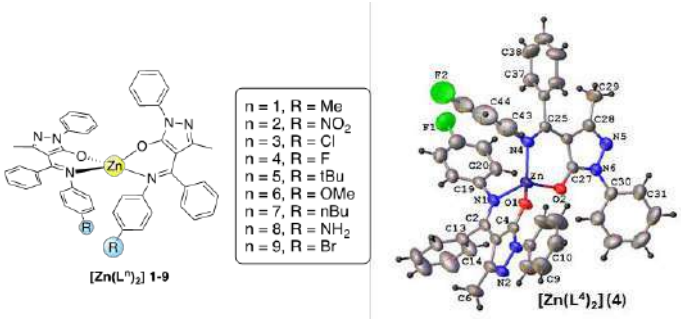

Figure 1

References:

[1] O. J. Abayeh, O. Achugasim, O. C. Eruteya, *World Sci. News* **2021**, *160*, 16–36.
[2] S. N. Loh, *Metallomics*, **2010**, *2*, 442-449.

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Di-Iron Complexes with Organosulfur Groups as Anticancer Agents

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Iron is an attractive element for developing drugs alternative to platinum chemotherapeutics, due to its bioavailability, non-toxicity in many forms, and feasible redox chemistry in physiological media. In the last years, we unveiled the anticancer potential of two families of dinuclear iron compounds resembling the structure of the active site of [FeFe] hydrogenase enzymes. Importantly, **I** and **II** feature a combination of appealing requisites for medicinal applications: multigram-scalable synthesis from inexpensive precursors, wide structural variability, adequate water solubility, and outstanding stability in aqueous media.[1] Over 70 compounds of types **I** and **II** have been preliminarily screened for their cytotoxicity in vitro, with some of them investigated in 3D cell models and also in vivo, providing promising results and highlighting structural-activity relationships that encouraged us to design novel structures with optimized activity.

It is extensively documented in the literature that incorporating sulphur functions is beneficial to the biological activity of diverse drug candidates.[2] Inspired by the anticancer properties and preventive effects of naturally occurring organosulfur compounds, the bridging vinyliminium ligand within **II** has been functionalized through the incorporation of sulphide moieties. The synthetic approach explored in this work takes advantage of the cooperative effects provided by the two adjacent iron atoms, that enable reactivity patterns otherwise unavailable on analogous monometallic compounds.

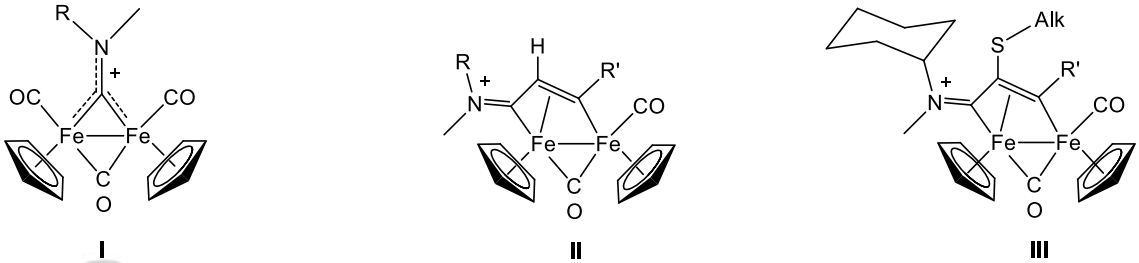

Figure 1: general structures of diiron complexes with anticancer activity (**I**, **II**) and derivatization with sulphide groups (**III**). Triflate or nitrate as counteranion. R, R' = alkyl or aryl groups; Alk = alkyl group.

References:

[1] D. Rocco *et al.*, Chem. Eur. J., 2019, 25, 14801–14816.
[2] (a) M. Feng *et al.*, Curr. Top. Med. Chem. 2016, 16(11), 1200-1216; (b) C. Cerella *et al.*, Anti-Cancer Agents Med Chem., 2011, 11, 267-271; (c) T. Ariga, T. Seki, BioFactors 2006, 26, 93–103.

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Does the Oxygen Evolution Reaction follow the classical OH*, O*, OOH* path on single atom catalysts?

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The Oxygen Evolution Reaction (OER) is a key part of water splitting. On metal and oxide surfaces it usually occurs via formation of three intermediates, M(OH), M(O), and M(OOH).[1] The last step consists of O_2 release. Generally, it was assumed that the same path occurs on single atom catalysts (SACs). [1] However, the chemistry of SACs may differ substantially from that of extended surfaces and is reminiscent of that of coordination compounds.[2,3] This raises the question of whether on SACs the OER follows the classical mechanism or not. Indeed, a set of 30 SACs were prepared by anchoring a metal atom (Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Pd and Pt) in a carbon matrix (graphene, nitrogen-doped graphene and carbon nitride). Conventional and unconventional pathways, see Figure 1, were then considered,[4] and in all cases at least one unconventional intermediate was found to be more stable than the classical one.

This demonstrates that the assumption done in modelling OER on bulk materials can not be transferred to the SACs as it is. Completely different prediction on the activity of SACs in OER can be made if one follows the assumption that only a sub-set of intermediates can form. Indeed, only once all the possible intermediates are considered, one can speculate about the preferred reaction pathway. The pathway followed to form O_2 from H_2O is metal and support dependent underling the complexity of this "simple" reaction. As an example, on Ti@DV-Gr, only one unconventional intermediate forms, η^2-O_2*. Different is the case of Fe@C_3N_4, where the entire pathway is characterised by the formation of unconventional intermediates. Considering Sc@4N-Gr, two intermediates are "classical" and two are unconventional. Finally, on Pd@C_3N_4 the classical and the unconventional paths lead to completely different predictions about the reactivity of the SAC.

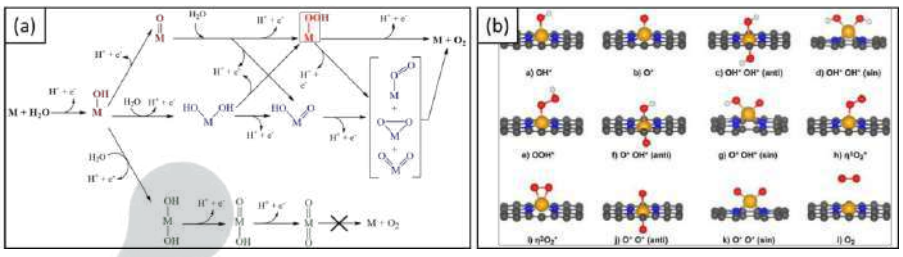

Figure 1: (a) OER scheme were the formation of all possible "classical" (in red) and "unconventional" intermediates (blue and green) are showed and (b) Possible OER intermediates on SACs.

References:

[1] J. K. Nørskov, J. Rossmeisl, A. Logadottir, J. Phys. Chem. B 2004, 108, 17886.
[2] L. A. Cipriano, G. Di Liberto, G. Pacchioni, ACS Catal. 2022, 12, 11682.
[3] G. Di Liberto, L. A. Cipriano, G. Pacchioni, J. Am. Chem. Soc. 2021, 143, 20431.
[4] L. Zhong, S. Li, ACS Catal. 2020, 10, 4313.

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INO-OR-018

Naproxen-gold (I) Complex as Innovative Approach Against *Staphylococcus* Species Diseases

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Nowadays, multidrug-resistant *Staphylococcus* strains are involved in nosocomial infections with high morbidity and mortality[1]. Consequently, antimicrobial agents with alternative mechanisms of action or targets are required. Repurposing drug investigations suggested Auranofin (AF, Figure 1), a gold(I) drug currently in clinical trials for treating rheumatoid arthritis, as an anti-*Staphylococcus* agent[2]. Therefore, in a previous study, AF and its *L*-acetylcysteine derivative (AF-AcCys, Figure 1) were tested against resistant strains of *S. aureus* and *S. epidermidis*[3]. Both compounds exhibited similar activity against *S. aureus*, while AF was 20-fold more active than AF-AcCys against *S. epidermidis* (Figure 1)[3]. Computational studies showed that the Au-S bond of AF-AcCys was slightly more stable than the one of AF (Figure 1) affecting the release of the cationic pharmacophore $[AuPEt_3]^+$ and consequently, their activity. Herein, we aimed to develop AF derivatives with a labile bond between the gold(I) pharmacophore and the ligand. Hence, the Naproxen (Npx) drug was selected as a ligand to replace the Au-S bond with the more labile Au-O bond. Additionally, the binding dissociation energy (BDE) evaluation of AF-Npx (Figure 1) confirmed its higher lability. Thus, AF, AF-AcCys, and AF-Npx were tested against *Staphylococcus* strains and biofilm formation. Subsequently, nanoparticles loaded with these drugs will be developed to determine the release and biological activity.

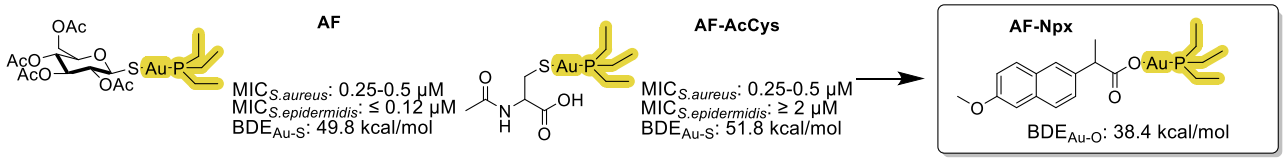

Figure 1: Chemical structures and experimental data of AF, AF-AcCys, and AF-Npx.

References:

[1] L. Wang, S. Ruan, Sci. Rep. 2017, 7 (1), 569 – 580.
[2] S. Thangamani, H. Mohammad, M.F.N. Abushahba, T.J.P. Sobreira, M.N. Seleem, Int. J. Antimicrob. Agents 2016, 47 (3), 195 – 201.
[3] L. Chiaverini, A. Pratesi, D. Cirri, A. Nardinocchi, I. Tolbatov, A. Marrone, M. Di Luca, T. Marzo, D. La Mendola, Molecules 2022, 27 (8), 2567 – 2578.

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Chiral Nickel(II)-based Metal-Hydroxide Organic Frameworks (MHOFs) as Spin-selective Catalysts of Oxygen Evolution Reaction

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Spin-polarized currents can reduce the overpotential required for the Oxygen Evolution Reaction (OER), which strongly limits the overall efficiency of the Electrochemical Water Splitting process (EWS).[1] Thanks to the Chiral Induced Spin Selectivity (CISS) effect,[2] chiral materials can create spin-polarized currents in the absence of external magnetic fields, promoting the formation of ground state O_2 ($S = 1$) while eliminating by-products with $S = 0$ (*e.g.*, H_2O_2). State-of-the-art catalysts for EWS are based on expensive and polluting noble metals like Pt and Ir. However, Metal Organic Frameworks (MOFs) containing first-row transition metals, including layered Metal-Hydroxide Organic Frameworks (MHOFs, see Fig. 1), are attracting increasing interest[3,4] due to their high surface area and porosity, low cost, "green" character, and tunability by chemical design. Since the use of CISS-active chiral MOFs (or MHOFs) as enhanced electrocatalysts for EWS is still an unexplored field, we synthesized a family of nanostructured chiral (Ni-C) and achiral (Ni-A) MHOFs based on Ni^{2+} and dicarboxylic ligands (Fig. 1), with low (1), intermediate (2) or high (3) crystallinity. The catalytic activity is found to increase with increasing crystallinity and Brunauer–Emmett–Teller (BET) surface area. More importantly, the current densities are systematically higher for the chiral samples than for the achiral ones (Fig. 1), confirming that chirality is a viable strategy to design efficient catalysts for EWS and OER.

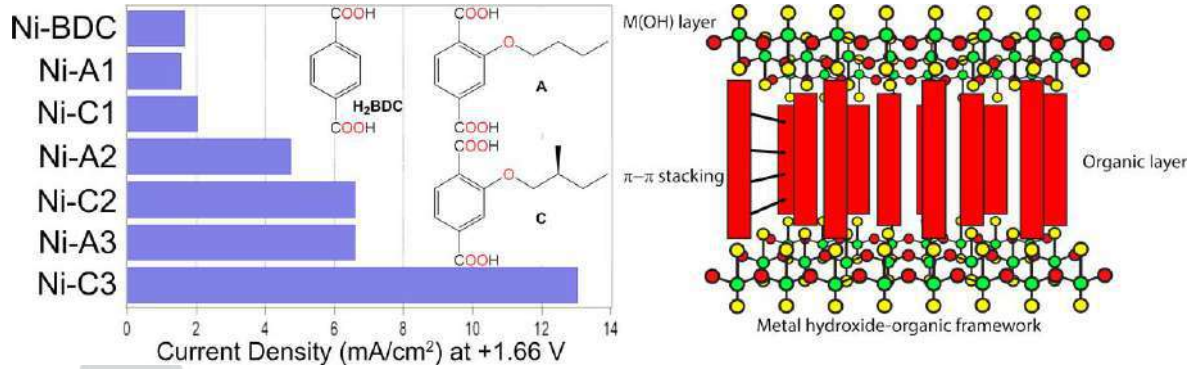

Figure 1: Left: Current densities of the Ni-MHOFs and structure of the ligands. Right: general model of a MHOFs.

References:

[1] W. Mtangi *et al.*, *J. Am. Chem. Soc.*, **2017**, *139*, 2794–2798.
[2] F. Evers *et al.*, *Adv. Mater.*, **2022**, *34*, 2106629.
[3] J. Du *et al.*, *Chem. Soc. Rev.*, **2021**, *50*, 2663–2695.
[4] S. Yuan *et al.*, *Nat. Mater.*, **2022**, *21*, 673-680.

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INO-OR-020

Exploring the efficacy of paramagnetic nanogels as MRI probes

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In recent years, nanogels (NGs) have gathered increasing interest among the wide array of nanoparticles for biomedical application. These soft and hydrophilic nanoparticles are composed of a 3D crosslinked network capable of retaining a large volume of water, thereby mimicking biological fluids[1]. NGs can be loaded with paramagnetic complexes, which are likely to exhibit a notable increase of relaxivity (r_1)[2]. Despite their appealing properties, little is known about the relaxometric properties and *in vivo* behaviour of these systems. For these reasons, we developed several paramagnetic NGs and fully characterized them. Specifically, we investigated: a) Ionic NGs incorporating Gd^{3+} complexes (type A NGs) with varying coordination geometries and hydration states (q = 2, 1, 0)[3,4]; b) Covalent NGs where Mn^{2+}/Gd^{3+}/Dy^{3+} chelates serve as both paramagnetic probes and cross-linking agents[5] (type B NGs). Ionic NGs demonstrated superior r_1 values compared to clinically available contrast agents, but low chemical stability in biological environment, with a tendency to degrade, leading to a rapid release of the paramagnetic complexes embedded in the matrix. Covalent NGs, instead, show r_1 values remarkably higher than that of clinical contrast agents at 1.5 T, high stability of the suspension in physiological conditions, with the absence of metal leaking or particles aggregation. *In vivo* test revealed good extravasation and accumulation of the NG, with high T_1 contrast (at 1 T) achieved at 24 h post-injection in mice bearing subcutaneous breast cancer model. We consider these findings to offer a valuable insight for the development of biocompatible, stable and efficient MRI probes.

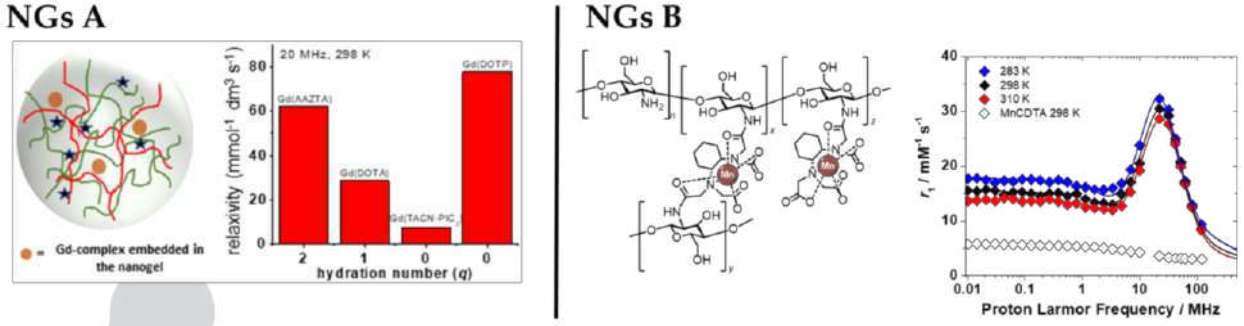

Figure 1: (left) Schematic representation of type A NGs incorporating Gd^{3+} chelates; (right) ^{1}H NMRD profiles of type B NGs crosslinked with Mn^{2+}-based complexes

References:

[1] Wang, H *et al. J. Mater. Chem. B*, 2017, 5, 6986-7007; [2] Courant, T. et al, *Angew. Chem., Int. E*d., 2012, 51, 9119-9122 ; [3] Carniato, F. *et al., ACS Appl. Bio. Mater.*, 2020, 3, 9065-9072 [4] Carniato, F. *et al., Inorg. Chem*. 2022, 61, 5380-5387 ; [5] Carniato, F. *et al., Small*., 2023, 19, 2302868-2302882

INO-OR-021

The crucial role of X-ray absorption spectroscopy for catalysts design

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Noble metal-based heterogeneous catalysts play a key role in clean air and environmental applications, since they are highly active for several oxidation reactions. On the other hand, the scarcity and high costs of platinum-group metals (PGMs) demand constant improvements in the design of these catalysts, by reducing the amount of the noble metal while maintaining or, ideally, improving their activity. Common approaches are identifying and stabilizing the active species, exploiting the interaction between the support and the noble metal, and tuning the catalyst structure during the operation (e.g., via pulses).

All these approaches are inevitably connected to the question of the structure of the active species and their fate under working conditions. PGMs are known to be highly mobile on many supports, yielding highly dynamic systems for which establishing structure-activity correlations is no trivial task.

Through the example of platinum-based catalysts for CO oxidation, it is shown how advanced characterization methods, like *operando* X-ray absorption spectroscopy,[1–3] are an essential and powerful complement to common characterization techniques for deriving accurate conclusions on the catalytic performances of the active sites (and in general, of functional materials), and for understanding how to manipulate them to improve the catalytic activity of PGM-based oxidation catalysts.

References:

[1] F. Maurer, J. Jelic, J. Wang, A. Gänzler, P. Dolcet, C. Wöll, Y. Wang, F. Studt, M. Casapu, J.-D. Grunwaldt, *Nat. Catal.* **2020**, *3*, 824–833.
[2] P. Dolcet, F. Maurer, M. Casapu, J.-D. Grunwaldt, *Catalysts* **2021**, *11*, 617.
[3] F. Maurer, A. Beck, J. Jelic, W. Wang, S. Mangold, M. Stehle, D. Wang, P. Dolcet, A. M. Gänzler, C. Kübel, F. Studt, M. Casapu, J. D. Grunwaldt, *ACS Catal.* **2022**, *12*, 2473–2486.

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Sn^{IV}-porphyrins/amino acid conjugates as mimic models for Artificial Photosynthesis

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Photosynthesis, a fundamental biological process, involves water oxidation reaction catalysed by three key steps in Photosystem II: initial absorption of visible light by the chromophore, followed by oxidation of the tyrosine donor and reduction of the quinone acceptor coupled with the transfer of a proton, through a *Proton Coupled Electron Transfer* mechanism (PCET).[1] Over the last decades, there has been a growing interest in developing systems that try to mimic natural ones, but most of them are covalent in nature, requiring demanding synthetic protocols.[2] To address this limitation, our focus turned on Sn^{IV}-porphyrins due to their distinctive electronic, optical and redox properties that make them intriguing as photoactive units.[3] Thus, we developed a family of Sn^{IV}-$(aa)_2$ porphyrins conjugates, with aa = *L*-tyrosine or *L*-tryptophan, that were easily assembled by axial ligation of the amino acid carboxylate moiety to the porphyrin metal centre. For two of such conjugates the formation of a radical pair state *via* PCET, by visible light excitation was observed (Figure, left).[4] Encouraged by these promising results, we altered both the relative position of the photoactive units, for instance by conjugating the amino acid residues at the porphyrin macrocycle periphery and the nature of the metal centre (Figure, right). Preparation, full characterization and photophysical studies of these new metallo-porphyrin/amino acid derivatives will be presented, also in comparison with the previously reported systems.

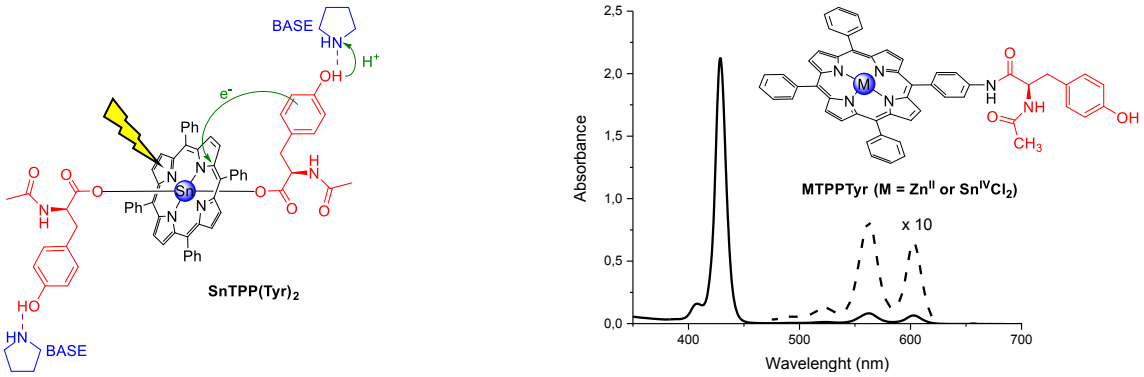

Figure. Left: Schematic representation of $SnTPP(Tyr)_2$ and photoinduced PCET. Right: Schematic representation of MTPPTyr.

References:

[1] N. Cox, D. A. Pantazis, F. Neese, W. Lubitz, Accounts of Chemical Research 2013, 46, 1588-1596.
[2] A. Pannwitz, O. S. Wenger, Dalton Trans 2019, 48, 5861–5868.
[3] D. P. Arnold, J. Blok, Coord. Chem. Rev. 2004, 248, 299-319.
[4] a) M. Natali, A. Amati, N. Demitri, E. Iengo, Chem. Commun. 2018, 54, 6148-6152. b) M. Natali, A. Amati, S. Merchiori, B. Ventura, E. Iengo, J. Phys. Chem. C. 2020, 124, 8514-8525. c) M. Natali, A. Amati, N. Demitri, E. Iengo, Chem. Eur J. 2021, 27, 7872-7881.

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INO-OR-023

Various Alkyne Functionalization Promoted By Coinage Metal N-Heterocyclic Carbene Complexes

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In recent decades, there has been increased investigation into the potential of late-transition metal owing to their relatively straightforward handling compared to traditional early-transition metal complexes, which are traditionally used in biological and catalytic applications.

In particular, Group 11 metal complexes featuring an *N*-heterocyclic carbene (NHC) ligand give result in readily tuneable species that may frequently be handled in non-inert environments and exhibit a variety of synthetic applications and bioactivities.[1] Our research group main focus is the development of silver(I) and gold(I) NHC complexes, active as catalysts in atom-economic multicomponent reactions, mainly involving carbon-carbon triple bond functionalization. These catalysts (Figure 1), whose imidazolium scaffold can be generated from readily available precursors,[2] are useful for the *A*[3] (aldehyde–amine–alkyne) coupling, hydroamination, and carboxylation of alkynes with a wide range of substrates, often in clean, green environments.

In this contribution, the synthesis and catalytic applications of our complexes will be covered, providing a mechanistic insight into three alkyne functionalizations which yielded us, respectively, propargylamines,[3] imines[4] and propiolic acids with conversions up to 99% in the presence of either our gold(I) or silver(I) based catalysts.

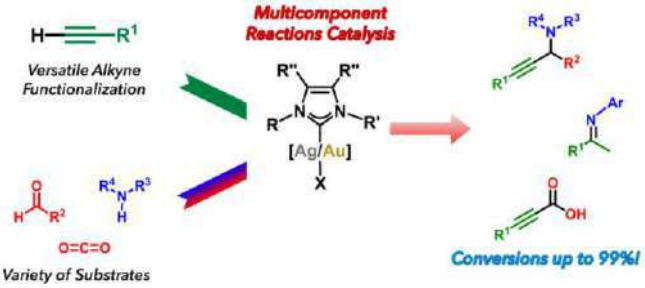

Figure 1: Multicomponent reactions promoted by Group 11 Ag(I)/Au(I) NHC complexes.

References:

[1] J.C. Lin, R.T. Huang, C.S. Lee, A. Bhattacharyya, W.S. Hwang, I.J. Lin, Chem. Rev. 2009, 109, 3561 – 3598.
[2] a) A. D'Amato, M. Sirignano, S. Russo, R. Troiano, A. Mariconda, P. Longo, Catalysts 2023, 13, 811; b) A. Mariconda, M. Sirignano, R. Troiano, S. Russo, P. Longo, Catalysts 2022, 12, 836.
[3] C. Costabile, A. Mariconda, M. Sirignano, A. Crispini, F. Scarpelli, P. Longo, New J. Chem. 2021, 45, 18509 – 18517.
[4] M. Sirignano, A. D'Amato, C. Costabile, A. Mariconda, A. Crispini, F. Scarpelli, P. Longo, Front. Chem. 2023, 11.

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INO-OR-024

Lignin-based hybrid drug delivery system for phytosanitary application

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Lignin is a complex biopolymer, particularly interesting because it is a low-cost material available in large quantities from renewable resources such as waste biomass[1].The chemistry and structural variability of lignin depend on the type of plant/waste from which it is extracted and the type of extraction process that is used. Thanks to the studies carried out on the chemical, physical and structural properties, lignin can be considered as a sustainable material that can be exploited because it can be used in many fields. Self-assembly and supramolecular organization of lignin are properties underlying the realization of drug delivery systems in the form of micro/nanocapsules or particles or a combination of them, capable of carring an active agent for the protection of agricultural and forest product, in the field of crop protection[2].

In this study, a bimodal drug delivery system has been developed using lignins obtained by organosolv processing from different biomasses. The system is characterised by a microscopic core-shell structure, with the shell being of lignin and the core containing a lignin nanoparticle dispersion. The dual character, *i.e.*, a microcapsule containing particles, allows for a timing mechanism that is based on different engineered stabilities of the systems.

Each system has been characterized in qualitative terms by studying morphology and size using microscopy techniques such as scanning (SEM) and transmission electron microscopy (TEM) and dynamic light scattering (DLS), respectively. The stability of the different formulations obtained has been studied through zeta-potential measurement and spectrophotometer release studies of the active agent, varying the salinity and pH conditions of the system. To take into account the variability and performance of the different systems in terms of lignins with different molecular structures, an in-depth structural characterization of the lignins used was carried out by spectroscopic (quantitative ^{31}P NMR, ^{1}H-^{13}C HSQC) and chromatographic (gel permeation chromatography) techniques.

The results of this work hold opportunities as innovative hybrid system for controlled drug delivery in the field of crop protection.

References:

[1] H. Lange, ED. Bartzoka, C. Crestini. De Gruyter, 2015, 257-282
[2] MH. Sipponen, H. Lange, C. Crestini, A.Henn, M. Österberg. ChemSusChem 2019, 12, 2039–2054

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Synthesis of mugineic acid family phytosiderophore analogues as low-cost and sustainable iron fertilizers for agriculture in poor soil

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Plants, like any living organisms, require a diverse array of essential nutrients to carry out fundamental physiological processes crucial for growth, development, and defence against environmental stressors. When these vital nutrients are lacking or insufficient in the soil, plants are susceptible to a range of adverse effects that compromise their health. Amongst these, iron chlorosis is a prevalent and widely observed nutrient deficiency, frequently occurring in plants cultivated in calcareous soils, resulting in the manifestation of yellowing leaves, drastic reduction in crop yield and demise of individual limbs or the entire plant. The main remedial approach for iron chlorosis involves the application of iron chelates as fertilizers - however, the synthetic pathways currently in use to produce most commercial products trace their origins back to the 1970s, lacking sustainability and contributing to pollution. Hence, it is crucial to investigate innovative, optimized processes to guarantee both cost-effectiveness and environmentally sustainable production.

To overcome this problem, it was previously proved by Prof. Namba's research group that the soil application of synthetic 2′-deoxymugineic acid (DMA), a natural phytosiderophore from the *Poaceae* family, can recover Fe deficiency in plants grown in calcareous soil. However, the high cost and poor stability of synthetic 2′-deoxymugineic acid preclude its agricultural use[1]. In this work, we develop more stable and less expensive proline-derivative (PDMA) analogues of DMA and demonstrate their practical synthesis, ability to create stable complexes with Fe(III) via DFT calculations, and biological activity.

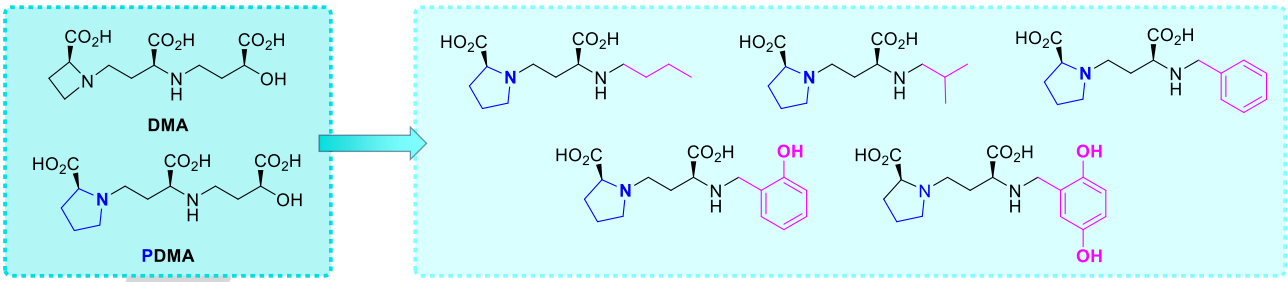

Figure 1: Previous results (left) and new differently substituted synthetic analogues of PDMA (right).

This publication is part of the project PNRR-NGEU which has received funding from the MUR – DM352/2022

References:

[1] M. Suzuki, A. Urabe, S. Sasaki et al., Nature Communications 2021, 12, 1558.

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INO-OR-026

Gold nanoparticles coated with glutathione for the design of targeted nanocarriers in personalized nanomedicine

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Gold nanoparticles (AuNPs) show peculiar chemophysical properties and have thus attracted in recent years the scientific interest of the academic and industrial communities for the design of tailored applications in personalized medicine. The self-assembly of glutathione-coated AuNPs (G-AuNPs) of ≈2 nm spontaneously produces, in physiological media, aggregates of ≈100-300 nm that are readily internalized in hepatic and neuronal cells [1] whereas the pristine singularly dispersed AuNPs are inactive. Aggregates of G-AuNPs functionalized with the dansyl chromophore are highly thermally responsive after excitation with a pulsed laser emitting in the near-infrared spectral region; considering the efficient penetration of this radiation throughout the tissues without damaging healthy cells this device can represent a powerful tool in photoablation of cancer cells.[1] Additionally, aggregates of G-AuNPs are efficient carriers of metal cations that can modulate the activity of glycogen synthase kinase 3 (GSK-3); the targeted in situ release of these metals at low dosage in specific cell compartments can allow fighting infectious and neurodegenerative diseases or controlling mood disorders regulated by GSK-3.[2] Finally, the incorporation of these systems in liposomes will be reported in this contribution, for the improved delivery of pharmaceuticals.

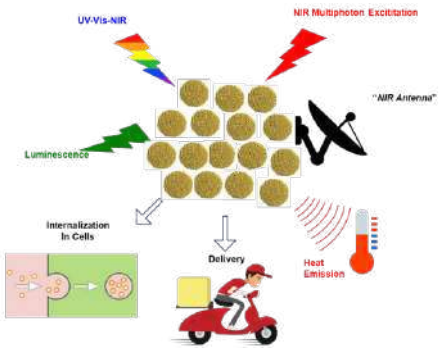

Figure 1. Functionalities of assembled glutathione-coated AuNPs.

References:

[1] A. Buonerba, R. Lapenta, A. Donniacuo, M. Licasale, E. Vezzoli, S. Milione, C. Capacchione, M. Tecce, A. Falqui, R. Piacentini, C. Grassi, A. Grassi. *Sci. Rep.* **2020**, 10(1): 11380.
[2] A. Buonerba, R. Piacentini, C. Grassi, A. Grassi. Use of glutathione-coated gold nanoparticles and functionalized with lithium (LiG-AuNPs) for the modulation of glycogen synthase kinase – 3 activity. *Patent*, PCT/IB2024/050915.

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Operando Study of Cobalt-Aluminum LDH for Oxygen Evolution Reaction

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This presentation focuses on the characterization of CoAl layered double hydroxide (LDH) as a viable, cost-effective electrocatalyst for efficient oxygen evolution rection (OER) in electrocatalytic water splitting under alkaline conditions. Morphological and compositional analyses were conducted using Transmission and Scanning Electron Microscopy (TEM, SEM), atomic force microscopy (AFM), and synchrotron radiation spectroscopy (at BACH beamline, Elettra), including x-ray photoemission spectroscopy (XPS) and near edge x-ray adsorption fine structure (NEXAFS). Operando NEXAFS and AFM were performed during OER.

Physical-chemical characterizations confirm that CoAl LDH has octahedrally coordinated Co with substitutional Al, and a homogeneous distribution of Co:Al in a 3:1 ratio. In electrochemistry, it exhibits a distinct activation trend with increasing activity in the OER. This enhanced activity is attributed to the leaching of Al and recrystallization, as revealed by operando measurements, which also show a unique redox behaviour different from the parent material, $Co(OH)_2$.[1] Operando measurements proved to be crucial for a comprehensive understanding, as pre- and post-catalysis analyses offer limited insights into real operating conditions.

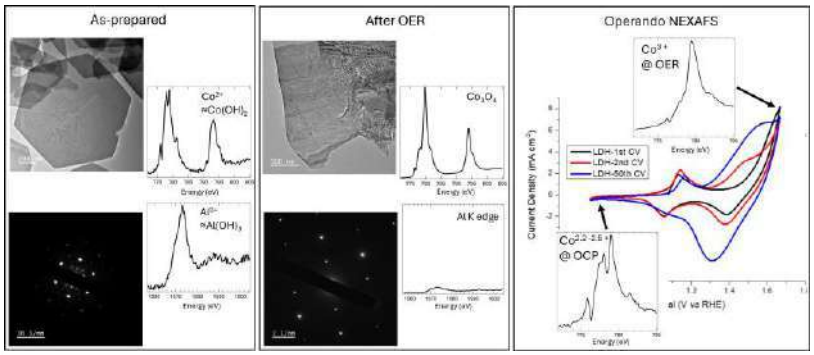

Figure 1: (Left) As-prepared TEM and NEXAFS measurements reveals CoAl LDH with Co^{2+} and Al^{3+} octahedrally coordinated, (centre) post-catalysis investigation shows Co_3O_4 and great loss of Al. (Right) Operando measurements prove a not trivial oxidation state at OCP with $Co^{2.2\text{-}2.5+}$, and Co^{3+} during OER.

References:

[1] J. Tyler Mefford, et al., Nature 2021, 593, 67-73

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INO-OR-028

Synthesis and Characterization of functionalized Gold Nanorods for Drug Delivery Applications

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Gold nanorods (AuNRs) have become increasingly popular in nanomaterials research due to their unique properties, including a tunable two-component surface plasmon resonance (SPR). This tunability makes AuNRs suitable for a wide range of biotechnological applications, from sensing to drug delivery. However, precise control of AuNR synthesis and functionalization is essential for reliable results[1,2]. We define a reliable route for AuNRs preparation and discuss in detail the surface functionalization of AuNRs using hydrophilic molecules such as L-cysteine, and demonstrate drug loading with *i*. a Cu(I) complex $[Cu(PTA)_4]^+PF_6^-$, known for its antitumour and antiviral activity, and *ii*. the radiopharmaceutical ^{99m}Tc-sestamibi, which is widely used for diagnostic purposes and whose theragnostic potential can be synergistically exploited with AuNRs for localised tumour cell damage[3]. Here, we describe our case studies that illustrate the tunability and versatility of AuNRs in different applications, and we present a multiphysics approach for the reliable structural, electronic and morphological characterization of these AuNRs, both in the bare (pristine) form and functionalized with specific molecules, carried out by combining complementary techniques: UV-Vis-NIR, DLS, XPS, XAFS, FE-SEM and TEM.

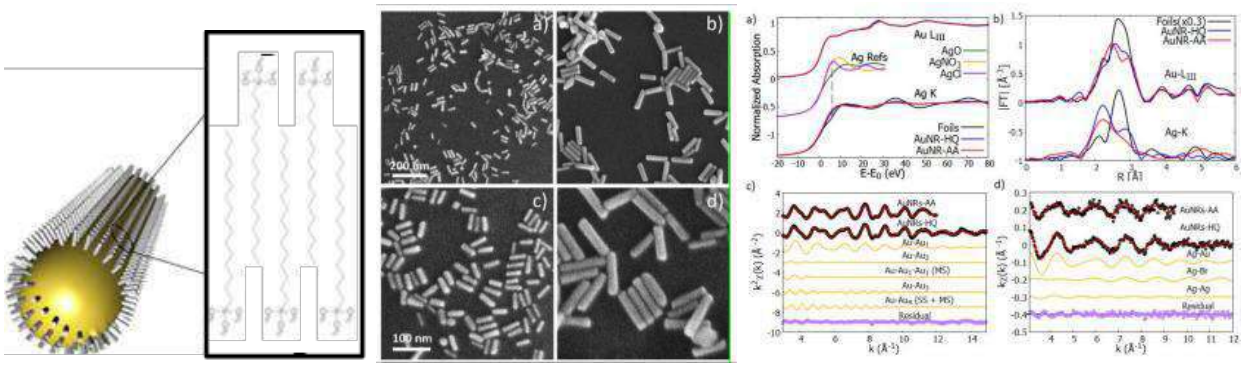

Figure 1: Scheme (left) and SEM (center) images of AuNRs. Right: *Au-LIII and Ag-K edges XAS analysis of AuNRs. a) XANES spectra b) FT of EXAFS spectra c-d) EXAFS spectra at Au-LIII and Ag-K edges.*

References:

[1] Maccora D. et al., Appl. Sci., 2019, 9, 3232.
[2] Amatori S. et al., Nanoscale Adv., 5, 3924-33 (2023)
[2] Binelli L. et al., Nanomaterials 2023, 13, 1898

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INO-OR-029

Photoswitchable chirality transfer in bright lanthanides quadruple stranded helicate-cages

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The step-by-step self-assembly pathway of a series of quadruple-stranded lanthanide cages have been studied and particular attention has been devoted to the energetic landscape of the equilibrium between the triple $[Ln_2L_3]$ and quadruple-stranded $[Ln_2L_4]^{2-}$. As proved by XRD and DFT calculations[1,2,3], the $[Ln_2L_4]^{2-}$ cage is present in solution as an equilibrating racemic mixture of left- and right-handed helicates and eventually the mesocate form. The equilibrium between the two opposite helical configurations can be orchestrated by encapsulation of a chiral guest, *i.e.* through a hierarchical chiral information transfer from a chirality at a primary level (the chiral guest) to the helicate composed of achiral components manifesting supramolecular chirality at a secondary level. Asymmetric induction by the chiral guest was studied by both CD and CPL. Moreover, the guest to host chirality transfer can be photoswitched by controlling the equilibrium between the triple- and quadruple-stranded cages by the addition of a photoacid that trigger the release of the chiral guest due the light-activated cage transformation.

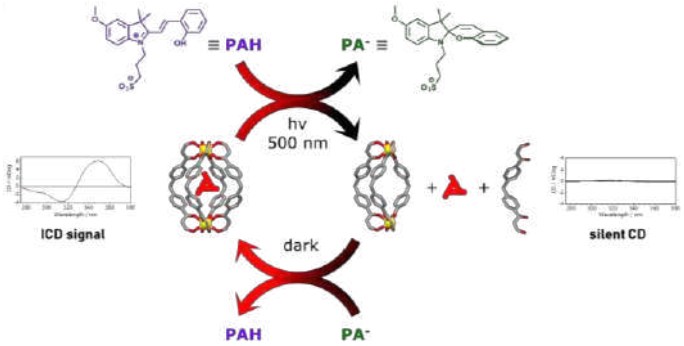

Figure 1: photoswitchable guest to host chirality transfer.

References:

[1] M. Rancan, J. Tessarolo, A. Carlotto, S. Carlotto, M. Rando, L. Barchi, E. Bolognesi, R. Seraglia, G. Bottaro, M. Casarin, G. H. Clever, L. Armelao, Cell Rep. Phys. Sci., 2022, 3, 1 – 16.

[2] S. Carlotto, L Armelao, M. Rancan, Int. J. Mol. Sci., 2022, 23, 10619.

[3] M. Rancan, M. Rando, L. Bosi, A. Carlotto, R. Seraglia, J. Tessarolo, S. Carlotto, G. H Clever, L. Armelao, Inorg. Chem. Front., 2022, 9, 4495 – 4505.

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INO-OR-030

Zeolitic Imidazolate Framework-8 (ZIF-8) for antimicrobial prevention

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Zeolitic Imidazolate Framework, also known as ZIF-8, is a subclass of MOF that shows excellent biocompatibility, stability under physiological conditions and responsiveness to the weak acidic environment associated with malignant tumors and other diseases, that is why it has attracted attention in the biomedical field.

As illustrated in *Figure 1*, in this work we are presenting the use of ZIF-8 in three different biomedical applications *a)* fabrication of Cellulose/ZIF-8 patches for the management of wound infections[1]; *b)* encapsulation of snail slime[2]; *c)* modification of titanium scaffolds with ZIF-8 for bone substitution and regeneration.

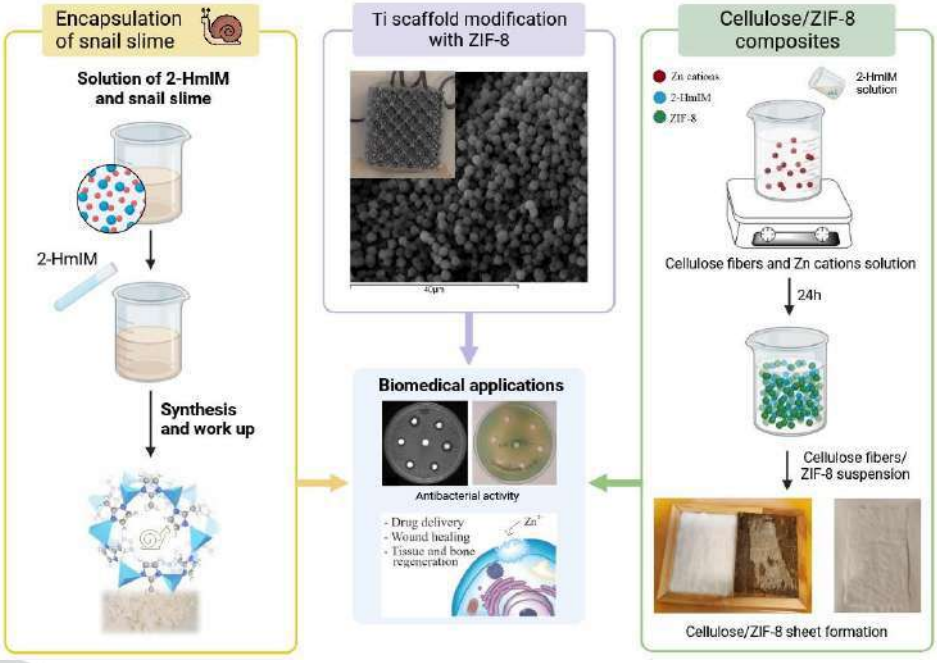

Figure 1: Schematic representation of the different research applications of ZIF-8.

References:

[1] Di Matteo, V.; Di Filippo, M.F.; Ballarin, B.; Gentilomi, G.A.; Bonvicini, F.; Panzavolta, S.; Cassani, M.C., J. Funct. Biomater. 2023, 14, 472.

[2] Di Filippo, M.F.; Di Matteo, V.; Dolci, L.S.; Albertini, B.; Ballarin, B.; Cassani, M.C.; Passerini, N.; Gentilomi, G.A.; Bonvicini, F.; Panzavolta, S., Nanomaterials 2022, 12, 3447.

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INO-OR-031

A concise synthetic approach to asymmetric β-functionalized antipodal *push-pull* porphyrins for potential application in photovoltaic, NLO and PDT

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Owing to their excellent electrochemical and photochemical properties, porphyrins are a class of molecules that have been studied for decades for use in photovoltaics, medicine and optoelectronics. This versatility is due to the possibility of introducing functional groups of different nature (electron acceptors or donors) at the *meso* and β-pyrrolic positions of the macrocycle. This allows fine-tuning of the properties and the generation of a high dipole moment for the *push-pull* effect involved in the aforementioned applications. Nearly all studies have focused on *meso*-substituted asymmetric porphyrins, which are synthesized with great effort. On the other hand, an alternative synthesis could be the post-functionalisation of a symmetrically substituted porphyrin; however, there are less cases in the literature where asymmetric β-substituted porphyrins bearing donor and acceptor groups linked on the macrocycle have been investigated as *push-pull* systems. In all of these β-functionalised architectures, the substituents are attached to the tetrapyrrolic core by the same linker or by the same fused ring, which results in a less effective transition of the dipole moment[1-3]

In our work, we present a new concise synthetic approach that, starting from a free base tetraphenylporphyrin, allows the selective introduction of acceptor and donor group in the final innovative structure, shown in Figure 1, offering the remarkable advantage of a highly asymmetric *push-pull* architecture that can be exploited in photoinduced electron transfer, PDT and NLO materials.

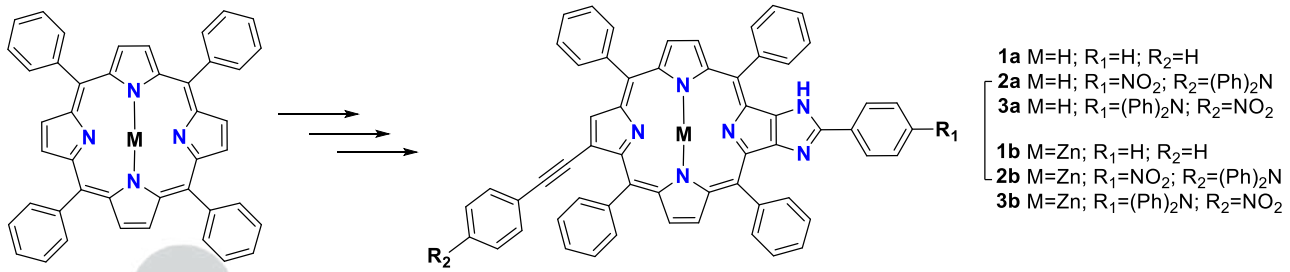

Figure 1: Core structure of asymmetric β-functionalized antipodal *push-pull* porphyrin.

References:

[1] Y. Zhang, T. Higashino, H. Imahori, J. Mater. Chem. A, 2023, 11, 12659-12680.
[2] R. Deshpande, L. Jiang, G. Schmidt, J. Rakovan, X. Wang, K. Wheeler, H. Kong, Org. Lett., 2009, 11, 4251-4253
[3] D. Curiel, K. Ohkubo, J. R. Reimers, S. Fukuzumi, M. J. Crossley, Phys. Chem. Chem. Phys, 2007, 9, 5260-5266

INO-OR-032

Physiochemical characterization of lipidic nanoformulations encapsulating Natamycin

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The human eye is particularly vulnerable to fungal and parasitic infections, caused e.g. by trauma from penetrating objects, carriage of microorganisms from adjacent structures, use of contact lenses. Negligence in timely treatment often results in vision impairment. Fungal keratitis is a major cause of blindness in corneal diseases and its topical treatment requires several eye-drops applications and may require additional injections or surgery. Natamycin, a tetraene polyene which acts by binding ergosterol, thus blocking fungal growth, is one of the proposed antifungal drug for topical treatments. However, its low retention at the ocular surface and scarce penetration across inner ocular tissues pose significant challenges. In this work, various lipid nanoparticles (LNP) and transethosomal (TE) systems loaded with Natamycin are physiochemically characterized and compared in terms of dimensions and stability studied by Dynamic Light Scattering, morphology investigated by Small Angle X-ray Scattering and Nuclear Magnetic Resonance, and encapsulation efficiency assessed with HPLC-DAD. Permeation in the organ was studied via a 3D-Printed tissue model

References:

[1] te Welscher, Y.M.; ten Napel, H.H.; Balagué, M.M.; Souza, C.M.; Riezman, H.; de Kruijff, B.; Breukink, E. J. Biol. Chem. 2008, 283, 6393–6401
[2] Gorantla, S.; Rapalli, V.K.; Waghule, T.; Singh, P.P.; Dubey, S.K.; Saha, R.N.; Singhvi, G. RSC Adv. 2020, 10, 27835–27855

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INO-OR-033

Using impacts for the self-assembly of coordination polymers and polynuclear metal complexes

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Mechanochemistry is based on the use of impacts to trigger chemical reactions.[1] Usually, solid reagents are ground by means of ball-milling apparatuses in the absence of solvent or using a very small volume of it. This makes mechanochemistry highly attracting from an environmental point of view, eliminating the major component that, in a typical reaction conducted in solution, becomes a waste at the end of the reaction. However, one of the major drawbacks of mechanochemistry resides in the difficulty to monitor the progress of the reaction, since the grinding of the reagents occurs inside a closed jar made by hard materials, which is then usually considered a black-box.[2] Furthermore, the high heterogeneity of the reactant system can make mechanochemistry perceived as a way to make reactions by chance rather than an innovative way by which developing selective synthetic processes.

In this communication, the authors will show that mechanochemistry can indeed be used for the selective synthesis of metal complexes and coordination polymers containing carboxylate and pyridine ligands, with considerable advantages in terms of reaction times and yields with respect to the same reactions conducted in solution. Subsequent selective mechanically induced ligand exchange processes will also be shown, to highlight the versatility of the technique.

Finally, the mechanochemical synthesis of new hexanuclear crown-complexes deriving from the combination of Zn-acetate, isonicotinamide and p-halogen-substiuted benzoic acids will also be described, together with their crystalline structure solved by single crystal X-ray diffraction analysis.

References:

[1] K. Horie, et al., Pure Appl. Chem. 2004, 76, 889 – 906.
[2] A.A.L. Michalchuk, F. Emmerling, Angew. Chem. Int. Ed. 2022, 61, e202117270.

INO-OR-034

Antioxidant activity of bioactive glasses loaded with flavonols

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Bioactive glasses (BGs) are bioactive and biodegradable materials capable of releasing biologically active ions being suitable for several applications as regeneration of *soft* and *hard* tissue.[1,2] The loading of BGs with antioxidant substances may result in a more potent regenerative capacity, having the potential of modulate oxidative stress and, subsequently, improving processes time healing.[3,4]

In order to identify materials with optimal antioxidant activity, we carried out an evaluation of a series of mesoporous bioactive glasses (MBGs) (pristine or cerium-doped) loaded with different flavonols (3-hydroxyflavone, quercetin and morin). The modification of the surface properties by Ce-doping and/or impregnation with antioxidant molecules was investigated by FT-IR spectroscopy, electron microscopy (FE-SEM) and nitrogen adsorption–desorption isotherms.

The results of *in vitro* release, performed in PBS (Phosphate Buffered Saline), show a quick bioactivity, i.e. formation of formation of an apatite layer. All the studied materials slowly release the impregnated flavonol. Measurements of the capacity to scavenge DPPH radicals indicate that the antioxidant activity, although always present, depends on the impregnated flavonols.

References:

[1] K. Zheng, B. Sui, K. Ilyasa, A.R. Boccaccini, Mater. Horiz. 2021,8, 300-335;
[2] K. Zheng, W. Niu, B. Lei, A.R. Boccaccini, Acta Biomaterialia 2021, 133, 168-186.
[3] M. Cazzola, I. Corazzari, E. Prenesti, E. Bertone, E. Vernè, S. Ferraris, Applied Surface Science, 2016, 367, 237-248;
[4] G. Lusvardi, F. Fraulini, S. D'Addato, A. Zambon, ACS Biomater. Sci. Eng. 2022, 8, 2890−2898.

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INO-OR-035

Magnetic and structural characterization of Fe(II) and (III) pyclen complexes

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In nature, most enzymatic oxidative processes are carried out by high-valent iron compounds.[1] The search for simple non-heme complexes as simpler synthetic models is crucial to the implementation of similar processes in laboratory and larger scales. Macrocyclic ligands play a leading role in this field, due to their ability to efficiently stabilize high oxidation states of iron-oxo compounds.[2]

Supporting ligands design, moreover, having a significant impact on the spin state of the nonheme iron (iv)-oxo and iron (v) complexes, exerts a huge influence on the outcome of oxygen atom transfer (OAT), hydrogen atom transfer (HAT), and electron transfer (ET) reactions.[3] Hence, a small library of several complexes of the pyclen family was synthetized to elucidate the effect of both macrocycle substituents and anionic ligands. Both iron (ii) and iron (iii) precursors were employed (**Figure 1**), and their structural and magnetic behaviour was fully characterized by means of Mössbauer spectroscopy, magnetometry and Raman spectroscopy. The generation of their active iron (iv) and iron (v) species was attempted with hydrogen peroxide and the characterization of their transition state was carried out with Mössbauer spectroscopy.

As expected, a strong correlation between their measured spin state and their reactivity in both C-H activation and alcohols oxidation reactions was discovered. This study was thus able to reveal the strong correlation between the structural and electronic features of this class of complexes and their observed reactivity.

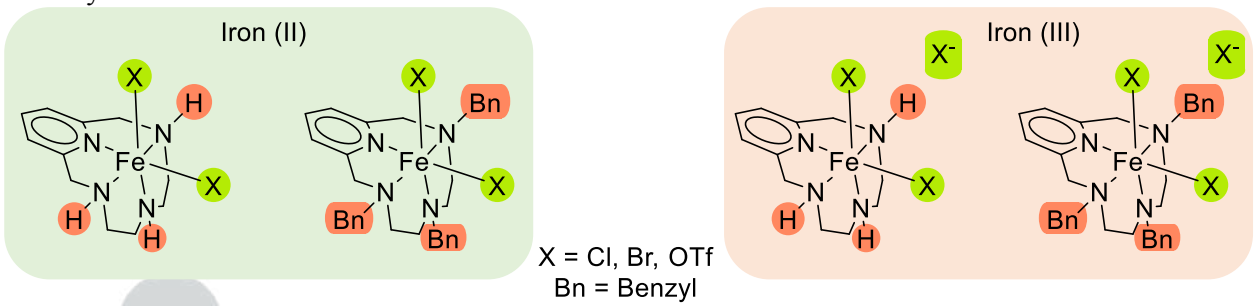

Figure 1: caption.

References:

[1] S. Sahu, D. P. Goldberg, J. Am. Chem. Soc. **2016**, *138* (36), 11410–11428.
[2] N. Panza, G. Tseberlidis, A. Caselli, R. Vicente, Dalton Transactions **2022,** *51* (28), 10635–10657.
[3] S. Hong, H. So, H. Yoon, K. B. Cho, Y. M. Lee, S. Fukuzumi, W. Nam, Dalton Transactions **2013,** *42* (22), 7842–7845

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INO-OR-036

Novel on/off switch hydrogel functionalized with cyclometallated Ir(III) complexes for in vitro cell imaging in 3D platforms

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Three-dimensional (3D) cell culture has shown to better mimic cells natural environment and to allow cell proliferation in a more realistic manner, compared to two-dimensional substrates in which cells are cultured on traditional flat substrates and adapt to this synthetic 2D environment, often becoming flattened and showing a non-natural behaviour. Therefore, the direct visualization of living cells growing onto 3D platforms in real-time promises to be a powerful tool to reveal information for biomedical investigation. However, cell staining often requires tedious sample preparation and can induce alterations of the natural cell cycle. Thus, the incorporation of a luminescent probe for cells visualization within 3D hydrogels, which combines the advantages of emission detection and hydrogel for 3D *in vitro* cell proliferation, is highly desirable for opening new paths for *in vitro* imaging techniques.[1]

Amongst the most studied emitters, cyclometallated Ir(III) complexes are very appealing as bio-imaging reagents for cellular visualization.[2] Besides their outstanding photophysical properties, they exhibit the possibility to easily tune the excited state energy over the whole visible electromagnetic spectrum, from the ultraviolet to the near infrared region by ligand modification.[3] In addition, the complexes emit from a triplet excited state displaying a very long excited state lifetime, in the microsecond range. These characteristic results in increased sensitivity and possibility of implementation of time-gated techniques with elimination of short-lived fluorescence background (~ns), rendering cyclometallated Iridium(III) complexes optimal candidates as luminescent bio-probes.[4]

Herein, we introduce a novel hydrogel for in vitro cell study, with covalently incorporated cyclometallated Ir(III)-luminescent probes. An Iridium(III) complex was designed with a "off/on" emission response versus different environments. In particular, this turning on and off of the emission relies on the interaction of an Ir(III) complex, covalently anchored to the hydrogel, with the cells plasma membranes or with its position in the water phase. Such a change in the environment, from aqueous solution to lipid layer, causes the turn on of the emission of the iridium complex.

The mechanism for the off/on switching from water to the lipophilic environment of the cell's plasma membranes is studied in detail, demonstrating that this novel luminescent probe-incorporated scaffold is a very interesting 3D platform for in vitro real-time investigation of cells.

[1] S. A. Langhans, *Front. Pharmacol*. **2018**, *9*, 6.
[2] A. Zamora, G. Vigueras, V. Rodríguez, M. D. Santana, J. Ruiz, *Chem. Coord. Rev.* **2018**, *360*, 34-76.
[3] J. Jayabharati, V. Thanikachalam, S. Thilagavathy, *Coord. Chem. Rev*. **2023**, *483*, 215100.
[4] P.Y. Ho, C. L. Ho, W. Y. Wong, *Chem. Coord. Rev.* **2020**, *43*, 213267.

INO-OR-037

A vapochromic chemosensor based on a Zn(II) salen-type complex for the detection of volatile organic compounds

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Volatile Organic Compounds (VOCs) are molecules, in liquid or solid form, which due to their high vapor pressure, can easily evaporate at room temperature. Some VOCs are responsible for air pollution and can be hazardous to human-health.[1] Thus, the development of feasible and low-cost chemosensors is relevant for the direct monitoring of VOCs in specific environments. In this context, the use of chemosensors based on Lewis acidic Zn(II) salen-type complexes can represent a promising strategy. The sensing mechanism implies the formation of stable penta-coordinated adducts between the Zn(II) salen-type complexes and VOCs having Lewis basicity, such as nitrogenous-containing VOCs (N-VOCs), involving significant colour and luminescence changes giving rise to characteristic vapochromism.[2]

In this contribution, we report on the unique thermo- and vapochromic properties of a Zn(II) salen-type derivative from the 2,3-diaminomaleonitrile, Zn(salmal), with 5,5′-tert-butyl- bulky substituents on the salicylidene rings. In particular, both the synthesized and anhydrous complex (i.e., the latter achieved by solvent evaporation under nitrogen conditions) show a marked vapochromism if exposed to saturated vapours of various VOCs.[3] Interestingly, we also demonstrate the possibility to fabricate simple and low-cost paper-based sensors (PBSs) able to discriminate N-VOCs by well-defined spectroscopic and distinct naked-eye colour changes (**Figure 1**).

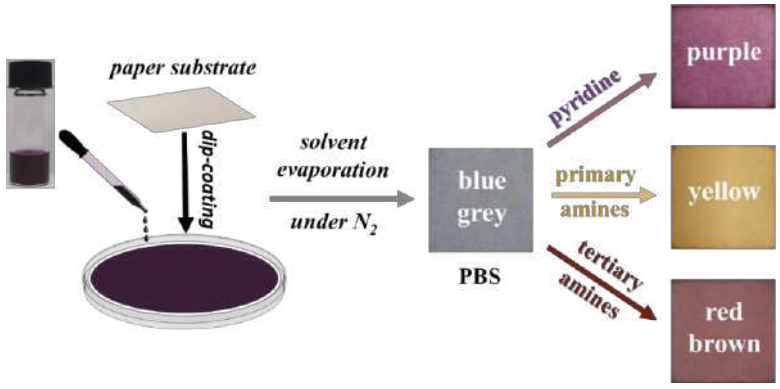

Figure 1: Scheme reporting the fabrication of PBS and its application to discriminate N-VOCs.

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References:

[1] C. Duan, H. Liao, K. Wang, Y. Ren, Environ. Res. 2023, 216, 114386.
[2] I. P. Oliveri, G. Malandrino, S. Di Bella, Inorg. Chem. 2014, 53, 9771-9777
[3] M. Gaeta, I. P. Oliveri, G. Munzi, F. Lo Presti, S. Di Bella, Inorg. Chem. 2024, 63, 3850-3858

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INO-OR-039

Unravelling the co-precipitation of spinel iron oxide nanoparticles via pH-potentiometric titrations

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Monodomain iron oxide nanoparticles with spinel structure (MNPs) are extremely interesting for a wide a range of applications, from technology to biomedicine[1]. Even though there is a well-established methodology to synthesize MNPs, the mechanism of their formation is still under investigation[2]. The co-precipitation of magnetite nanoparticles occurs after the addition of a base to the solution of precursors, typically Fe(II) and Fe(III) chlorides. In this contribution, we explore the formation mechanism of magnetite nanoparticles through different titrations of Fe(II)/Fe(III) solutions with sodium hydroxide in the presence of L-glutamic acid as a capping agent. The titration/co-precipitation experiments are performed by injecting the base at a constant temperature in the reaction batch containing the precursors and the capping agent. Morpho-structural features of MNPs are studied by X-Ray Diffraction (XRD) and Transmission Electron Microscope (TEM). Thermogravimetric analysis coupled with Fourier-transform Infra-red spectroscopy (TGA-FTIR) is used to investigate molecular coating on nanoparticle surface. Colloidal stability and hydrodynamic diameter of the nanoparticle' dispersions are evaluated by Dynamic Light Scattering (DLS). The magnetic properties (i.e. field and temperature dependence of magnetization) and Hyperfine structure of MNPs will be investigated by VSM magnetometry and Mössbauer spectroscopy respectively. Finally, the experiment is repeated by dripping the solution of the Fe(II)/Fe(III) precursors into the reaction batch already containing the sodium hydroxide and the L-glutamic acid.

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References:

(1) Materón, E. M.; Miyazaki, C. M.; Carr, O.; Joshi, N.; Picciani, P. H. S.; Dalmaschio, C. J.; Davis, F.; Shimizu, F. M. Magnetic Nanoparticles in Biomedical Applications: A Review. *Applied Surface Science Advances* **2021**, *6*. https://doi.org/10.1016/j.apsadv.2021.100163.

(2) Usman, M.; Byrne, J. M.; Chaudhary, A.; Orsetti, S.; Hanna, K.; Ruby, C.; Kappler, A.; Haderlein, S. B. Magnetite and Green Rust: Synthesis, Properties, and Environmental Applications of Mixed-Valent Iron Minerals. *Chemical Reviews*. American Chemical Society April 11, 2018, pp 3251–3304. https://doi.org/10.1021/acs.chemrev.7b00224.

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PET depolymerization using Zn^{2+} based DES

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Polyethylene terephthalate plastic (PET) is one of the most extensively used materials worldwide because it is affordable, lightweight, and extremely durable. A proper end-of-life management is essential, in order to meet growing environmental concerns. In recent years, there has been an increasing focus on the chemical breakdown and recycling of PET materials, whose primary goal is the recovery of the polymer components (monomers) that are used to create PET, namely ethylene glycol and the more expensive terephthalic acid. Such compounds can be used to synthesize again the virgin polymer, resulting in a complete recycling of the original waste.

Zn^{2+} ions have been shown to catalyze PET hydrolysis by attacking the carbonyl group as Lewis acid as described in the reaction in Figure 1. This reaction yields the starting PET monomer but requires high temperature and a long reaction time (180 ° C 24 h)[1], making it economically non-viable for PET waste recycle.

In this work, we present a new approach, based on the use of a deep eutectic solvent (DES) composed of $ZnCl_2$ and urea in 1:3.5 molar ratio. The outcome is an onset of depolymerization of post-commercial PET flakes in a microwave oven, occurring already in less than 5 minutes. To gain insight into the process, the resulting depolymerization products are characterized by FTIR-ATR and XRD measurements.

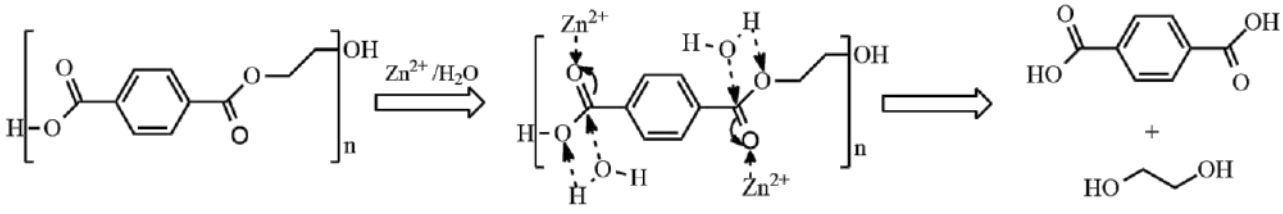

Figure 1: Tentative hydrolysis mechanism of PET using Zn^{2+} as catalyst.

References:

[1] Y. Wang, Y. Zhang, H. Song, Y. Wang, T. Deng, X. Hou, Journal of Cleaner Production, 2019, 208, 1469-1475.

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MNPs@Captisol® assemblies for magnetic water remediation

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One of the increasingly valuable natural resources is clean water. As an example, intensive farming plays the dual role of an avid consumer and a potential polluter. In this regard, agrochemicals are considered emerging water pollutants that might be harmful to the environment and public health.

Here we propose a new tool for water purification based on sulfobutylether-β-cyclodextrin (Captisol®) and magnetic nanoparticles (MNPs) supramolecular assemblies (MNP@Captisol®). The nano/microstructured morphology and cyclodextrin (CD) functionalization ensure respectively large surface-to-volume ratio and selectivity and sensitivity towards agrochemicals capturing [1]. Once the inclusion complex between CD and the pollutant is formed, it is removed from aqueous solution by simply magnetic settling. The novel assembly based on trade Fe (II/III) oxides nanoparticles covered by Captisol® was prepared under Argon bubbling and vortex mixing, purified by magnetic settling, and characterized by DLS, TGA, XPS, TEM analyses and magnetization measurements. The MNPs@Captisol® assembly showed interesting preliminary results toward Paraquat water remediation. Due to its widespread use in agricultural and non-agricultural settings and its toxicity to humans and wildlife, the herbicide was selected as pollutant model in our studies.

Acknowledgements:
This project was supported by the NextGenerationEU project SAMOTHRACE "SiciliAn MicrOnanoTecH Research And innovation CEnter" ECS00000022 - CUP B63C22000620005 and by the PON "Ricerca e Innovazione" 2014-2020, Azione IV.5 "Dottorati e contratti di ricerca su tematiche Innovazione and green" for the fellowship of N.B. Captisol® was a generous gift from Ligand (San Diego, CA-USA).

References:

[1] N. Goyal, A. Amar, S. Gulati, R. S. Varma, ACS Appl. Nano Mater 2023, 6(15), 13766–13791

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Insights into graphene oxide reactivity through different functionalization strategies

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Graphene is a bi-dimensional nanomaterial composed of sp^2 hybridized carbon atoms. Since its discovery in 2004, it has catalyzed the interest of the scientific community due to its notable properties and peculiar structure. Its potential applications are countless, nonetheless, it possesses three main drawbacks: it is poorly dispersible in polar solvents, its synthetic pathways are not currently suitable for scalable quantities of products and its functionalization reactions are limited[1]. In the group of graphene-like materials graphene oxide (GO) can be considered an optimal starting point for producing hybrid functional materials. GO is a versatile nanomaterial that overcomes the limitations of pristine graphene while it both retains and can retrieve several of its properties[2]. It is composed of a graphitic sheet decorated with a wide variety of oxygen functional groups (OFGs) e.g. epoxides, hydroxyls, carbonyls, and carboxyls[3]. Such moieties expand the chemistry of GO compared to pristine graphene. Indeed, the properties of GO can be tuned by exploiting these OFGs through a series of functionalization reactions[2].

This study aims to obtain insights into GO reactivity through a series of functionalization strategies. The reaction pathways investigated focused on producing aminated GO (GO-NH_2) and carboxylated GO (GO-COOH) by exploiting epoxide ring opening reactions and O-acylation pathways[2,3]. Through the knowledge obtained the focal point is to produce graphene-based hybrid materials with target properties for applications in specific fields[2]. The reactions proposed are fully characterized by employing XPS, Raman spectroscopy, and UV-Vis spectroscopy.

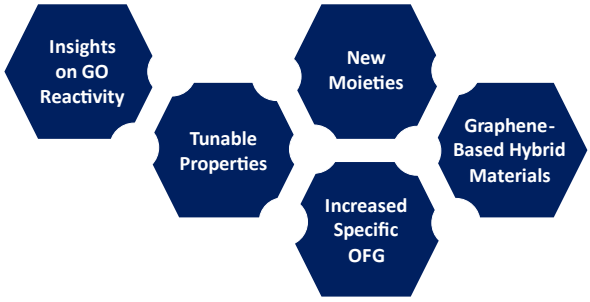

Figure 1: Schematic representation of the project

References:
[1] C. Anichini, P. Samorì, Small 2021, 17, 2100514.
[2] S. Guo, et al., Nat. Rev. Phys. 2022, 4, 247 – 262.
[3] F. Amato, et al., Nanoscale Adv. 2023, 5, 893 – 906.

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Exploration of different synthetic routes for the design of tailored nanophosphors

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In recent years, many efforts have been devoted to obtain inorganic nanomaterials with controlled size, shape and crystalline phase, features which all play a relevant role in determining the final functional properties[1]. In particular, it is well known that the conditions under which a material is produced (either thermodynamic or kinetic regime) strongly affect its composition (i.e., distribution and/or intermixing of the present elements), its structure (formation of a particular polymorph, segregation) and therefore the resulting functional properties of materials.

This work is focused on a systematic and comprehensive comparison of the effect of different synthetic routes on the functional optical and chemical-physical properties of luminescent nanomaterials. In this context, we paid special attention to the comparison between two different synthetic routes, i.e., inverse miniemulsion (wet-chemistry)[2] and ball milling (solid state-chemistry). These synthetic approaches are established as powerful methods to control the final size and size distribution of the resulting nanoparticles. Eu^{3+}-doped calcium molybdate $CaMoO_4$ [2,3] was chosen as model system, as it is an interesting promising material for the development of new phosphors for optics and solid-state lighting[4].

The target system was synthesised with different Eu^{3+} amount through the two different synthetic routes, resulting in both cases in crystalline Eu^{3+}-doped calcium molybdate (PXRD). Further XAS analyses at Eu L_3-edge and Mo K-edge were carried out to investigate the dopant-induced variations on the electronic and short-range structure of the Eu^{3+}-doped samples. By performing in situ XAS measurements during annealing processes at 900°C in vacuum and in He flow, we followed the evolution of the Eu^{3+}, resulting in a partial reduction of Eu^{3+} to Eu^{2+}, with different degree and kinetics depending on the different synthetic routes. The presence of Eu^{2+} is hypothesised to be related to the observed quenching of the emission (λ_{exc}=302 nm) both for miniemulsion and ball milling samples, likely due to the presence of an intervalence charge transfer[5].

References:

[1] S. Polarz, Adv. Funct. Mater. 2011, 21, 3214–3230.
[2] C. Mazzariol, F. Tajoli, A. E. Sedykh, P. Dolcet, J.-D. Grunwaldt, K. Müller-Buschbaum, S. Gross, ACS Appl. Nano Mater. 2023, 6, 15510-15520.
[3] A. I. Becerro, M. Allix, M. Laguna, D. González-Mancebo, C. Genevois, A. Caballero, G. Lozano, N. O. Núñez, M. Ocaña, J. Mater. Chem. C 2018, 6, 12830-12840.
[4] M. Laguna, N. O. Nuñez, A. I. Becerro, M. Ocaña, CrystEngComm 2017, 19, 1590-1600.
[5] J. J. Joos, L. Seijo, Z. Barandiarań J Phys Chem Lett 2019, 10, 1581–1586.

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Exchange bias in metal-doped single-phase ferrites induced by defect engineering of core@shell nanoparticles.

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The crystal site occupancy of different divalent ions and the induction of lattice defects (vacancies, dislocations, stacking faults and antiphase boundaries) represent an additional tool for modifying the intrinsic magnetic properties (e.g. high coercive field and/or exchange bias) of spinel ferrites nanoparticles.[1] An efficient strategy to introduce defects into the ferrite spinel lattice is the controlled oxidation of core@shell AFM@F(i)M $Fe_{1-x}O@Fe_3O_4$ NPs. Interestingly, with this approach also defected cobalt ferrite with very large exchange bias are obtained. However, the final NPs displayed a magnetic behaviour strongly affected by the contribution of the antiferromagnetic component, due to the formation of a large magnetic disorder spinel ferrite sub-domains.[2] A possible strategy to overcome the drawback is to add, to the defected cobalt ferrite, a second divalent cation able to restore the magnetic order while retaining the lattice defects. Here we present an investigation aimed to rationalize the effect of $Co^{(II)}$ and $Ni^{(II)}$ on the lattice defects induced in spinel ferrite NPs by solvent mediated mild oxidation of AFM@FiM precursors, and on how they affect the magnetic properties. 20 nm core@shell nickel, cobalt doped-iron oxide NPs synthetized by thermal decomposition method,[3] were oxidized to the single-phase nanocrystals. As a result, the appearance of crystal defects and antiphase boundaries improves the magnetic properties of the starting compounds and leads to the appearance of exchange bias at room temperature.

Acknowledgments

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References

[1] A. Lappas, *et al.*, Phys. Rev. X, 2019, 9, 1–17.
[2] A. López-Ortega, *et al.* Chem. Mater., 2017, 29, 1279–1289.
[3] B. Muzzi, *et al.* Small, 2022, 2107426, 2107426.

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How to guide photocatalytic applications of titanium dioxide co-doped with nitrogen and carbon by modulating the production of reactive oxygen species

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In the past few decades heterogeneous photocatalysis achieved a leading role in the research field of environmental remediation. Among the visible light active materials that find application in this field, titanium dioxide modified with non-metals such as C and N has been, and still is, extensively studied.[1,2,3,4]

This work is carried out in collaboration with Colorobbia Research Centre (Ce.Ri.Col)[5] which develops visible light active materials.[6] Different systems were prepared on a pilot scale with remarkable visible light photocatalytic activity using a commercial TiO_2[7] and ammonium citrate as a simultaneous source of N and C. Furthermore, we were able to shed light on the key role of C modification in driving the photoactivity towards a specific application.

We obtained a family of catalysts of variable composition containing nitrogen mainly in the oxide bulk and a partially graphitized carbonaceous phase at the surface. For the photoactivity assessment two tests were employed: NO_x abatement in gas phase and phenol degradation in aqueous phase. The characterization highlighted that the bulk nitrogen allows the formation of localized states in the band gap of TiO_2 and it is primarily involved in the production of superoxide ($O_2^{\bullet-}$) while carbonaceous species are mainly located at the surface, and linked to the photogeneration of singlet oxygen ($^1O_2$) which has a crucial role in driving the photoactivity both in gas and liquid phase. In gas phase (NO_x abatement) $^1O_2$ is detrimental for the photoefficiency, whereas in liquid phase (phenol degradation) this species has a beneficial role. Therefore, the photocatalyst activity can be modulated according to its actual application tuning the carbon content.

References:

[1] Y-Y. Wang, Y.-X. Chen, T. Barakat, Y-J. Zeng, J. Liu, S. Siffert, B-L. Su, J. Energy Chem. 2022, 66, 529-599.
[2] J. Huang, L. Dou, J. Li, J. Zhong, M. Li, T.Wang, J. Hazard. Mater. 2021, 403, 123857.
[3] A. Zollo, S. Livraghi, E. Giamello, A. Cioni, V. Dami, G. Lorenzi, G. Baldi, J. Environ. Chem. Eng. 2023, 11, 109451.
[4] A. Zollo, S. Livraghi, E. Giamello, A. Cioni, V. Dami, G. Lorenzi, G. Baldi, S. Agnoli, M. A. Baluk, A. Gołąbiewska, A. Zaleska-Medynska, J. Environ. Chem. Eng. 2023, 11, 111523.
[5] http://www.colorobbiaconsulting.it/ce.ri.col..html
[6] Patent WO2019/ 211787
[7] Patent WO2006/061367

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New CPL active Ln(III) complexes: from the design to the potential application

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Chiroptical Ln(III) complexes are arousing more and more interest, thanks to their potential application in both optical materials[1,2] and biological[3] fields. In this contribution, the optical, chiroptical and thermodynamic properties of new Ln(III) complexes bearing differently substituted hydroxycoumarins (Figure 1) have been investigated. Different sensitization efficiencies of the Tb(III) and Eu(III) luminescence have been detected, with CoumB exhibiting the highest efficiency for Tb(III) ($\eta_{sens} \geq 62\%$). The energy position of the ligands' excited states has been experimentally determined, whilst the dynamics of the ligand-to-metal energy transfer process has been computationally studied.

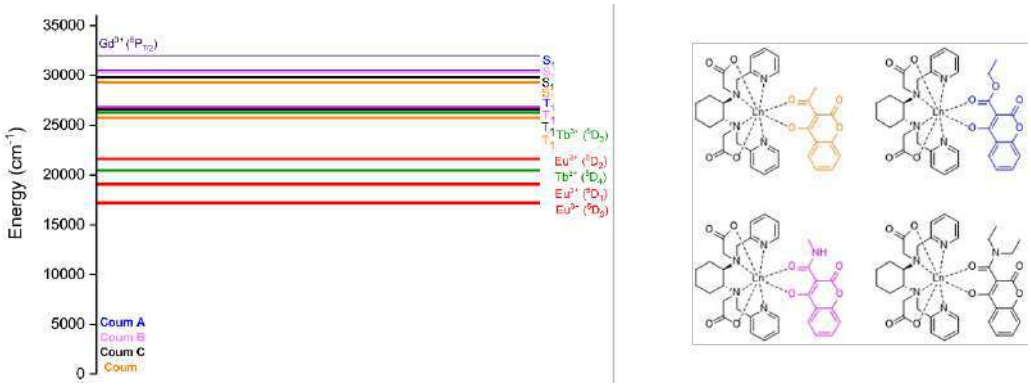

Figure 1: (Left) Energy diagram of S_1 and T_1 levels of the different coumarin ligands and Ln(III) excited states and (right) chemical structure of the Ln(III) complexes (Ln = Eu, Gd, Tb) with differently substituted coumarin ligands.

References:

[1] N.F.M. Mukthar, N.D. Schley, G. Ung, J. Am. Chem. Soc. 2022, 144, 6148-6153.
[2] S. Ruggieri, S. Mizzoni, C. Nardon, E. Cavalli, C. Sissa, M. Anselmi, P.G. Cozzi, A. Gualandi, M. Sanadar, A. Melchior, F. Zinna, O.G. Willis, L. Di Bari, F. Piccinelli, Inorg. Chem. 2023, 59, 5050-5062.
[3] A.T. Frawley, R. Pal, D. Parker, Chem. Commun. 2016, 52, 13349-13352.

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Towards the full atomic-to-nanometer characterization of CdSe Quantum Dots

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Quantum dots (QDs) have been extensively studied over the last three decades due to their finely size- and shape-tunable optical and electronic properties. The relevance and disruptive nature of QDs discovery was sealed with the awarding of the 2023 Nobel Prize in Chemistry. Studying and controlling many important structural features like size, size dispersion, crystal structure, defectiveness, surface structure, and faceting was challenging from the early days[1] and still lacks established analytical approaches today. We tackled this problem by combining X-ray total scattering techniques in the wide- (WAXS) and small-angle regions (SAXS), and by using the Debye scattering equation (DSE) based modelling approach.[2] The core advantage of this analytical approach lies in its capability to use specially tailored models, which encompass the studied structural features, to fit high-quality total scattering data. This approach has been successfully applied several classes of QDs including PbS[3,4], zincblende CdSe[5], and perovskites[6,7]. We have now developed a novel approach to characterize wurtzite CdSe QDs in the 2.3 to 5.6 nm size range to obtain an atomic-to-nm characterization encompassing defectiveness and morphology. The simultaneous SAXS/WAXS total scattering data modelling revealed a faceted hexagonal prismatic morphology, characterized by the variable presence of {001}, {100}, and {011} facets. Moreover, the analysis demonstrated a markedly different trend in the concentration of stacking faults within wurtzitic QDs relative to their average size, differing from previous observations in zincblende CdSe QDs.

This work demonstrates the potential of the proposed analytical approach to disentangle complex and intertwined features of structure defectiveness and nanocrystal morphology, which could have a significant impact on the final properties of CdSe QDs and semiconductor nanocrystals in general.

References:

[1] M. G. Bawendi et al, J. Chem. Phys., **1989**, 91, 7282-7290.
[2] A. Cervellino et al, J. Appl. Crystallogr., **2015**, 48, 2026-2032.
[3] F. Bertolotti et al, Nat. Mat., **2016**, 15, 987–994
[4] L. Allara et al, Npj Comput. Mater., **2024**, 10
[5] D. Moscheni et al, ACS Nano. **2018**, 12, 12558–12570.
[6] F. Bertolotti et al, ACS Nano, **2017**, 11, 3819–3831
[7] F. Bertolotti et al, Small Struct., **2024**, 5, 2300264

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Electroluminescent Copper(I) Complexes for Lighting Applications

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Copper is one of the most available transition metals in the Earth's crust and seawater. It is employed in many natural processes and finds application in different fields, such as dye-sensitized solar cells, solid-state lighting devices, and redox-active catalysts. In particular, the last years marked an increase in the interest for photoactive copper complexes, due to their potential use in solid-state lighting devices. In this context, Light-emitting Electrochemical Cells (LECs) are of high interest for soft-lighting applications and disposable (opto)electronics, and copper complexes offer a sustainable alternative to electroluminescent materials based on poorly available second and third-row transition metals.[1]

Recently, fully Cu(I)-based white LECs have been achieved *via* host:guest approach, reaching on par performances of the Ir(III)-based counterpart.[2,3] Among the variety of possible combinations, tetrahedral heteroleptic $[Cu(P\hat{}P)(N\hat{}N)]^+$ are one of the most studied options. Herein we present a new series of such compounds, with the aim of expanding the colour range of the emission towards the green-blue part of the visible spectrum. The complexes are based on Xanthphos as the P^P ligand and on differently substituted pyridine pyrazoles as the N^N ligand. They have been structurally and electronically characterized and the most promising ones have also been incorporated and tested in prototypal LEC devices.

Figure 1: General structure of the emitting complexes.

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References:

[1] G.U. Mahoro, J. Fernandez-Cestau, J. L. Renaud, P. B. Coto, R. D. Costa, S. Gaillard, Advanced Optical Materials 2020, 8, 2000260.
[2] L. M. Cavinato, S. Wölfl, A. Pöthig, E. Fresta, C. Garino, J. Fernandez-Cestau, C. Barolo, R. D. Costa, Advanced Materials 2022, 34, 2109228.
[3] C. E. Housecroft, E. C. Constable, Journal of Materials Chemistry C 2022, 10, 4456–4482.

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SERS enhancement of Methylene Blue exploiting thin polydopamine coating on Silver nanoparticles

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Polydopamine (PDA) is a versatile biopolymer with great adhesive properties[1] that spontaneously self-polymerizes from dopamine (DA) in weak alkaline media and in presence of oxygen[2]. Here we describe the coating process of silver nanoparticles (AgNPs) with an ultra-thin layer of PDA to increase SERS signal of Methylene Blue (MB), as hypothesised on the basis of the well-known affinity between PDA and MB[3]. The control of the thickness is crucial since the SERS enhancement is strictly dependent on the distance between the target molecule and the plasmonic substrate. Four different thicknesses were obtained, labelled as @PDA003/006/012/031 stating for the different amounts of DA monomer employed (mg/mL).

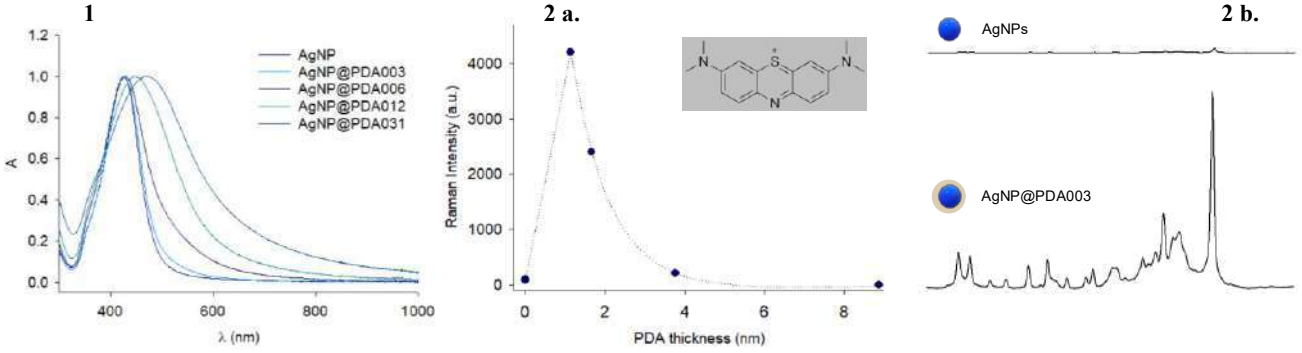

Figure 1: Uv-visible normalised spectra of bare AgNPs and PDA coated AgNPs with different shell thicknesses. **Figure 2 a.:** SERS intensity trend of Methylene Blue 10^{-6} M at 1624 cm^{-1} as PDA thickness increase. **Figure 2 b.:** SERS spectra of Methylene Blue employing respectively AgNPs and AgNP@PDA003 as SERS substrate.

The substrates have been characterized with TEM microscopy, Dynamic Light Scattering (DLS), Uv-Visible and Raman spectroscopy, demonstrating that huge increase in the SERS signal of MB can be obtained with a careful tuning of PDA thickness if compared to bare AgNPs.

References:

[1] W. Ye, H. Huang, W. Yang, X. Wang, C. Ren, Q. Hu, Y. Li, B. Ren, *Analyst* **2017**, *142*, 3459–3467
[2] H. Lee, S. M. Dellatore, W. M. Miller, P. B. Messersmith, *Science* **2007**, *318*, 426–430.
[3] J. Fu, Z. Chen, M. Wang, S. Liu, J. Zhang, J. Zhang, R. Han, Q. Xu, *Chem. Eng. J.* **2015**, *259*, 53–61.

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Polymerisable ligands: the route to phosphorescent Ir(III)-based metallapolymers

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Phosphorescent metallapolymers have recently gained great interest due to the possibility of endowing polymers with the bright and color tunable emission typical of Ir(III) cyclometalates with general formula $[Ir(C^N)^2(N^N)]^{0/+}$ [1]. In this context, we designed a series of "polymerizable ligands" capable of coordinating the metal center and, at the same time, being able to copolymerize with methacrylic monomers. Therefore, we equipped four well-known diimine ligands $(N^N)^{2,3}$ with a polymerizable styril unit. Then, metallapolymers were obtained either by the complexation of a pre-formed MMA-L copolymer with different amounts of appropriate Ir fragments, or by the copolymerization of the mononuclear Ir(III) complexes with MMA. The new hybrid materials displayed intense phosphorescence in the solid state, with high PLQY and Ir(III)-centred emission colors spanning from blue to orange, paving the way for the application of this new class of metallapolymers as LSCs.

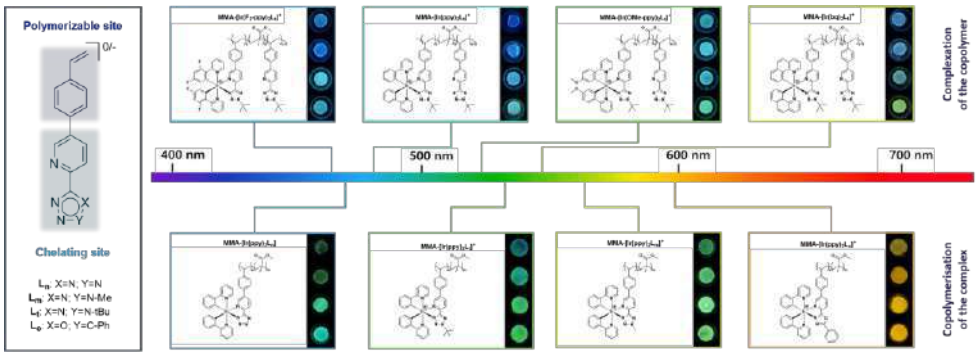

Figure 1: General structure of the polymerizable ligands; materials structures and appearance under UV light.

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References:

[1] C. L. Ho, W. Y. Wong, Coord. Chem. Rev., 2011, 255, 2469–2502.
[2] S. Stagni, S. Colella, A. Palazzi, G. Valenti, S. Zacchini, F. Paolucci, M. Marcaccio, R. Q. Albuquerque, L. De Cola, Inorg.Chem., 2008, 47 (22), 10509-10521.
[3] J. Zhang, L. Zhou, H. A. Al-Attar, K. Shao, L. Wang, D. Zhu, Z. Su, M. R. Bryce, A. P. Monkman, Adv. Funct. Mater., 2013, 23 (37), 4667–4677.

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Luminescent solar concentrators based on energy transfer in polyurethane matrices

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For a more sustainable energy transition, the use of solar energy has become of paramount importance, and Luminescent Solar Concentrators (LSC) represent an important solution for a smarter and more integrable photovoltaic. LSC are transparent slabs, generally made of glass, coated with a thin polymeric film containing a luminescent dye, that absorbs and re-emits a portion of the solar radiation. The emitted light is concentrated at the edges and converted into electricity by small photovoltaic cells.

Luminescent perylene diimide and benzothiadiazole dyes have been considered because of the possibility to improve the LSC performance through a Förster Energy Transfer (FRET) process, leading to enhanced light-harvesting efficiency and cost effectiveness[1]. Also, their covalent incorporation into a polymeric backbone allows a homogeneous distribution in the matrix, hence allowing an efficient energy transfer, and it also offers a reduced molecular aggregation, thus, a reduced aggregation-caused quenching[2].

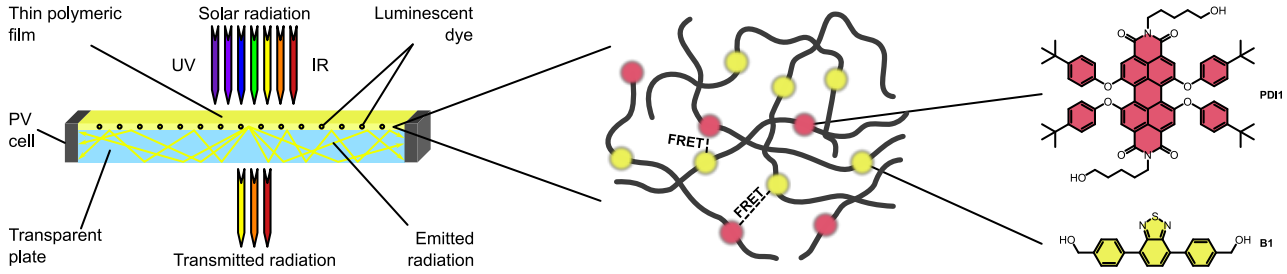

Figure 1: schematic representation of an LSC (left), of the synthesized polyurethanes (centre), and of the dyes **PDI1** and **B1** (right).

Here we present new LSC devices in which the donor, benzothiadiazole **B1**, and the acceptor, perylene diimide **PDI1**, are covalently incorporated into innovative polyurethanes. In particular, an LSC device realized with a polymer incorporating both **B1** and **PDI1** in a 1.00:0.15 ratio exhibited a photovoltaic efficiency of 0.63 % and an impressive external photon efficiency of 3.97 %. Therefore, covalent incorporation of **B1** and **PDI1** in a polyurethane matrix and the FRET process represents a step forward in the development of LSC.

References:

[1] B. Balaban, S. A. Carter, Journal of Luminescence 2014, 146, 256 – 262.
[2] S. P. Russo, W. W. H. Wong, Journal of Material Chemistry C 2020, 8, 8953 – 8961.

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Investigating the morphology and spectroscopic properties of lanthanide-doped alkaline-earth fluoride nanomaterials on varying the synthetic conditions

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Lanthanide-doped alkaline-earth nanoparticles (NPs) are emerging luminescent tools for biomedical diagnostics applications [1-3]. In order to optimize the NPs performances it is of paramount importance to understand how the synthesis conditions influence the chemical-physical as well as the luminescence properties of the NPs.

Microwave (MW) assisted hydrothermal synthesis is a technique that reduces reaction times and at the same time improves the reproducibility of the synthesis due to the possibility of finely tuning the reaction conditions, such as temperature and time. In the present investigation, we focused on the preparation of Er^{3+}, Yb^{3+} and Eu^{3+} ions doped CaF2 or SrF2 NPs using MW assisted procedure by correlating the synthesis parameters, including the concentration of the reagents and capping moieties with the size and morphology of the NPs as well as their luminescence properties.

In particular, luminescence spectra and decay curves in the visible and infrared regions have been investigated. From preliminary data, we observed a relevant influence of the reaction temperature and time on the size of the NPs. Moreover, the colloidal properties as well as structural morphology of the NPs are heavily modified upon the variation of the capping moiety. The concentration of the starting metal and fluoride precursors plays an important role in controlling the NPs size and, in particular conditions, also the crystallinity of the NPs. The growth of a shell of the same host surrounding the NPs can be easily induced with the same synthetic procedure. By proper doping of the shell, it is possible confer different emission properties and also improve the intensity efficiency of the luminescence.

References

[1] E.Milan, N. Mattei, Francesca Dalla Nese, A. Borrelli, C. Cannas, F. Tajoli, R. Signorini, E. Radicchi, A. Speghini, J. Lumin., 270 (2024) 120544.
[2] M. Quintanilla, Y. Zhang, L. M. Liz-Marzán, Chem. Mater. 2018, 30, 8, 2819–2828
[3] P. Cortelletti, A. Skripka, C. Facciotti, M. Pedroni, G. Caputo, N. Pinna M. Quintanilla, A. Benayas, F. Vetrone, A. Speghini, Nanoscale, 2018, **10**, 2568-2576

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Atomistic modeling for the chirality transfer study in chiral hybrid perovskites

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Hybrid organic–inorganic perovskites (HOIPs) have emerged as excellent materials for solar cell applications. Indeed, their extreme tunability and facile synthesis have opened the door to many new applications. Chiral HOIPs are attracting great interest as promising frameworks for chiroptoelectronics as well as spintronics applications. The chiroptical properties observed in chiral HOIPs can be explained understanding the chirality transfer from the chiral organic molecules to the achiral inorganic octahedra. A key element of the chirality transfer mechanism involves the distortion of the coordination geometry of the inorganic octahedra induced by the presence of chiral ligands. The specific process through which a chiral bias is generated from a chiral organic ligand to the inorganic scaffold has remained unclear until now. [1,2]

In this study, we propose a tailored simulation workflow based on Density Functional Theory (DFT) and Time-Dependent Density Functional Theory (TD-DFT)[3] to theoretically explore the chirality transfer mechanism inducing chirality generation and coordination geometry distortion. To this aim, we investigate the chiroptical response of lead- and tin-based 2D chiral perovskites, specifically 2D R- and S-(MBA+)2PbI4[4] and R- and S-(MBA+)2SnI4.[5] We explore the most impactful factors influencing their Circular Dichroism (CD) signals through ab-initio molecular dynamics simulations and the analysis of the density of electronic states (DOSs). Our findings reveal that the relevant chiroptical features are linked to a chirality transfer event driven by a metal–ligand overlap of electronic levels. This effect is more evident for tin-based chiral perovskites showing higher excitonic coupling. Recent simulations on thermodynamics and kinetics aspects of the early stage of their chiral formation will be also discussed.

References:

[1] A. Pietropaolo, A. Mattoni, G. Pica, M. Fortino, G. Schifino, G. Grancini, Chem 2022, 8, 1231.
[2] H. Duim, M. A. Loi, Matter 2021, 4, 3835.
[3] M. Fortino, A. Mattoni, A. Pietropaolo, J. Mater. Chem. C 2023, 11, 9135.
[4] J. Ma, C. Fang, C. Chen, L. Jin, J. Wang, S. Wang, J. Tang and D. Li, ACS Nano 2019, 13, 3659.
[5] H. Lu, C. Xiao, R. Song, T. Li, A. E. Maughan, A. Levin, R. Brunecky, J. J. Berry, D. B. Mitzi, V. Blum and M. C. Beard, J. Am. Chem. Soc. 2020, 142, 13030.

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Plasma-Driven Engineering of Metal Halide Perovskite Interfaces for Photovoltaic Applications

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Metal halide perovskite (MHPs) solar cells represent a promising newcomer in the front of emerging photovoltaic technologies to address the dramatic energy crisis and climate change that we are facing. The exceptional properties of MHPs derive from their hybrid organic-inorganic nature, which allows also for low-cost and straightforward processing. Despite the exceptional performances achieved, a major limitation, still preventing the uptake of the technology, is related to the reduced stability of these materials when exposed to the external environment. Herein, an effective defect passivation of MHP surfaces is a key strategy to tackle both the stability and the enhancement of solar cell performances. We propose here an innovative use of plasma, as a solvent-free, scalable, and non-invasive promising strategy to boost MHP solar cells performances[1]. As benchmark material we used Methylammonium Lead Iodide perovskite; thus, we have exposed the surface of polycrystalline thin films made of this material to different plasma conditions implying the variation of power, gas, treatment time and pressure. The impact of *Ar*, N_2, H_2 and O_2 low pressure plasmas (LPPs) on $MAPbI_3$ optochemical properties and morphology was correlated to the performance of the photovoltaic devices and rationalized by density functional theory calculations. An interesting improvement in photoluminescence was observed for the *Ar* and H_2 treated films, while an improvement in PCE was observed only for the *Ar* treated device. This result was ascribed to the efficient removal of the superficial organic component, revealed through X-ray photoelectron spectroscopy (XPS), following suitable surface passivation by the electron transporting layer deposition. Starting from these encouraging results, new plasma surface treatments are now object of evaluation, such as atmospheric pressure plasma processes, the plasma-deposition of thiophene-like films, and the study of LPP treatments applied to tin-based perovskite solar cells.

References:

[1] A. Perrotta, S. Covella, F. Russo, F. Palumbo, A. Milella, V. Armenise, F. Fracassi, A. Rizzo, S. Colella, W. Kaiser, A. A. Alothman, E. Mosconi, F. De Angelis, A. Listorti, *Solar RRL*, 2023, 7, 2300345.

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Electrochemiluminescence-based biosensors

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Electrochemiluminescence (ECL) can be defined as the generation of light by electron transfer between species generated electrochemically.[1] Thanks to the combination between electrochemical and spectroscopic methods, ECL possesses several advantages, such as (i) temporal and spatial control on light emission, (ii) intrinsically very low background and high sensitivity and rapidity, and (iii) broad dynamic range with low volumes (≤1 mL). Thanks to all these advantages, ECL is very appealing for the development of cheap Point of Care (PoC) devices. In this context, we are interested in the design of ECL-based biosensors, with a particular attention, in the framework of the Eclipse Project,[3] for the detection of infectious pathogens. Nowadays, the most accurate *in vitro* diagnostic tests are still mainly based on pathogens' Nucleic Acid (NA) detection by real-time PCR assays. However, PCR-based methods are typically quite complex and slow, requiring NA extraction and purification, and expensive devices. To overcome these limitations, while maintaining the same sensitivity, we are trying to take profit of a synergistic combination of several elements, such as (i) the design of bio- and nano-structures for signal amplification in luminescence-based techniques, (ii) the identification of new biotechnological approaches for the recognition of the desired analytical target endowed with high affinity and selectivity, and (iii) push the electrochemiluminescence detection technologies to unprecedented sensitivities, through a detailed study of all the mechanisms leading to the generation of light. In this context, very promising results have been already obtained for the Hepatitis B Virus[3] and Sars-Cov-2 have been already obtained, with LoD in the aM range, while the extension to other pathogens is in progress.

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[1] A. J. Bard in Electrogenerated chemiluminescence, Marcel Dekker (2004) New York.
[2] https://eclipse-project.eu
[3] P. Nikolaou, E. L. Sciuto, A. Zanut, S. Petralia, G. Valenti, F. Paolucci, L. Prodi, S. Conoci, Biosensors and Bioelectronics, 2022, 209, 114165.

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Transition metal complexes of Schiff base ligands as G-quadruplex DNA binders

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Square planar Schiff base complexes of transition metal ions have been recently designed and synthesized, as potential G-quadruplex (G4) DNA-binders.[1,2] Besides the important role of the metal ion in determining the DNA-binding strength and sequence affinity, the nature of aromatic ring on the N,N' bridge of the Salen scaffold (Fig. 1) and of the positively charged side chains allow to opportunely tune the DNA-binding properties of the resulting metal complexes. Furthermore, these compounds show interesting oxidation activity of guanine DNA bases into 8-oxoguanine. The oxidation mechanism and how this may affect the G4-DNA structure and stability is being investigated by experimental and computational approaches.

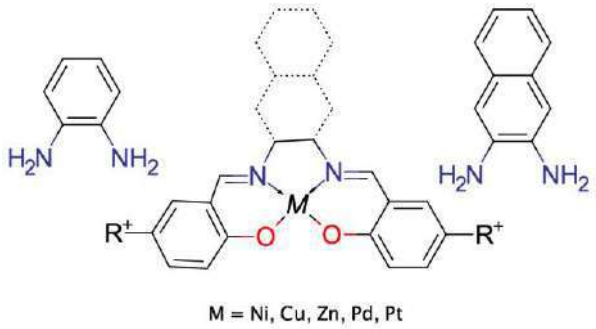

Figure 1: Structure of generic Salen-like metal complexes

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References:

[1] R. Bonsignore, E. Trippodo, R. Di Gesù, A.P. Carreca, S. Rubino, A. Spinello, A. Terenzi, G. Barone, *Dalton Trans.* **2024**, DOI: 10.1039/d4dt00092g

[2] L. D'Anna, S. Rubino, C. Pipitone, G. Serio, C. Gentile, A. Palumbo Piccionello, F. Giannici, G. Barone, A. Terenzi, *Dalton Trans.*, **2023**, *52*, 2966.

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Solar to chemical energy conversion with plasmonic photocatalysts

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The storage of solar energy in the form of chemical bonds through the synthesis of fuels and chemicals is a strategic approach to dispatch on-demand and continuous supply of clean energy carriers. Semiconductor photocatalysts naturally transduce solar radiation in redox photo-potentials, thus enabling chemical transformations. In contrast, metal nanostructures present a wide range of non-linear optical effects that enable enhanced light-matter interaction, while keeping unique catalytic properties for the activation of chemical reactions. In this contribution, I will discuss our most recent results showing how interface engineering and nanoscale assembly generate advanced plasmonic photocatalysts with both improved optical and photocatalytic activity for various technologies, including colloidal photocatalysis, fuel cells, photoelectrochemical cells, and solar thermal processes. I will show how plasmonic photocatalysts produce several intense effects such as near fields, hot carriers, and local heating, which can be leveraged to enhance reaction rates or stir product selectivity in ways that are not conventionally observed neither for classic heterogeneous catalysts nor for semiconductor photocatalysts.

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Mesoporous bioactive glasses with tailorable antioxidant and therapeutic properties

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Bioactive glasses (BGs) are well-established biomaterials traditionally used for *hard* tissue regeneration[1,2]; to avoid post-surgery inflammation and infections, BGs can be tailored with antioxidant and antibacterial properties by doping with therapeutic inorganic ions (TIIs) or loading with organic molecules. Our research focused on the development of doped and loaded BGs that can act as antioxidant systems and drug delivery systems (DDSs)[3-6]; specifically was developed a series of cerium doped mesoporous BGs (Ce-MBGs)[5] studied by tailored enzymatic and antibacterial assays. Ce-MBGs with high specific surface area (SSA), can dismutate H_2O_2 and simultaneously act as DDSs for biomolecules (e.g. polyphenols), which confers them the additional ability to scavenge $O_2^{\bullet-}$. By loading antibiotics as model drugs, Ce-MBGs present controlled release for up to 10 days in an antibacterial assay on *E.coli*, without affecting bioactivity or antioxidant activity even at high loading. Ce-MBGs are therefore excellent DDSs (**Figure 1**) that also present modulable antioxidant properties[8]. More recently, MBGs are emerging as promising scaffolds for *soft* tissue applications such as muscle regeneration, wound dressing and tendon healing. We explored also the synthesis of injectable composite hydrogels to confer those properties to materials suitable for *soft* tissue applications.

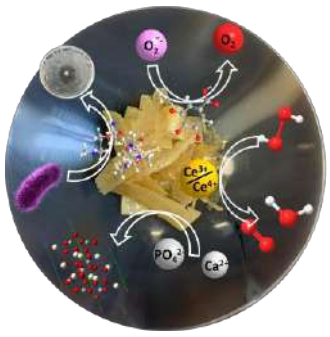

Figure 1: Ce-MBGs applications

References:

[1] Hench L.L., Mater. Sci. Forum. 1999, 293, 37-64

[2] Vallet-Regi M.et al,. Mater. Today Bio. 2021, 11, 1-15

[3] Lusvardi, G et al.; ACS Biomater. Sci. Eng., 2022, 8, 2890-2898

[4] Fraulini F. et al, J. Funct. Biomater., 2023, 129, 1-14

[5] Zambon A. et al. 2023, 18, 30875-30880

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INO-PO-001

Fluorine activation of promising platinum compounds as anticancer drugs against orphan tumors

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Glioblastoma (GBM) and pancreatic cancer are classified as orphan tumors. For both, the only available treatment includes maximal safe surgical resection, followed by radiotherapy and chemotherapy based on platinum drugs. Unfortunately, neither of these therapies can offer a high survival rate (5-6% maximum).[1,2]

For this reason, nowadays, many studies have been focused on the synthesis of new platinum compounds with the aim to increase the efficacy against these kinds of tumors. Since one of the main issues in cancer treatment is the bioavailability, starting from an already published complex (**Pt-IV**)[3] we decided to synthesized two new molecules (**1** and **2**) in which we modified the diamine core adding a fluorine in different positions in order to change the solubility of the complex and its biological activity.[4]

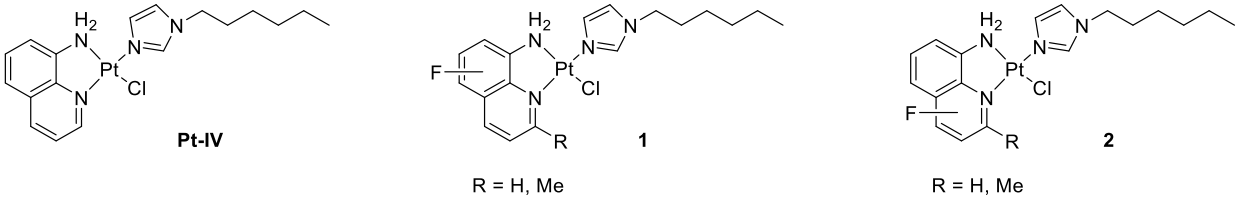

Figure 1: The already published complex (**Pt-IV**) and the new ones (**1** and **2**).

Pt-IV was already tested for its antitumoral activity against glioblastoma cell lines (U87-MG) and the IC_{50}, evaluated in terms of ability to affect cell proliferation, was 5.3 ± 0.55 μM.[5]

The influence of introducing the fluorine atom in the diamine skeleton will be evaluated in terms of cytotoxicity against orphan tumors.

References:

[1] Davis ME. *Clin J Oncol Nurs.,* **2016**; 20(5 Suppl):S2-8
[2] Puckett Y, Garfield K., *StatPearls [Internet]*, **2024**
[3] Facchetti, G., Ferri, N., Lupo, M.G., Giorgio, L. and Rimoldi, I. *Eur. J. Inorg. Chem.*, **2019**: 3389-3395
[4] Lüdtke, C. Haupt, A. Wozniak, M. Kulak, N. *Journal of Fluorine Chemistry,* **2017**, 98-105
[5] V. Coccè, E. Martegani, L. Doneda, I. Rimoldi, G. Facchetti, G. Coffetti, G. Lucchini, L. Roncoroni, A. Giannì, C. Corradini, G. Alessandri, E. Ciusani, F. Cilurzo, S. Franzè, F.Paino, A. Pessina *Cancer Nano,* **2024**, 15:5

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INO-PO-002

Development of advanced biomedical devices for hard and soft tissue applications

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Phosphate-based glasses (PGs) are promising bioresorbable materials for controlled delivery of therapeutic species. In this work different synthesis techniques are used: *sol-gel (SG)* and *coacervation (COA)*.[1] Cerium mesoporous PGs (Ce-MPGs, *SG synthesis*), in the system P_2O_5-CaO-Na_2O-$(CeO_2)x$ (x = 0, 1, 3, 5, 10 mol %), have been developed. Cerium, like superoxide dismutase (SOD) enzyme, is able to destroy highly reactive oxygen or nitrogen species.[2] To increase antioxidant properties, Ce-MPGs were loaded with polyphenols (Quercetin, Morin Hydrate and 3-Hydroxyflavone).[2] The studied loaded glasses show a relevant SOD-mimetic activity, these PGs are able to reduce post implantation inflammation and reduce the recovery time. Manganese and copper powders (Mn-PGPs, Cu-PGPs, *COA synthesis*), in the system P_2O_5-CaO-Na_2O-$(YO)_x$ (Y=Mn or Cu. x = 0, 1, 3, 5, 10 mol %), have been also studied.[3] Bioactivity tests performed on PGPs, Mn1-PGPs and Cu1-PGPs into different medium, show the formation of hydroxyapatite-like precursor, after few days of immersion (Figure 1 red marked). Mn-PGPs and Cu-PGPs have great potential in hard tissue regeneration, not only as a drug delivery system. Copper is also able to mimics the activity of SOD enzyme and Cu-PGPs show a very high antioxidant capability.

Figure 1: SEM image of PGPs (A), Cu1-PGPs (B) and Mn1-PGPs (C) after immersion, respectively, into Tris-HCl Buffer solution, simulated biological fluid and cell medium McCoy's 5A.

References:

[1] D. Carta, *et al*. Phosphate-based Glasses Prepared via Sol–Gel and Coacervation. Phosphate and Borate Bioactive Glasses, The Royal Society of Chemistry, 2022, chapter 6.
[2] G. Lusvardi, *et al*. Loading with Biomolecules Modulates the Antioxidant Activity of Cerium-Doped Bioactive Glasses. ACS Biomaterials Science & Engineering 2022 8 (7), 2890-2898.
[3] V. Mourino, *et al*. Metallic ions as therapeutic agents in tissue engineering scaffolds: an overview of their biological applications and strategies for new developments. J. R. Soc. Interface (2012) 9, 401–419.

INO-PO-003

Electrochemilumiluminescent systems for bio-sensing applications

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Electrochemiluminescence, or electrogenerated chemiluminescence (ECL), is a process that uses an applied electrical bias to generate reactive species at an electrode surface that undergo subsequent electron-transfer reactions to generate luminescent species[1].The biggest advantages of this technique are the absence of the background noise from the excitation source, used in traditional photoluminescent measurements, high specificity and an excellent sensitivity. Nowadays the ECL technology is largely used in the development of immunoassays[2].

However, sensitivity of ECL strongly depends on the nature of the emitters, therefore the development of new strategies to improve ECL-based assays is still a relevant research topic and the aim of this project. Our strategy to achieve signal increase is to build systems in which a large number of ECL-emitters are anchored on a three-dimensional (3D) platform, which in this case is constituted by silica nanoparticles (NPs), functionalized on the surface with electrochemiluminescent Ir(III) complexes. We selected Ir(III) complexes as emitters of choice since they show outstanding photophysical properties, such as high emission efficiency, easy-tuning of the emission range by changing the C^N ligand and ancillary ligand together, excellent stability[2]. Furthermore, the introduction of negatively charged solubilizing groups (SG, sulfonates) on the Ir complex ligands would allow for both increasing solubility in aqueous media and preventing non-specific binding interactions with unwanted biological targets.

Although some Ir(III) complexes for ECL applications appeared in the literature, only a few examples of Ir complexes soluble in aqueous media or aqueous organic media have been reported[3,4].

In this communication, the synthesis of Ir(III) water soluble complexes, their characterization, as well as their anchoring to nanoparticles (Figure 1) will be illustrated.

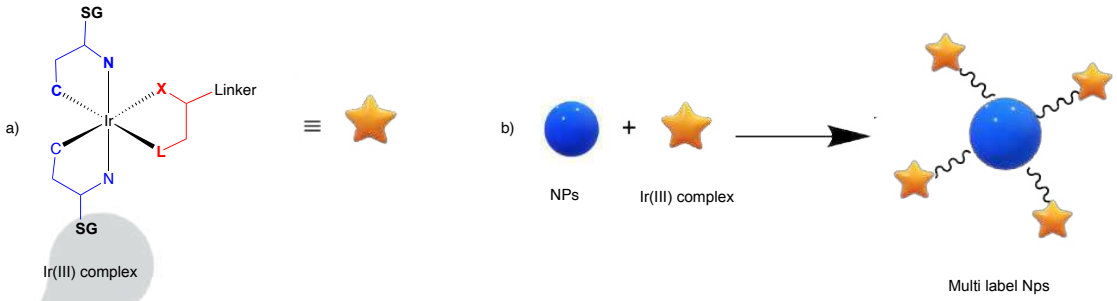

Figure 1. a) Ir(III) complexes structure, b) Anchoring to nanopaticles (NPs)

References:

[1] N.E. Tokel, A. J. Bard, J. Am. Chem. Soc., 1972, 2862-2863.

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INO-PO-004

Development of constrained DACH-containing chelators for radiopharmaceutical applications

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Nuclear medicine exploits radiopharmaceutical for diagnostic and therapeutic purposes across various diseases. ^{68}Ga ($t_{1/2}$ = 1.13 h, $I_{\beta+}$ = 89%, $E_{\beta+\,avg}$ = 830 keV) stands out as a leading option for Positron Emission Tomography (PET) due to its advantageous characteristics. To effectively bind the metal, chelating agents are essential. Macrocyclic chelators generally show slow kinetics, requiring harsh radiolabeling conditions unsuitable for many biomolecules used as targeting vectors. On the other hand, non-macrocyclic ligands offer faster complexation kinetics under milder conditions, but their complexes typically exhibit lower thermodynamic stability. HBED[1] is a promising acyclic chelator for ^{68}Ga, forming complexes with high thermodynamic stability. To address the drawbacks of acyclic chelators, we have developed a novel class of constrained chelators based on HBED, incorporating a "rigid" *trans*-diamminocyclohexane (DACH) backbone. This structural constrain can enhance the metal-ligand complex stability. In this study, new constrained DACH-containing chelators were synthetized and thoroughly characterized. The complexation with Ga was performed in D_2O and MeOD-d_4 at room temperature, followed via NMR spectroscopy. Preliminary findings suggest promising potential for these chelators in developing novel radiopharmaceuticals for ^{68}Ga. Further studies will focus on completing the investigation of these molecules and performing the radiolabeling of the complexes obtained, as well as evaluate the complexation with other metals of interest.

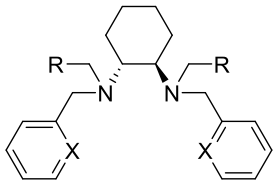

Figure 1: General structure of this new class of chelators.

References:

[1] T. I. Kostelnik, C. Orvig, Chem. Rev., 2019, 902-956

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INO-PO-005

Pd(II)/phosphine/curcumin complexes as potential anticancer agents

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Palladium(II) complexes have stimulated the research interest mainly due to their in vitro cytotoxicity against various cancer cell lines, and their low cytotoxicity in healthy cells[1,2]. Thus, in this work, we combined Pd(II)/phosphine systems with the natural product, curcumin, as a ligand, obtaining a series of complexes, which were characterized by elemental analysis, molar conductivity, cyclic voltammetry, mass, NMR (^{1}H, ^{31}C, ^{31}P{^{1}H}), UV-vis, and IR spectroscopies, and four of them (A1, A2, A4, and A5) by X-ray crystallography. The $[Pd(cur)(PPh_3)_2]PF_6$ (A1), $[Pd(cur)(dppe)]PF_6$ (A2), $[Pd(cur)(dppp)]PF_6$ (A3), $[Pd(cur)(dppb)]PF_6$ (A4) and $[Pd(cur)(dppf)]PF_6$ (A5), where dppe = 1,2-*bis*(diphenylphosphino)ethane, dppp = 1,3-*bis*(diphenylphosphino)propane, dppb = 1,4-bis(diphenylphosphino)butane, and dppf = 1,1'-*bis*(diphenylphosphino)ferrocene (P-P). The *in vitro* cell viability of the complexes A1-A5, cisplatin, and the free ligand curcumin were evaluated by the MTT colorimetric assay against the MDA-MB-231 (human triple-negative breast tumor cells), SK-BR-3 (human breast tumor cells), A549 (human lung tumor cells), A2780 (human ovarian carcinoma cells), A2780cis (cisplatin-resistant human ovarian carcinoma cells), and MRC-5 (non-tumor human lung cells). For the tumor cell lines tested, the complexes showed good anticancer activities. The results showed that in general the complexes had lower IC_{50} values than free curcumin and the precursors $[PdCl_2(P\text{-}P)]$. In the MDA-MB-231 cell line, complexes A1 and A5 stood out, with their lowest IC_{50} values, around 5 □mol/L, and the complexes showed to be more active (lower IC_{50} values) against the ovarian cell lines. Complex A1 was 23- and 22-fold more cytotoxic than cisplatin, against the A2780 and A2780cis cells, respectively. The A1 complex was studied on A2780cis cells and it was found that this complex inhibits colony formation and induces cell cycle arrest in the G1 phase in a concentration-dependent manner and leads to cell death by apoptosis. The DCFDA assay revealed a potent ROS induction for complex A1.

Acknowledgments: FAPESP (2017/15850-0;2023/02475-8), CAPES and CNPq.

References:

[1] A. Valentin, S. Bakalis, K. Gkatzionis, G. Palazzo, N. Cioffi, C. Di Franco, E. Robler, A. Brooker, M. M. Briton, J. Med. Chem. 2009, 52(2), 484 – 491.
[2] Y. Li, Z. Gu, C. Zhang, S. Li, L. Zhang, G. Zhou, S. Wang, J. Zhang, Eur. J. Med. Chem. 2018,144, 662 – 671.

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INO-PO-006

Exploring Titanium-OSSO Complexes for Stereoselective Polymerization of 1-Vinylcyclohexene and (*S*)-4-Isopropenyl-1-Vinyl-1-Cyclohexene, along with Styrene Copolymerization

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The global focus on environmental sustainability has led to a shift towards using renewable resources in various industrial processes. In polymer production, significant progress has been made by using monomers derived from renewable sources to make polyolefins. This departure from traditional petrochemical-based materials signifies a move towards more eco-friendly practices in the polymer industry. Polyolefins like polyethylene and polypropylene are widely used in packaging, construction, and other applications, traditionally made from petroleum-based monomers. However, due to concerns about climate change and limited fossil fuel resources, researchers and industries are exploring alternatives, including using renewable monomers. A significant advancement in synthesizing polyolefins from renewable monomers involves using metal complexes with OSSO-type ligands, which exhibit remarkable catalytic activity and selectivity in polymerizing bio-based monomers, thus facilitating efficient production of high-quality polyolefins[1].

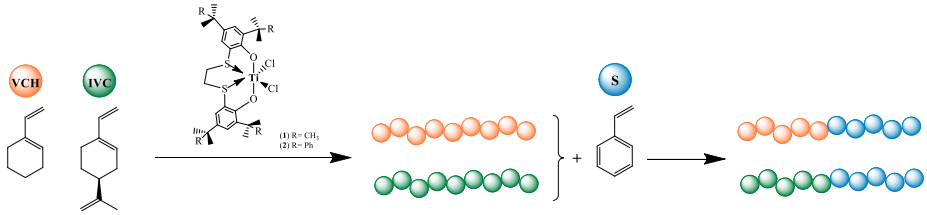

Figure 1: General scheme of the synthesis of polyolefins promoted by [OSSO]-Titanium complexes.

Two titanium complexes with OSSO-type ligands are explored for their catalytic capabilities in promoting stereoselective polymerization of (*S*)-4-isopropenyl-1-vinyl-1-cyclohexene (IVC), a monomer of natural origin that was synthesized starting from perillaldehyde, found most abundantly in the herb perilla[2]. Previously, the same study was conducted on 1-vinylcyclohexene (VCH) using it as a model monomer as it has the same structure as IVC except for the isopropenyl substituent. Both IVC and VCH were copolymerized with styrene (S) to obtain a perfect diblock copolymers.

References:

[1] V. Paradiso, V. Capaccio, D.H. Lamparelli, C. Capacchione, *Coordination Chemistry Reviews* **2021**, 429, 213644.
[2] H. Liu, F. You, W. Shi, X. Hu, Y.-M. So, X. Shi, *Polymer Chemistry* **2023**, 14 (38), 4474–4480.

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INO-PO-007

α-Diimine ligands with a fluorinated skeleton: coordination chemistry to palladium and relevant catalytic activity

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During the last two decades Pd(II)-based Brookhart type complexes, of general formula [Pd(Me)(MeCN)(N-N)][PF_6] (N-N = α-diimines, DAB or BIAN), have been extensively studied as homogeneous catalysts for the copolymerization of ethylene with polar vinyl monomers, such as acrylic esters, to obtain functionalized polyolefins (**FPO**), very interesting macromolecules that could represent an environmental-friendly improvement with respect to simple polyolefins.[1]

We have now studied a new series of α-diimine ligands characterized by halogenated aryl substituents on the backbone (Figure 1).[2] In contrast to DAB derivatives, the coordination to palladium of the fluorine substituted ligands **3** - **5** resulted to be rather difficult and new synthetic strategies are under investigation. For instance, we have now found that ligand **5** does not react with [Pd(cod)(Me)Cl], unless [Pd($PhCN)_2Cl_2$] is present in the reaction mixture, leading to [Pd(**5**)(Me)Cl] thanks to the transfer of the diolefin to the latter palladium precursor. In the case of ligand **3**, which is also inert towards [Pd(cod)(Me)Cl], the synthesis of [Pd(**3**)(Me)Cl] was tentatively achieved through the transmethylation reaction performed on [Pd(**3**)Cl_2] that, in turn, was obtained from the reaction of **3** with [Pd($PhCN)_2Cl_2$].

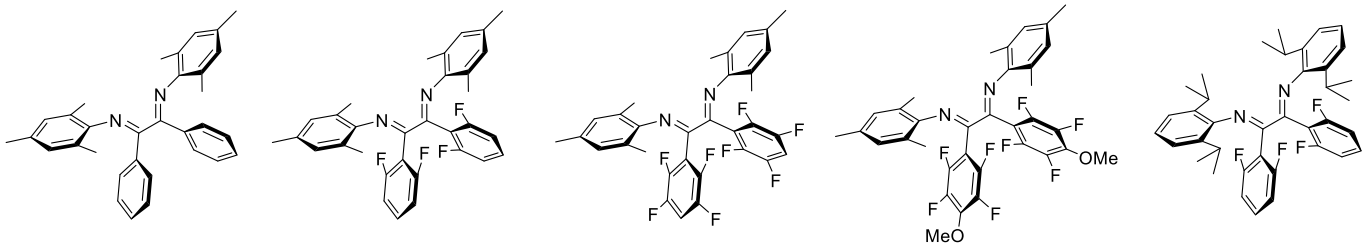

Figure 1: The investigated halogen-substituted α-diimine ligands.

The catalytic behaviour of the corresponding cationic complexes [Pd(**1**)(Me)(MeCN)][PF_6] and [Pd(**2**)(Me)(MeCN)][PF_6] in the ethylene/methyl acrylate copolymerization will be also presented.

Acknowledgements:
MUR (PhD PON Program) is acknowledged for the fellowship (K.A.H.).

References:

[1] F. Wang, C. Chen, Polymer Chemistry 2019, 10, 2354 – 2369.
[2] T. Lieu, O. Daugulis, Organometallics 2022, 41, 3249 – 3256.

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INO-PO-008

Fluoride Binding by Lanthanide(III)-Complexes Investigated by Multinuclear and Multifrequency NMR Techniques

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The ability of complexes to recognize anions represents a significant challenge for coordination chemistry and it is attracting increasing interest due to its potential applications in technological and biomedical fields. In this work, we investigated the interaction between fluoride ion and two Ln^{III}-based complexes characterized by different coordination geometries and hydration numbers (q = 1, 2) (**Figure 1**).[1] For this purpose, a combination of high- and low-resolution NMR techniques has been employed. Specifically, fast-field cycling relaxometry (^{1}H longitudinal relaxation rates *vs* B_0) and ^{17}O NMR measurements (oxygen transverse relaxation rates *vs* temperature) were performed on the Gd^{III}-complexes. The affinity constant (K_A) of the complexes with F^- was determined *via* relaxometric titration. The thermodynamic and kinetic parameters, associated with the chemical exchange of water molecules with fluoride, were determined by acquiring ^{19}F NMR spectra at different temperatures over the diamagnetic analogue Y^{III}-complexes.[2] The results of this study represent a fundamental step towards the development of new Ln^{III}-receptors with enhanced anion affinity and selectivity.

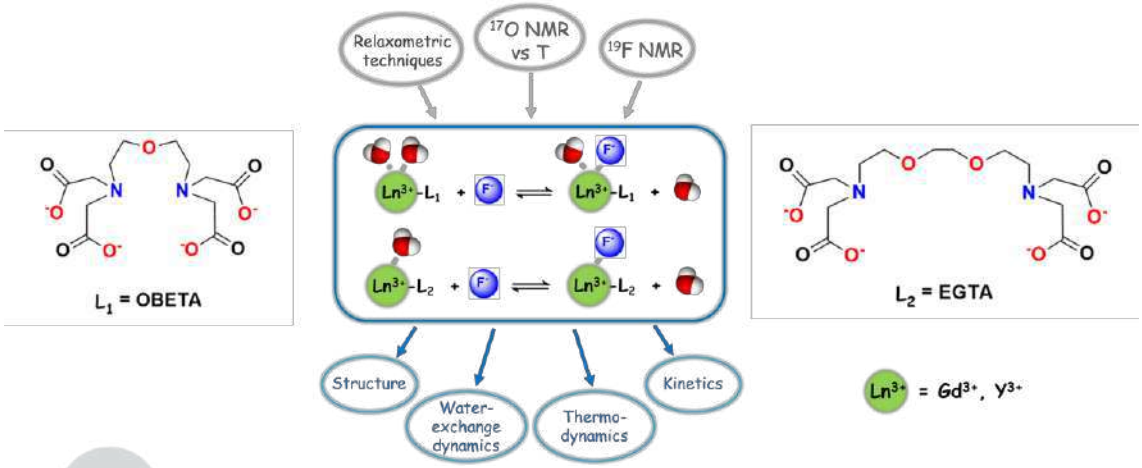

Figure 1: Low- and high-field NMR techniques used to study the interactions between Ln^{III}-complexes and fluoride.

References:

[1] Z. Baranyai, M. Botta, R. Negri *et al.*, Chem. Eur. J. 2012, 18, 7680 – 7685.
[2] D. Lalli, F. Carniato, L. Tei, C. Platas-Iglesias, and M. Botta, Inorg. Chem. 2022, 61, 496−506.

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INO-PO-009

GO and RGO doped metals: new MORAL materials for catalytical applications

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Metal ORganic Alloys (MORALs) are a class of materials composed by organic molecules embedded in a metal structure. The chemical reduction of metal salts in the presence of graphene oxide (GO) suspension led us to the obtaining of GO doped metal dusts (GO@metal).

The subsequential reduction of embedded GO using thiophene in order to obtain reduced graphene oxide (RGO) allowed a further modification of the materials to achieve RGO@metal.

These materials have been characterized by different analytic techniques such as TEM microscopy, XRPD, XPS and FT-IR, proving the coexistence of metal nanoparticles together with graphene oxide[1]. Tested in different reactions, their catalytical activity emerged particularly in the nitro-group reduction[2] and Suzuki-type C-C cross coupling.

The incorporation of GO and RGO in the metals has given the materials greater stability as catalysts in subsequential reaction runs and improved conversion when compared to the undoped metals obtained following the same protocol.

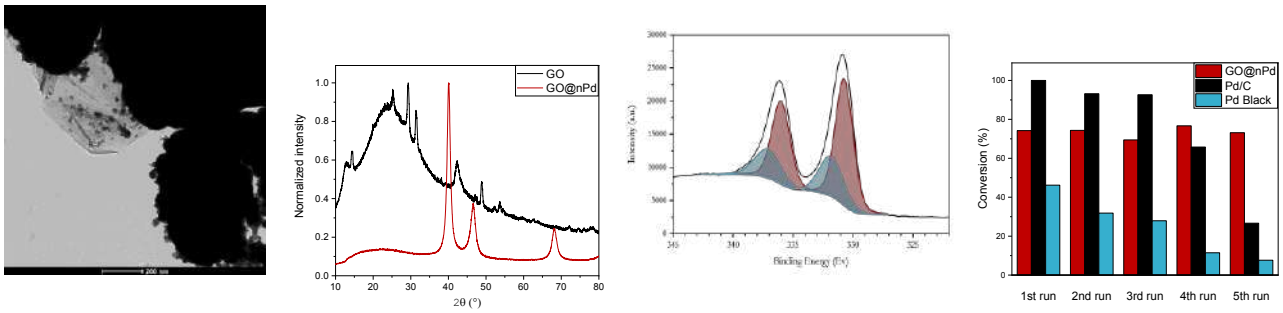

Figure 1: from left to right, TEM image, XRPD spectrum and XRF spectrum detail of the material GO@nPd (graphene oxide in palladium nanoparticles), and conversion of nitrobenzene in aniline compared with other Pd-based catalysts.

References:

[1] M. Formenti, M.P Casaletto, G. Barone, M. Pagliaro, C. Della Pina, V. Butera, R. Ciriminna, Advanced Sustainable Systems 2024, 2300643 (1-8).
[2] M. Formenti, M. Pagliaro, C. Della Pina, R. Ciriminna, Green Synthesis and Catalysis, 2024 in press.

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INO-PO-010

Design, synthesis and characterization of glyco-conjugated copper(II) complexes as potential anticancer agents

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Thiosemicarbazones (TSC), semicarbazones (SC) and acylhydrazones are at the same time molecules with biological activity and versatile ligands towards transition metal ions[1]. Cu(II) complexes are promising compounds as an alternative to platinum based drugs in antitumor therapies, since copper is an endogenous metal and cancer cells have an abnormal copper balance[2]; therefore, the use of this metal could improve the selectivity towards cancer cells. Cancer cell metabolism is also characterized by an enhanced uptake and utilization of glucose[3]: consequently, a useful tool to further increase the selectivity of an anticancer agent is its glyco-conjugation, which also improves water solubility.

In this context, three novel ligands, the TSC $\mathbf{H_2L^1}$, the SC $\mathbf{H_2L^2}$ and the acylhydrazone $\mathbf{H_2L^3}$ and their copper (II) complexes (Fig. 1) have been successfully synthesized and characterized. The coordination properties of the ligands towards Cu^{2+} ions have been studied in aqueous solution by mean of UV-vis spectrophotometric titrations. Evaluation of their cytotoxic activity is currently ongoing.

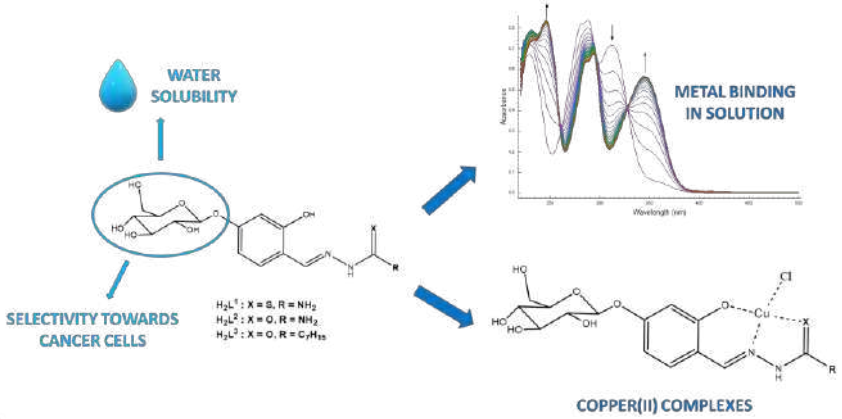

Figure 1: Ligands $\mathbf{H_2L^1}$, $\mathbf{H_2L^2}$ and $\mathbf{H_2L^3}$: molecular structure and coordination properties.

References

[1] Y. Yu et. al., J.Med.Chem. 2009, 52, 5271–5294.
[2] D. A. da Silva et. al., J.Inorg. Biochem. 2022, 226, 111634.
[3] M. G. Vander Heiden et al., Science, 324, 2009.

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INO-PO-011

Reductive cyclization of nitroarenes with CO surrogates for the synthesis of six-membered heterocycles

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Transition-metal catalyzed reductive cyclization of nitroarenes represents an efficient and versatile strategy to afford N-heterocyclic compounds in one step. In this regard, carbon monoxide emerges as an optimal reductant, allowing clean reactions and a simplified work-up, with gaseous carbon dioxide as the sole stoichiometric byproduct. Recently, the use of CO-surrogates, molecules capable to release CO during the reaction, has allowed to release the constraints for autoclaves, pressurized lines and safety measures, generally required to handle gaseous carbon monoxide.[1] Our group has recently reported that phenyl formate acts as an excellent CO-source in the palladium/phenanthroline catalyzed synthesis of indoles,[2] carbazoles[3] and oxazines.[4] A further improvement has been achieved by employing formic acid, in the presence of an equimolar amount of acetic anhydride and a base[5,6] as a more atom economical and cheaper CO-surrogate. Among the various possible heterocycles obtainable by intramolecular reductive cyclization reactions, those leading to six-membered rings had proven to be more challenging. Here we report the synthesis of phenazines, an important scaffold present in several natural and synthetic products with biological activity. Despite harsher conditions are required to carry out the cyclization with respect to the five-membered ones, it was possible to employ a catalytic ratio of 4000, uncommon for these kind of reactions.

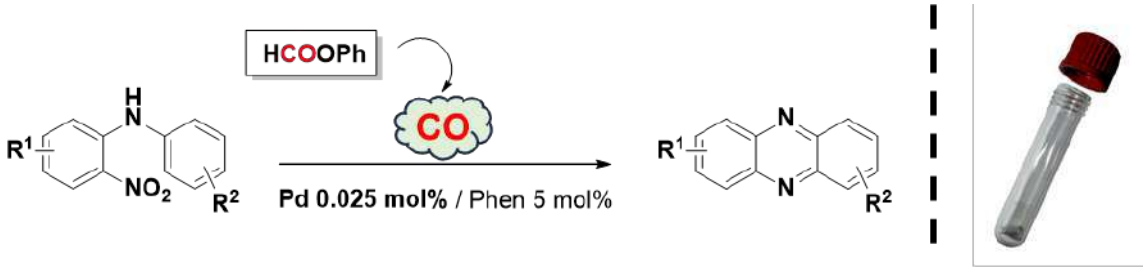

Figure 1: synthesis of phenazine scaffold from o-nitro anilines. Reaction are performed in a thick-walled glass tube

References:
[1] F. Ragaini, F. Ferretti, M. A. Fouad, *Catalysts*, **2023**, 13, 224-234.
[2] M. A. Fouad, F. Ferretti, D. Formenti, F. Milani, F. Ragaini, *Eur. J. Org. Chem*. **2021**, 4876-4894.
[3] D. R. Ramadan, F. Ferretti, F. Ragaini, *J. Catal.* **2022**, 409, 41-47.
[4] M. A. El-Atawy, D. Formenti, F. Ferretti, F. Ragaini, *ChemCatChem* **2018**, 10, 4707-4717.
[5] M. A. Fouad, F. Ferretti, F. Ragaini, *J. Org. Chem.* **2023**, 88, 5108-5117.
[6] M. A. Fouad, F. Ferretti, S. Galiè, F. Ragaini, *Eur. J. Org. Chem*. **2023**, 26, e202300809.

INO-PO-012

Shape-controlled synthesis of Au nanostructures and their photocatalytic activity

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We present the synthesis, characterization, and photocatalytic testing of gold nanoparticles of different size and morphologies. Gold nanoparticles exhibit a strong localised surface plasmon resonance (LSPR) when irradiated, which is majorly influenced by the morphology of the nanoparticles and their dielectric environment. This interaction of gold nanoparticles with the light makes them suitable for photocatalytic activity. We optimise the synthetic routes to obtain different sizes and shapes of gold nanoparticles with desired optical response. For size-controlled synthesis of Au nanospheres, we use the citrate-reduction method. This is followed by deposition of the nanoparticles over a metal oxide support, which is crucial to study the interaction of gas molecules with our plasmonic photocatalyst. To preserve the reactivity of the nanoparticles, it is essential to remove the stabiliser ligands. We aim to study the effect of plasmonic excitation in binding and unbinding of the reactants to the catalyst of different morphologies under dark conditions and light illumination (with different intensity and polarisation) using operando IR spectroscopy to unravel the fundamental interaction regulating the plasmonic photoactivity of the prepared materials.

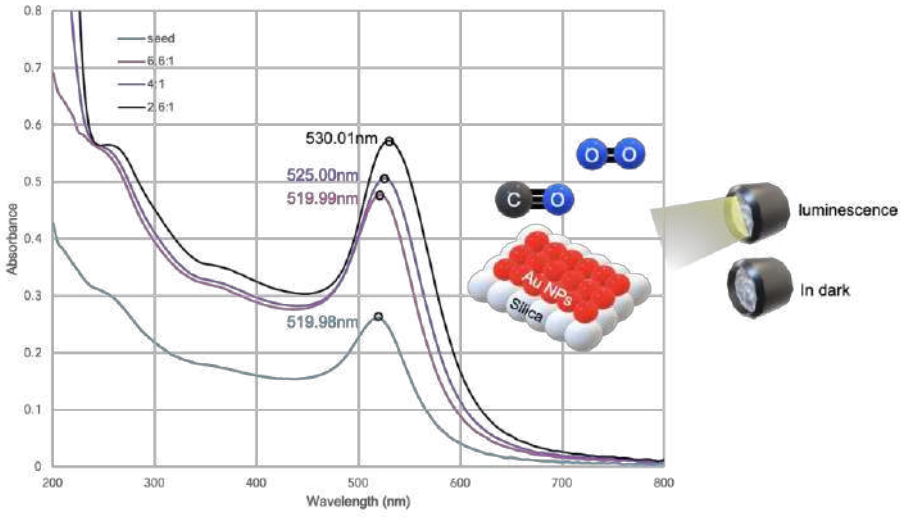

Figure 1: Au nanospheres of different sizes (exhibiting different peaks) supported over silica, used as a catalyst to interaction of gaseous reactants in absence and presence of light.

References:

[1] N.G. Bastús, J. Comenge, V. Puntes, Langmuir 2011, 27, 11098 – 11105.
[2] J. A. Lopez-Sanchez *et al.,* Nature chemistry, 2011, 3, 551 – 556.

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INO-PO-013

Nanostructured Catalysts for Enhanced CO_2 reduction: Insight from Electrochemical and Spectroscopic studies

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The rising levels of atmospheric carbon dioxide (CO_2) and the growing socio-economic impacts of global warming underscore the pressing demand for sustainable approaches to CO_2 utilization and conversion. In this context, the perspective of using renewable sources and low-cost transition metal-based catalysts to promote an electrochemical reduction of CO_2 emerges as a promising avenue to contrast massive utilization of fossil resources for fuel and chemical production.[1,2] However, the efficiency and selectivity of CO_2 electroreduction in aqueous electrolytes is mainly limited by the competitive hydrogen evolution reaction. Recently, the electrodeposition of highly hydrophobic molecular films from water-soluble organic additives was found to significantly improve the electrocatalytic CO_2 reduction performances of polycrystalline nanostructured metal surfaces, thus inhibiting or suppressing hydrogen evolution.[3,4]

According to this strategy, in our group we have designed some heterocyclic organic salts and investigated their adsorption properties on polycrystalline metals as well as their effect as promoters of electrocatalytic CO_2 reduction. In this contribution, we present a molecular tuning strategy involving the functionalization of the surface of some metal electrodes with organic molecules. We firstly synthesized a series of organic salts used as substrates for the functionalization of the metallic surface *via* electrodeposition. Through electrochemical studies, such as cyclic voltammetry, we investigated their electrochemical behaviour in reduction. Furthermore, employing a combination of electrochemical and spectroscopic techniques, we identified and analysed the species adsorbed on the polycrystalline metal foil. We investigated the structural factors and physicochemical properties of the molecular film. Finally, explored their potential catalytic contribution to catalysis by analysing important parameters such as product selectivity, catalytic activity, and the stability.

Overall, this contribution aims to deepen our understanding of CO_2 reduction and advance the development of efficient electrocatalysts for sustainable energy conversion.

References:

[1] F. Franco, C. Rettenmaier, H. S. Jeon, B. Roldan Cuenya, Chem. Soc. Rev. 2020, 49, 6884- 6946; B. Domingo-Tafalla, E. Martínez-Ferrero, F. Franco, E. Palomares-Gil, Molecules 2022, 27, 1081
[2] S. Fernández, F. Franco, C. Casadevall, V. Martin-Diaconescu, J. M. Luis and J. Lloret-Fillol, *J Am Chem Soc*, 2020, 142, 120–133.
[3] A. Thevenon, A. Rosas-Hernández, J. C. Peters and T. Agapie, *Angewandte Chemie*, 2019, 131, 17108–17114.
[4] A. Thevenon, A. Rosas-Hernández, A. M. Fontani Herreros, T. Agapie and J. C. Peters, *ACS Catal*, 2021, **11**, 4530–4537

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Electrochemical Reduction of Carbon Dioxide to Formate with Electrodeposited Catalyst

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The increase of carbon dioxide in the atmosphere and the continued use of fossil fuels are two very important problems in nowadays society, the electrochemical reduction of carbon dioxide for the production of high value chemicals can be a partial solution to both of those problems[1]. Catalysts are very important in the development of a system that can be efficient and convenient with this technology, in particular copper catalysts have been studied for a long time because of the multiple shape this metal can assume and also because of the catalysts' versatility and great numbers of possible products obtained[2].

In this work we show how we approached a copper catalyst, Cu_2Se, with a synthesis made via electrodeposition, this type of synthesis was already studied[3], but the resulted catalyst was never tested for carbo dioxide redction. The synthesis of the catalyst and its deposition on conductive support happens at the same time, reducing both the time and the cost necessary for the catalyst's production. We studied different materials as substrates, noticing a different catalytic activity depending on the subrate. The obtained systems have been tested for the catalytic reduction of carbon dioxide in water, the production of formate as a liquid product was identified and quantified.

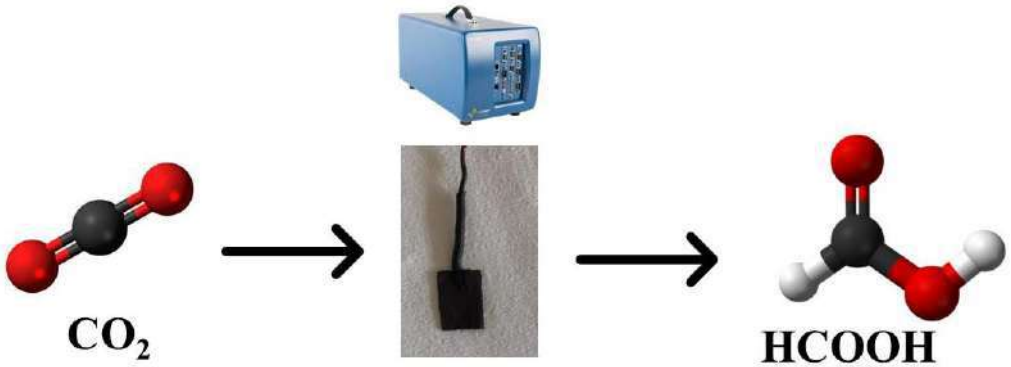

Figure 1: Scheme of carbon dioxide reduction with electrodeposited catalyst

References:
[1] C. Wang, Y. Chen, Adv. Mate. 2023, 35, 2303179.
[2] D. Yang, Q. Zhu, Nat. Comm. 2019, 10, 677.
[3] Lipkkow D., Strehblow H., Electrochimica Acta 1998, 43, 2131-2140.

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INO-PO-015

Synthesis and characterization of electroluminescent copper(I) complexes

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Last years have witnessed an increase in the interest in photoactive copper(I) complexes, because of their potential use in solid-state lighting devices. In particular, ionic copper(I) coordination compounds are currently investigated as electroluminescent materials to be used in the active layer of Light-Emitting Electrochemical Cells (LECs), as a more sustainable alternative to poorly available second and third-row transition metals.[1]

Among the variety of complexes, tetrahedral heteroleptic $[Cu(P\hat{}P)(N\hat{}N)]^+$ are one of the most studied. Focusing on the N^N ligand, 2,2'-bypiridine and 1,10-phenanthroline derivatives have been extensively investigated, but moving to ligands containing 5-membered N-heterocycles can be interesting in term of expansion of the colour range of emission, in particular towards the green-blue part of the visible spectrum.[2,3]

In this context, herein we present the synthesis, the characterization and the application in device of a series of $[Cu(P\hat{}P)(N\hat{}N)]^+$ complexes, based on Xanthphos as the P^P ligand and on differently substituted pyridine-pyrazoles as the N^N ligand (Figure 1). The compounds have been structurally characterized by NMR and XRD techniques. The photophysical properties have been investigated through UV-Vis absorption and emission spectroscopies (Figure 1), while the electrochemical behaviour has been tested by means of cyclic voltammetric measurements. The most promising compounds of the series have also been incorporated and tested in prototypal LEC devices.

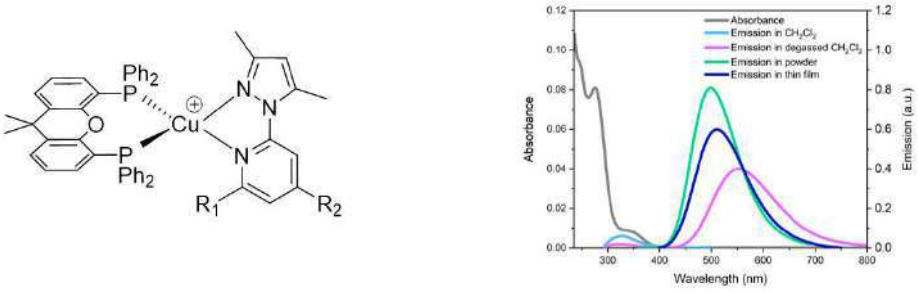

Figure 1: Chemical structure and photophysical properties of synthetized complexes.

References:

[1] G.U. Mahoro, J. Fernandez-Cestau, J. L. Renaud, P. B. Coto, R. D. Costa, S. Gaillard, Advanced Optical Materials 2020, 8, 2000260.
[2] C. E. Housecroft, E. C. Constable, Journal of Materials Chemistry C 2022, 10, 4456-4482.
[3] L. M. Cavinato, S. Wölfl, A. Pöthig, E. Fresta, C. Garino, J. Fernandez-Cestau, C. Barolo, R. D. Costa, Advanced Materials 2022, 34, 2109228.

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INO-PO-016

LANTHANIDE BASED EMITTERS AS QUANTUM LIGHT SOURCES

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In recent years, research has focused on optimizing light sources for use in the latest technology optical devices, such as linear photonic integrated circuits and telecom optical fibers. Recently, quantum photonics is becoming increasingly popular in view of the potentialities of single-photon emitters and entangled photons in data communication and security. In this framework, luminescent lanthanide ions offer a promising alternative to current quantum light sources based on inorganic bulk materials, in view of the long-lived and highly coherent emission provided by intra-shell f-f transitions. These ions can be combined with suitable organic ligands able to behave as antennas, that is, they absorb light, transfer the absorbed energy to the metal via an intersystem crossing process and induce enhanced sensitized lanthanide emission. In this work, we investigate novel lanthanide-based complexes to be proposed as flexible quantum light sources. Tripodal benzimidazole[1] organic ligands derivatives have been reacted with lanthanide ions (Eu, Tb, Sm, Er, Yb, Nd, Gd), to afford highly crystalline materials showing luminescent properties in the visible and near-infrared spectral ranges. The correlation between the observed emission and the geometry and symmetry of the compounds is investigated. This research is performed in the framework of the EIC Pathfinder Challenges "ARTEMIS " GA 101115149 and PRIN2022 PNRR "QuantaMol" Prot. P2022PKW4T projects.

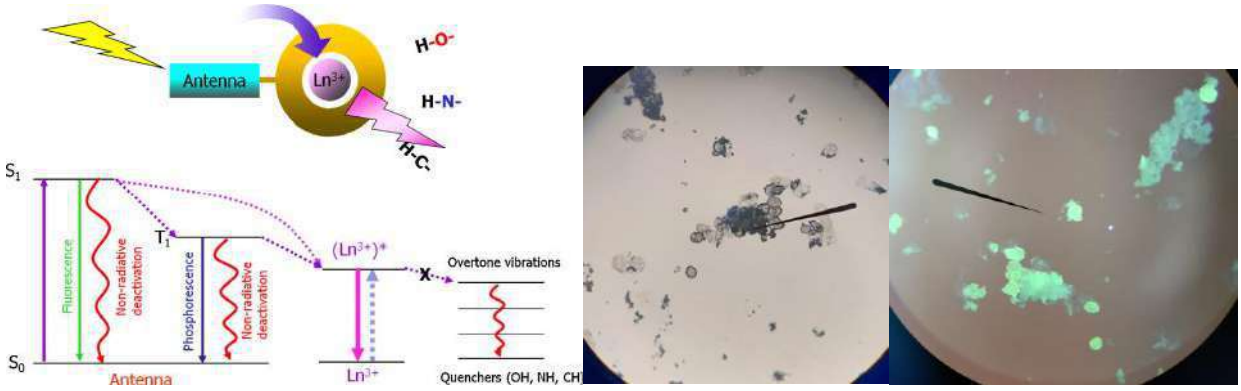

Figure 1: Antenna effect for a generic lanthanide complex (left); Terbium complex crystals under natural light (center) and under UV light (right).

References:

[1] A. Cruz-Navarro, D. Hernández-Romero, A. Flores-Parra, J.M. Rivera, S.E. Castillo-Blum, R. Colorado-Peralta, *Coord. Chem. Rev.*, 2021, *427*, 213587.
[2] W.L. Chan, C. Xie, W.S. Lo, J.C. G Bünzli, W.K. Wong, K.L. Wong, *Chem. Soc. Rev.*, **2021**, *50*, 12189

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KTb_3F_{10} nanoparticles for optical thermometry: synthesis and spectroscopic characterization

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The search for novel materials as luminescent probes is a hot topic for the rapid development of optical diagnostic techniques in biomedicine. Among the multitude of phosphors, lanthanide doped inorganic nanomaterials exhibit notable luminescence properties in the optical range (UV, visible and Near Infrared). In particular, the multiple emissions of lanthanide ions can be exploited in non-invasive optical nanothermometers with submicrometric spatial resolution.

In this communication, we will focus on the synthesis and spectroscopic characterization of KTb_3F_{10} nanoparticles (NPs) doped with Eu^{3+} ions. These lanthanide-doped fluoride nanoparticles have been synthesized using hydrothermal conditions and the structural properties have been analysed by X-ray powder diffraction (XRPD) technique. TEM measurements have been exploited to study the size and morphology of the NPs.

The emission properties of the NPs has been measured to investigate the local environment of the Eu3+ dopant ions. Moreover, a preliminary investigation of their thermometric properties has been carried out using a luminescence intensity ratiometric method based on the emissions of the Tb^{3+} and Eu^{3+} ions. In particular, the Stark levels of the $^7F_6$ ground state of the Tb^{3+} ion were selectively excited with laser radiation in resonance with the $^7F_6 \rightarrow {}^5D_4$ Stark transitions. Then the $Tb^{3+} \rightarrow Eu^{3+}$ energy transfer mechanisms [1] have been monitored at different temperatures, in particular in the physiological range (20-50 °C). The emission spectra of energy transfer mechanisms $Tb^{3+} \rightarrow Eu^{3+}$ were compared to the emission of the selective excitation of Eu^{3+} of $^7F_1 \rightarrow {}^5D_0$ transition. Laser excitation was also exploited to study the dynamics of the excited states of the lanthanide ions in order to confirm energy transfers in the NPs.

References:

[1] A.N. Carneiro Neto, R.T.Jr. Moura, A. Shyichuk, V. Paterlini, F. Piccinelli, M. Bettinelli, O.L. Malta, *J. Phys. Chem. C* **2020**, *124*, 10105–10116.

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INO-PO-018

Unexpected assembly of hexanuclear macromolecular complexes obtained under ball-milling conditions

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IUPAC defines a mechanochemical reaction as "a reaction that is induced by the direct absorption of mechanical energy" and lists mechanochemistry as one of the "Ten Chemical Innovations That Will Change Our World"[1]. The popularity of mechanochemistry is rapidly growing owing to its low environmental impact deriving from the reduced amount of solvent employed and the possibility of reaching new compounds isolable only under mechanochemical conditions [2]. Herein, we present the unexpected self-assembly of hexa-nuclear Zn-complexes synthesized using ball-mill grinding techniques, along with their solid-state structural characterization.

The reaction between zinc acetate, isonicotinamide, and a 4-X-substituted benzoic acid (X = Cl, Br, I) were conducted by means of a vibrating ball mill resulting in the formation of species containing six tetrahedrally coordinated zinc nuclei arranged in a crown fashion, as depicted in Figure 1.

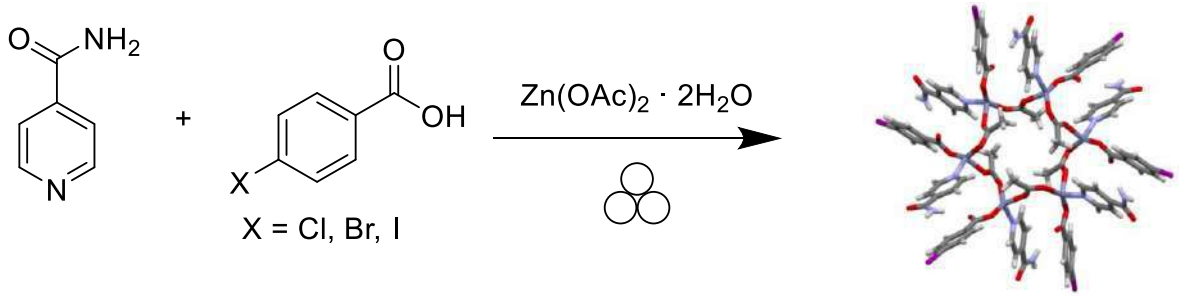

Figure 1: General reaction for the formation of the Zinc complexes.

Isonicotinamide and benzoate ligands act as monodentate ligands, while the acetate bridges two metal atoms. This unprecedented type of assembly is a clear example of how mechanochemistry can give access to unexpected reaction routes and new types of products that are difficult to isolate by solution based synthesis.

References:

[1] Fernando Gomollón-Bell, Chemistry International 2019, 41, 12– 17.
[2] Tomislav Friščić, Cristina Mottillo, and Hatem M. Titi, Angewandte Chemie Int. Ed. 2020, 59, 1018–1029.

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Innovative therapies for multiple sclerosis based on PEG-functionalized gold nanoparticles.

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Gold nanoparticles (AuNPs) find wide application in nanomedicine, from imaging to therapy[1]. Like all nanomaterials, they have at least a size between 1 and 100 nm, which leads to the phenomenon of plasmonic resonance bands: surface electrons can be collectively excited upon interaction with electromagnetic radiation of the appropriate wavelength, and the resulting absorption is known as Localised Surface Plasmon Resonance (LSPR)[2]. In this framework AuNPs were synthesised using polyethylene glycol (PEG-SH) as hydrophilic capping agent, to enhance the biological response[3]. The AuNPs-PEG have a small size (20 nm x 80 nm), showing LSPR in water at λ_{max} = 530 nm: this increases the surface/volume ratio and the loading of drug used in the treatment of multiple sclerosis. Spectroscopic characterisations by UV–visible (Figure 1), FT-IR, X-ray photoelectron spectroscopies were carried out, verifying the gold surface functionalization. Moreover, Dynamic Lighth Scattering and Z potential studies confirmed the size and stability in water solution. These preliminary studies encourage the use of this system to increase the bioavailability of drugs, reducing their effective dose and therefore side effects.

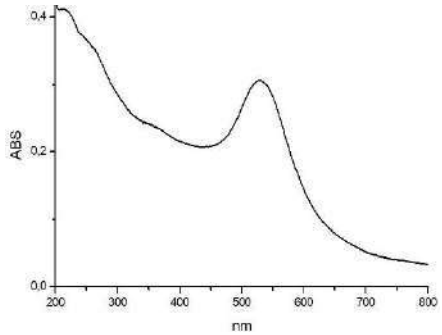

Figure 1**: Uv-vis of AuNPs-PEG in water solution: LSPR at 530 nm**

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References:

[1] I. Venditti, et al., Nanomaterials 2020, 10, 1898
[2] I. Venditti, et al., AIP Conference Proceedings 2021, 24165, 020019
[3] S. Hanan, et al., Environmental Science and Pollution Research 2022, 29, 21235-5

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Long-term surface reactivity of asbestos in simulated body fluids

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Inhalation of asbestos fibres is associated with the development of several lung diseases, including incurable malignancies. The production of reactive oxygen species (ROS) is recognized as a significant factor in triggering inflammation, which, if prolonged, can lead to fibrosis and cancer. ROS can originate from cellular processes such as phagocytosis, as well as from redox reactions catalysed by iron sites exposed on the surface of asbestos fibre. While asbestos potency to catalyse free radical generation is well established, few is known on how the interplay between asbestos surface and biological fluids may modify this reactivity.

To clarify whether the interaction of fibres with biological fluids can modify the surface reactivity, crocidolite and tremolite asbestos were incubated in artificial lysosomal fluid at 37°C for 28 days. Biodurability (Si and Mg release) and surface chemical composition were evaluated by ICP-OES and XPS, respectively. ROS generated by pristine and incubated fibres were assessed by measuring •OH radicals through the spin trapping technique coupled with EPR spectroscopy. •OH radical release in oxidizing environment was monitored up to 15 days (indicative of long-term reactivity). To mimic the condition encountered by fibres phagocytized by macrophage and subsequently released into inflamed epithelial tissue due to frustrated phagocytosis, the spin-trapping measures were carried out at pH 4.5 and 7.4, respectively.

Crocidolite and tremolite asbestos showed different durability and underwent changes in surface composition, with alterations in Fe abundance and reactivity depending on the dissolution rate and the amount of Fe in the bulk, which are both higher for crocidolite than tremolite. However, despite the different dissolution, both asbestos were still reactive in •OH radical release following incubation in artificial lysosomal fluid. Additionally, both displayed higher •OH production under neutral than under acidic pH.

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CO_2 Capture and Conversion to C1 Chemicals with Copper/Nickel Bis(amino)bipyrazolate Metal−Organic Frameworks

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The reaction involving 3,5-diamino-4,4′-bis(1H-pyrazole) (3,5-H_2L) with copper (II) and nickel (II) acetates under solvothermal conditions resulted in the formation of four mixed-metal metal−organic frameworks (MIXMOFs). Despite their relatively low specific surface areas, these MIXMOFs exhibited notable CO_2 adsorption capacities at ambient temperature and pressure, with the highest values observed for $Cu_{0.05}Ni_{0.95}$ and $Cu_{0.2}Ni_{0.8}$ (5.6 wt% CO_2), along with reasonably high isosteric heat of adsorption, particularly for $Cu_{0.2}Ni_{0.8}$ (Qst = 26.2 kJ/mol). All MIXMOFs were evaluated as heterogeneous catalysts in carbon dioxide electrochemical reduction (CO_2RR) in acetonitrile solution under varying potential conditions. The most favorable outcomes were achieved at E = −1.5 V vs. Ag/AgCl/KCl sat. In addition to hydrogen evolution (HER) side reactions, the main reduction products observed under these conditions were CO and CH_4. $Cu_{0.05}Ni_{0.95}$ exhibited superior performance, achieving an overall [CO+CH_4] conversion of ~200 ppm and a Faradaic efficiency of ~52%. Notably, the selectivity of CO_2RR products appeared to be correlated with the predominant metal ion within the catalyst: while $Cu_{0.05}Ni_{0.95}$, enriched in nickel, predominantly produced CO, $Cu_{0.5}Ni_{0.5}$, with a higher copper content, mainly generated CH_4. [1]

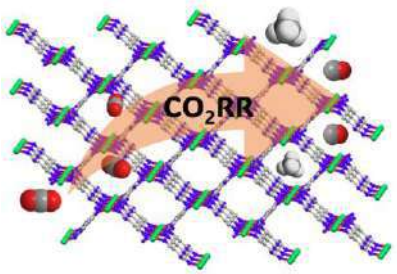

Figure 1: Representation of the crystal structure of [$Ni_{0.5}Cu_{0.5}$ (3,5-L)].

References:

[1] P. Campitelli, A. Tombesi, C. Di Nicola, C. Pettinari, A. Mauri, S. Galli, T. Yan, D. Liu, J. D. Duan, S. Goswami, G. Tuci, G. Giambastiani, J. T. Hupp and A. Rossin, *ACS Appl. Energy Mater.*, 2023, 6, 9231–9242.

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Synthesis of Block and Multi-Block Copolymers Based on Polyesters from ROCOP of Phthalic Anhydride and Epoxides from Renewable Sources

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Polyesters are amongst the most widely applied oxygenated polymers. Most of commercial polyesters is prepared by polycondensation, they are found in applications spanning packaging, fibres, rigid plastics and engineering materials. Other routes, like ring-opening polymerization (ROP) of lactones and ring-opening copolymerization (ROCOP) of epoxides and cyclic organic anhydrides, have been explored to synthetize polyesters[1] coming from renewable source. With ROCOP the properties of the resulting materials can be easily manipulated by facile substitution of just one of the monomers and it may enable new materials based on aliphatic or semi-aromatic polyesters which are inaccessible using ROP due to thermodynamic reasons and this is interesting to increase thermal and mechanical properties.

In this context, block and multi-block copolymers possessing polyester blocks with different rigidity have been synthesized by ROCOP of phtalic anhydride and epoxides like cyclohexenoxide (CHO) and vinyl-cyclohexenoxide (vCHO) and others from renewable sources like epoxy methyl undecenoate (EMU) and glycidyl geraniol ether (GGE) respectively from fatty acids and terpene alcohols. Polymerizations were conducted resorting to insertion coordination transition metal catalysts like [OSSO]-type-Fe(III) with PPNCl, a catalytic system already demonstrated capable of promoting the synthesis of polycarbonates through ROCOP of epoxides and CO_2[2]. Different synthetic strategies have been explored, monomer conversions were monitored by NMR spectroscopy and, in all cases, block copolymers are obtained due to the different polymerization rate of the epoxides. Furthermore, to modify the thermal properties of the polymers, copolymerization tests were carried out by varying the ratios between the epoxides which influence the formation of blocks with different rigidity. The polymers were characterized by Nuclear Magnetic Resonance techniques (^{1}H-NMR, ^{13}C-NMR, HSQC e DOSY), Gel Permeation Chromatography (GPC), Differential Scanning Calorimetry (DSC) and their ability to separate into microphases was investigated by Atomic Force Microscopy (AFM).
For a possible application these new synthesized polymers can be investigated within the properties of TPEs.

References:

[1] S. Paul, Y. Zhu, C. Romain, R. Brooks, P.K. Saini, C.K. Williams, Chem. Commun., 2015, 51, 6459.
[2] F. Della Monica, B. Maity, T. Pehl, A. Buonerba, A. De Nisi, M. Monari, A. Grassi, B. Rieger, L. Cavallo, C. Capacchione, ACS Catal., 2018, 8, 6882−6893.

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INO-PO-023

Sustainable Hydroponics: Examining the Effectiveness of Vermitea on the Growth, Nutrient Uptake, and Metabolism of *Diplotaxis Muralis*

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Sustainable food production for the world's growing population is a major challenge. To meet the demand for food, an additional 2.7-4.9 million hectares of land will be needed for agriculture each year[1]. Unfortunately, one-third of arable land is already contaminated with various pollutants, leading to a heightened interest in hydroponic farming for food security. However, hydroponics typically relies on mineral fertilizers, which are derived from finite resources. Furthermore, their continuous use can result in the accumulation of toxic elements in edible plants. As a result, farmers are actively seeking sustainable farming solutions. Vermitea, a liquid extract of vermicompost (organic fertilizer processed by earthworms), has emerged as a potential substitute for inorganic nutrient solutions in hydroponic cultivation[2]. In this study, we evaluated the effectiveness of vermitea in the hydroponic cultivation of *Diplotaxis muralis* plants. Our findings demonstrate that enhanced vermitea solutions (with similar electrical conductivity and pH values to the Hoagland solution) resulted in higher biomass production, SPAD values, and nutrient assimilation. The lower nitrate content in vermitea solutions also improved the quality of rocket leaves. Nuclear Magnetic Resonance (NMR) spectroscopy, a key analytical technique in metabolomics, was used to analyze the metabolic profile of *Diplotaxis muralis* plants grown in three different hydroponic nutrient solutions[3]. Our research suggests that enhanced vermitea can completely replace inorganic nutrient solutions in hydroponic farming.

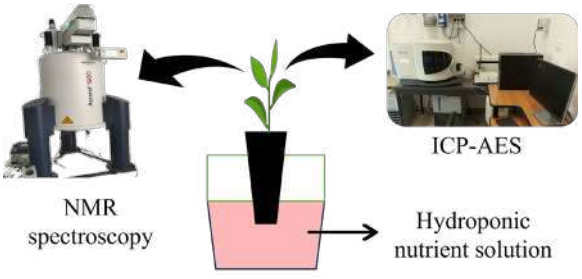

Figure 1: Metabolomic and Elemental Analysis of Rucola (*Diplotaxis muralis*) Plants Cultivated in Various Hydroponic Nutrient Solutions.

References:

[1] P. Abhilash, V. Tripathi, S.A. Edrisi, R.K. Dubey, M. Bakshi, P.K. Dubey, H. Singh, S.D. Ebbs, 2016, 1, 54-65.
[2] S.u. Rehman, F. De Castro, A. Aprile, M. Benedetti, F.P. Fanizzi, 2023, 13, 1134.
[3] M. Lucarini, M.E. Di Cocco, V. Raguso, F. Milanetti, A. Durazzo, G. Lombardi-Boccia, A. Santini, M. Delfini, F. Sciubba, 2020, 9, 945.

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INO-PO-024

A novel 1,2,4-triazole copper(II) complex as a catalyst for Glaser reactions

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Triazoles are versatile ligands for the preparation of copper coordination polymers,[1] magnetic materials,[2] bioactive compounds[3] or copper catalysts.[3] In this work, we synthesized a new triazole ligand, the 1H-3,5-ditrifluoroacetamido-1,2,4-triazole, L, following a literature method.[4] Upon reaction of L with copper(I) oxide in acetonitrile, pale green crystals were isolated from acetonitrile and the single crystal X-ray diffraction evidenced that the copper centres are penta-coordinated affording a roughly square pyramidal geometry. Each Cu ion is respectively coordinated to two oxygens of amide groups and to two nitrogens of two triazoles of the faced ligands, with the triazoles bridging the two metal centres. The two copper ions display planar square geometry extended to a square-based pyramid by coordination of an acetonitrile molecule, resulting in a structure composed of two square-based pyramids oriented in opposite directions, with acetonitrile molecules occupying the apical positions. An additional acetonitrile solvent molecule is present in the asymmetric unit (Figure 1) of the unit cell. The UV-vis spectra display the appearance of a typical broad absorption band centred at around 666 nm. The dinuclear copper complex is persistent in solution as highlighted by ESI-MS with molecular peaks at m/z 702.6 attributed to $[Cu_2L_2\text{-}H]^+$ and at m/z = 704.6 likely due to $[Cu_2L_2]^-$. Preliminary catalytic studies show that $[Cu_2L_2(CH_3CN)_2]$ is active in the Glaser reaction.[5]

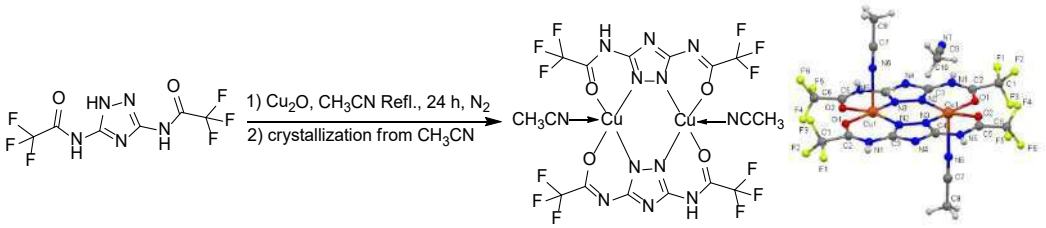

Figure 1: Scheme for the preparation of $[Cu_2L_2(CH_3CN)_2]$ (left); depiction of the molecular structure of $[Cu_2L_2(CH_3CN)_3]$ (right).

References:

[1] https://doi:10.1021/cg800774z
[2] https://doi:10.1039/d1ra03107d
[3] https://doi:10.1016/j.jinorgbio.2009.10.020
[4] https://doi.org/10.1002/jps.2600701126
[5] https://doi.org/10.1039/A908014G

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Exploring the Antitumor Potential of Novel Platinum(II)-Nucleoside Complexes of the type *cis*-[Pt(NH$_3$)$_2$(Guo/dGuo)X] (X = Cl, Br, I): Synthesis, Characterization, and Cytotoxicity Studies

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The investigation of metal-based complexes with potential antitumor activity has been a major focus in recent years, following the success of cisplatin. Despite the effectiveness of approved platinum drugs against various types of cancer, their lack of selectivity towards cancer cells and high toxicity have prompted the search for new platinum-based antitumor agents. Among these, platinum(II)-nucleoside compounds have shown promise as antimetabolites for anticancer therapy[1]. Complexes of the type *cis*-[Pt(NH$_3$)$_2$(Am)Cl]$^+$ (Am = heterocyclic amine derived from pyridine, pyrimidine, purine, piperidine, or saturated amine) have demonstrated high stability and solubility in aqueous media, as well as interesting antitumor potential *in vitro* and *in vivo* against various tumors, including sarcoma and leukemia[2]. Recently, we synthesized six complexes of the type *cis*-[Pt(NH$_3$)$_2$(Am)X]$^+$, where Am = guanosine (Guo, **a**) or 2'-deoxy-guanosine (d-Guo, **b**) and X = Cl (**1**), Br (**2**), I (**3**). These cationic platinum species were characterized by NMR spectrometry and their potential antiproliferative activity was evaluated in different cancer cell lines. Our findings suggest that halogen substitution may be a simple method to alter the cytotoxic and biological activities of these complexes, while maintaining their molecular structure.

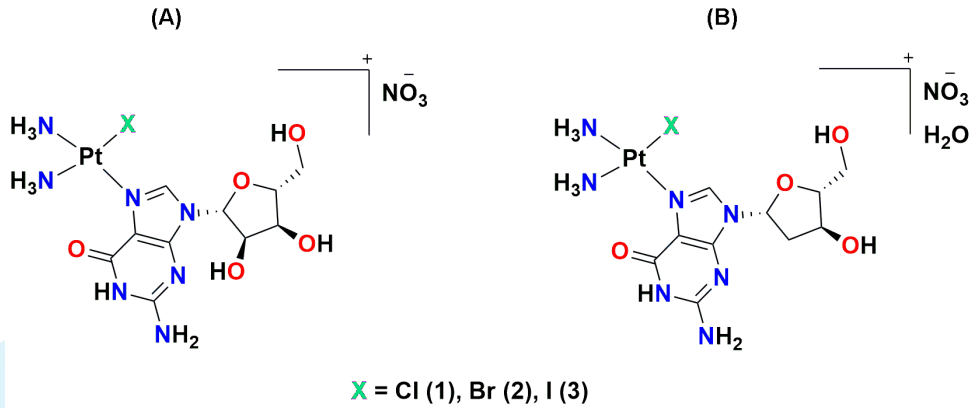

Figure 1: Chemical structures of platinum(II) nucleoside monoadducts, including (**A**) *cis*-[Pt(NH$_3$)$_2$(Guo)X]$^+$ (**1a**, **2a**, **3a**) and (**B**) *cis*-[Pt(NH$_3$)$_2$(dGuo)X]$^+$ (**1b**, **2b**, **3b**) complexes; where X = Cl (**1**), Br (**2**) or I (**3**).

References:

[1] F. De Castro, E. Stefàno, E. De Luca, M. Benedetti, F.P. Fanizzi, Pharmaceutics 2023, 15, 941.
[2] L.S. Hollis, A.R. Amundsen, E.W. Stern, Journal of Medicinal Chemistry 1989, 32, 128–136.

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Synthesis, Characterization, and Evaluation of the Cytotoxic Properties of Novel Water-Soluble Monofunctional Platinum(II) Complexes Incorporating Imidazole Derivatives and Phenanthroline

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Platinum-based drugs such as cisplatin, carboplatin, and oxaliplatin, are commonly used in clinics to treat various cancers. However, due to their limited success, there is a significant need to develop nonclassical platinum complexes. Among these, monofunctional platinum(II) complexes are particularly interesting due to their unique chemical properties, water solubility, and potential biological significance[1]. This study aims to enhance the solubility and anticancer activity of a novel class of compounds that combine imidazole and phenanthroline derivatives. Interestingly, the new complexes [Pt(η^1-C_2H_4OEt)(NH_3)(phen)]Cl (**2**), [Pt(η^1-C_2H_4OEt)(1-hexyl-1*H*-imidazole)(phen)]Cl (**3**), and [Pt(η^1-C_2H_4OEt)(1-hexyl-1*H*-benzo[d]imidazole)(phen)]Cl (**4**) can be synthesized from the precursor [Pt(η^1-C_2H_4OEt)Cl(phen)] (**1**). These complexes are particularly intriguing as they may serve as substrates for cell plasma membrane transporters due to their cationic nature and water solubility, unlike cisplatin[2]. As observed with other monofunctional Pt(II) complexes, these compounds may form sterically hindered adducts with DNA, thereby interacting with DNA-RNA polymerases[3]. Mass spectrometry and Nuclear Magnetic Resonance (NMR) spectroscopy were used to characterize these Pt(II) derivatives. The anticancer activity of the newly synthesized complexes was evaluated using the sulforhodamine B (SRB) assay on both healthy (HK-2) and malignant (HeLa and Caki-1) cell lines. Notably, complex **3** exhibited the highest level of cytotoxicity in both normal and malignant cell lines. However, when compared to healthy cells (HK-2), complex **2** showed the highest selectivity for malignant cells (Caki-1) among the studied complexes.

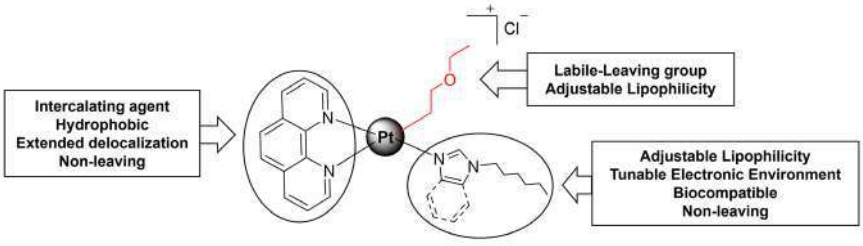

Figure 1: Illustrates the main features of ligands bound to platinum in the investigated complexes [Pt(η^1-C_2H_4OEt)(1-hexyl-1*H*-imidazole)(phen)]Cl (**3**) and [Pt(η^1-C_2H_4OEt)(1-hexyl-1*H*-benzo[d]imidazole)(phen)]Cl (**4**)

References:

[1] Ali A. Almaqwashi, W. Zhou, *et al*., Journal of the American Chemical Society 2019, 141, 1537 – 1545.
[2] F. De Castro, E. Stefàno, *et al*., Pharmaceutics 2021, 13, 642
[3] G. Y. Park, J. J. Wilson, *et al*., Proceedings of the National Academy of Sciences 2012, 109, 11987 – 11992.

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Improved mechanochemical synthesis of MIL-100(Fe) and MIL-100(Fe)@Carbon Metal-Organic Framework composite for PFAS polluted waters remediation

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MOFs are a class of crystalline solids with permanent porosity. They are coordination polymers made up of metal ions or metal clusters linked together by organic ligands. MOFs are promising materials for application in the chemical industry of the future due to their outstanding properties. Their porosity and the high tunability of internal surface open many possibilities for their use in different fields such as catalysis, gas storage and separation[4]. However, their application is often hindered by the cost of the precursor and by the demanding synthetic conditions. Moreover, the manufacturing of MOFs containing materials is still in early development. One of the most promising MOF is MIL-100 (Fe): it was firstly synthetized by Férey et al. and possesses large cages with diameters of about 25 and 29 Å[1] with reported Langmuir surface area up to 2800 m^2/g. One big advantage of this MOF is that is built by inexpensive and non-toxic constituent such as Iron and trimesic acid. However, its synthetic procedure requires toxic organic solvents, such as DMF and hazardous synthetic additives (i.e. hydrofluoric acid or nitric acid), and high temperature and pressure[1]. Recently there were some attempts to prepare this material in a greener way and a water-based synthesis for MIL-100 (Fe) was developed[2]. However, the use of water as solvent is still problematic since it consumes an important resource and produces a lot of wastewaters rich in inorganic salts and acids. As a result, solvent free synthesis seems to offer an ideal mean to obtain this material. It was recently reported that hand grinding of the precursor powders and subsequent annealing of the mixed powder at high temperature followed by immersion in water can produce MIL-100 (Fe)[3]. Here we propose a new synthetic method which replaces hand grinding with the use of a ball miller to improve reproducibility and scalability of the production of MIL-100 (Fe). This process offers advantages over the previous methods since it is more rapid, preventing waste of time, and it uses lower temperature and less water, thus improving energy efficiency and reducing waste and resource consumption. Moreover, we could extent this procedure to a new method for the creation of a new composite material made of intimately bonded MIL-100 (Fe) on carbon particles. This material opens the possibility of improved manufacturing of MOFs since this powder can be formed in a pellet that better fit existing technology for adsorption of gases or molecules from liquid phase. We assessed the crystallinity of the materials using X-ray powder diffraction and their gas adsorption properties through N_2 adsorption isotherms. We also tested these materials for the removal of perfluoroalkyl substances, PFASs, from water, with promising results.

References:

[1] P. Horcajada et al., 2007, 27, 2820-2822
[2] T. Steenhaut et al., 2020, 44 (10), 3847–3855.
[3] B.E. Souza et al., 2020, 8 (22), 247–8255
[4] K. Xiang-Jing et al., 2021, 7 (8), 1115-1139

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A New Trimeric Palladium Scaffold only Supported by Nitrogen Ligands

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Ar-BIAN (bis(arylimino)acenaphthene) Schiff bases have found wide application as ligands for both transition and main group metals because their rigid structure imparts the correct geometry for chelation and improves the stability of the compounds against hydrolysis and rupture of the central C-C bond. We have previously reported on the synthesis of the reduced form of the BIAN compounds, Ar-BIANH$_2$.[1,2] We now report that treatment of palladium acetate with these ligands results in the reduction of palladium(II) to palladium(0) and coordination of the so formed Ar-BIAN to the latter. In the absence of other ligands, an unprecedented trinuclear complex was obtained, which is formally the first palladium(0) compound only stabilized by nitrogen ligands. Its X-ray structure shows that each palladium atom is coordinated in a standard κ^2N chelating way to an Ar-BIAN ligand and in a η^2 way to a C=N double bond of another Ar-BIAN ligand. The latter is itself chelating a second palladium atom and the same bonding scheme extend to a third Pd(Ar-BIAN) unit, which closes the loop over the first palladium atom (Figure 1).

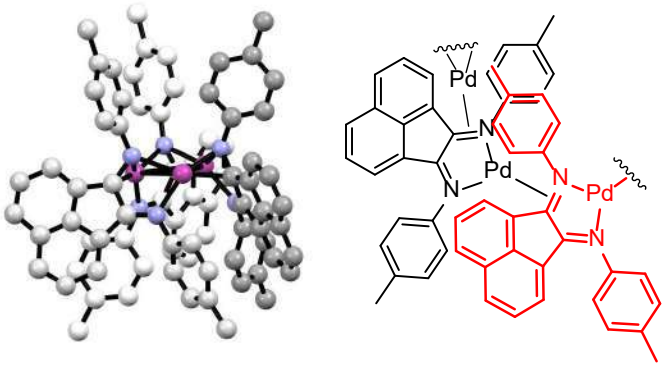

Figure 1: X-Ray structure of trimeric [Pd(4-MeC$_6$H$_4$-BIAN)]$_3$ and its partial bonding scheme.

Overall, the complex has a propeller shape, with the six aryl rings divided in two inequivalent groups. Other complexes have also been obtained showing unusual structures and their synthesis will be described.

This work was supported by MUR and Next Generation EU (PRIN2022ZJSCW3)

References:

[1] M. Viganò, F. Ferretti, A. Caselli, F. Ragaini, M. Rossi, P. Mussini, P. Macchi, *Chem. Eur. J.* **2014**, *20*, 14451-14464.
[2] A. Cimino, F. Moscatelli, F. Ferretti, F. Ragaini, S. Germain, J. Hannedouche, E. Schulz, L. Luconi, A. Rossin, G. Giambastiani, *New J. Chem.* **2016**, *40*, 10285-10293.

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Exploiting high throughput experimentation tools in iron-catalyzed ethylene/alfa olefin copolymerization

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Brookhart's and Gibson's independent discoveries that iron complexes with bis(imino)-pyridine ligands (BIP) are excellent catalysts for ethylene homopolymerization had a strong impact on the research in the field of coordination insertion polymerization.[1-3] One of the main unsolved problems in this field deals with the introduction of polar functional groups into the otherwise apolar skeleton of polyolefins. Therefore, there is a remarkable interest in the development of efficient catalysts for the direct, controlled, copolymerization of ethylene with vinyl polar monomers and the use of iron as the metal for such catalysts represents a major, but ambitious, goal. High Throughput Experimentation (Fig. 1) investigation is a powerful tool to unravel suitable candidates for this reaction.

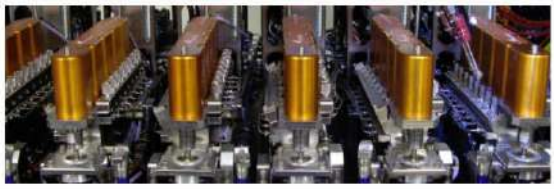

Fig. 1. Parallel Pressure Reactor.

We have now revisited three examples of Brookhart's and Gibson's catalysts (Fig. 2) and applied them to the copolymerization of ethylene with 1-hexene, as a starting alfa-olefin, before addressing our attention to polar vinyl monomers. All precatalysts generated active species leading to ethylene/1-hexene copolymers with an incorporation of the alfa-olefin up to 3.0 mol%. A remarkable effect of BIP ligand and reaction conditions on catalyst performances were observed and will be presented in this contribution. As an example, complex with **L2** generated the most active species with values up to 15.3 kg CP $mmol_{cat}^{-1}h^{-1}$ at 50 °C in the production of the copolymer with an Mn value of 5.9 kDa. This catalyst resulted to be also active at 70 °C. All the copolymers obtained with the three catalysts have polydispersity values in the range 2.3-12.6, thus indicating the formation of multiple active species.

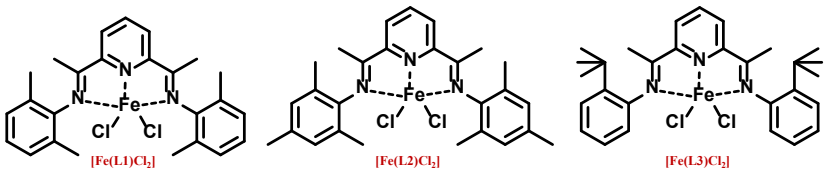

Fig. 2. The studied precatalysts.

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References:

[1] B. L. Small, M. Brookhart, J. Am. Chem. Soc. 1998, 120, 7143 – 7144.
[2] G.J.P. Britovsek, V.C. Gibson, B.S. Kimberley, P.J. Maddox, S.J. McTavish, G.A. Solan, A.J.P. White, D.J. Williams, Chem. Commun. 1998, 849-850.
[3] L. Lidong, P.T. Gomes, in Olefin Upgrading Catalysis by Nitrogen-based Metal Complexes II, Chapter 3, 77-198.

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INO-PO-030

Diffusional and heteronuclear NMR investigation of the formation of sulfide-based electrolytes for all-solid-state lithium-ion batteries

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Batteries are the fastest-growing storage technology and make an important contribution in tackling the effects of climate change. Of all existing types, lithium-ion batteries are extremely effective in powering a wide range of applications, which require high energy densities and safety features.[1] In this scenario, all-solid-state batteries seem to exhibit the right combination of performance and non-flammability.

Sulfide-based materials are promising solid electrolyte candidates achieving ionic conductivities comparable to those of liquid electrolytes. These electrolytic systems are synthesized by the reaction of Li_2S with P_2S_5 in different molar ratios affording several ionic conductors also called LPS systems.[2] Recently, sulfide-based electrolytes can also be prepared in the liquid state using polar and aprotic solvents, offering the prospect of a more scalable approach.[3] However, the ionic conductivity of the so-obtained materials may be lower than those prepared through the other routes, and some attempts to improve their performances are hindered by a lack of understanding of their speciation and formation reaction mechanism in solution. In this contribution, we will show the results of our preliminary spectroscopic studies aimed at assessing the processes of dimensional growth and mixing/integration of inorganic components, by using ^{31}P and $^{6/7}Li$ diffusional NMR techniques.

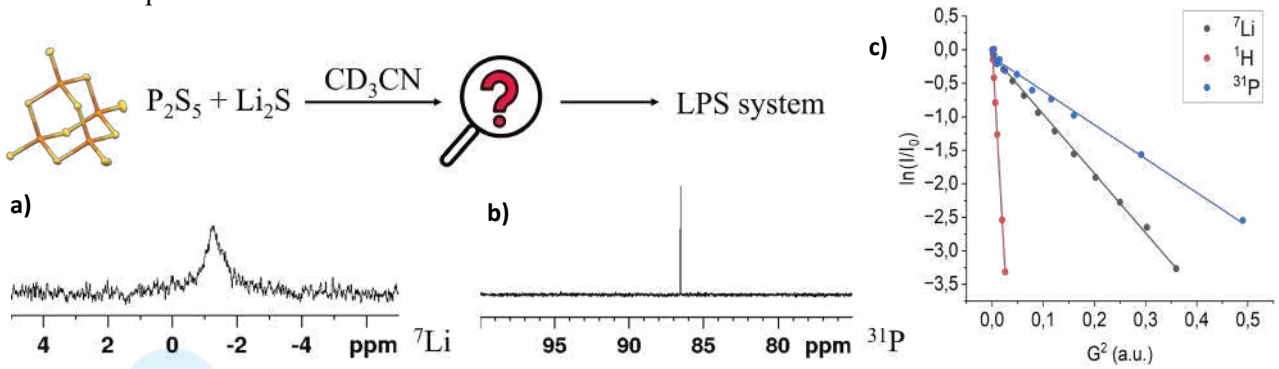

Figure 1: a) ^{7}Li and b) ^{31}P NMR spectra, and c) trends of $\ln(I/I_0)$ vs G^2 (a.u. = arbitrary units) of an LPS sample in CD_3CN. Benzene was used as internal standard in PGSE NMR experiments.

References:

[1] A. Manthiram et al., Nat. Rev. 2017, 2, 1 – 16.
[2] Ö.U. Kudu et al., J. Power Sources 2018, 407, 31 – 43.
[3] A. Miura et al., Nat. Rev. 2019, 3, 189 – 198.

INO-PO-031

Metals and metal oxides thin films deposition for food packaging application

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In recent years, many innovative food packaging techniques are being developed due to changes in production processes, retail practices and growing consumers demands of healthier, higher-quality and with a longer shelf-life food products.

Cold plasma surface modification of materials, particularly thin film deposition processes, can offer a good strategy to address these requests. Since these processes are carry out at room temperature, they can be used for the treatment of thermolabile materials such as natural and artificial polymers, or to deposit biomolecules or microorganism. These characteristics make these processes less environmental impactful and extremely attractive for industries[1,2].

The purpose of this project is the deposition of inorganic and composite thin film by means of different kind of cold plasmas to improve barrier properties of food packaging or to obtain active coating to control the release of metals and metal oxide.

Enhance barrier properties means to better preserve the food matrix shielding external factors that can impact negatively on food quality like oxygen and moisture responsible of common degradation processes. Active packaging is a recent type of packaging, characterized by the incorporation of bioactive or chemoactive molecules. This technology allows to increase the shelf-life of products and their quality by minimizing or replacing the addition of additives directly to the food[3,4].

Two deposition methods will be investigated and applied both individually or in combination: 1) Plasma enhanced-chemical vapour deposition (PE-CVD)/sputtering processes to obtain barrier coatings and composites made up by a matrix and nanoparticles of metals or the corresponding oxides, which will release ions with an antibacterial function; 2) Atomic layer deposition (ALD) to deposit metal oxides barrier layers or active layers like ZnO and Al_2O_3.

The deposited films will be characterized by means of different techniques. Permeability will be evaluated measuring water vapor transmission rate (WVTR) and oxygen transmission rate (OTR). The effectiveness of the films against bacteria and fungi will also be evaluated through specific tests.

References:

[1] F. Palumbo, C. Lo Porto, F. Fracasssi, *et al*., Coatings 2020, 10(5), 440.
[2] D. R. Boris, V. D. Wheeler, N. Nepal, et al., J. Vac. Sci. Technol. A 2020, 38, 040801.
[3] F. Versino, F. Ortega, Y. Monroy, et al., Foods 2023, 12(5), 1057.
[4] M. Vähä-Nissi, M. Pitkänen, E. Salo, *et al.*, Thin Solid Films 2014, 562, 331 – 337.

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INO-PO-032

Chiral gold nanoparticles for optical sensing applications

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Gold nanoparticles (AuNPs) find wide application in advances technologies, such as optoelectronics, sensing, imaging and therapy [1,2]. This is due to their synthetic versatility, engineering possibilities and particular chemical-physical properties, such as the Localised Surface Plasmon Resonance (LSPR)[3]. Among all challenges regarding the fabrication of AuNPs, the simple production of chiral nanoparticles remains open. Studying the synthesis and functionalization of chiral inorganic surfaces aids in understanding the dynamics at the organic-inorganic interface and will play a crucial role in their translation for biomedical applications. Although a few studies have described the transfer of molecular chirality into micrometre-sized helical ceramic crystals, this technique has yet to be implemented for metal nanoparticles with sizes of tens or hundreds of nanometres [4]. In this framework, chiral AuNPs were synthesised using wet method in tree steps, using Cetyltrimethylammonium bromide (CTAB) and L-cysteine (Lcys) as capping agents. The obtained chiral AuNPs showed typical LSPR at λ_{max} = 580 nm. Spectroscopic characterisations by FT-IR, X-ray photoelectron spectroscopies were carried out, verifying the gold surface functionalization. Moreover, Dynamic Lighth Scattering and Z potential studies confirmed the nanosize and colloidal stability in water solution, preliminary optical investigations the chirality. These preliminary studies encourage the use of this system which shows high potential in the field of optical chiral sensors.

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References:

[1] I. Venditti, et al., Nanomaterials 2020, 10, 1898
[2] Z. Zhang, et al., Theranostics 2013, 3(3), 223
[3] E. Hendry, E. et al. Nat. Nanotechnol. 2010, 5, 783
[4] H. E. Lee, et al. Nat Commun 11, 263 (2020).

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INO-PO-033

Ru(II), Rh(III) and Ir(III)- Arene Complexes containing Pyrazolone-Based Hydrazones Ligands as suitable catalysts for tandem Knoevenagel condensation reactions

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The formation of carbon–carbon bonds is a quest that has required a lot of research throughout the last 125 years of the history of chemistry. These new bonds are the key to producing a wide variety of products with high impact on every aspect of human life, and the Knoevenagel condensation reaction is one of the most important methodologies for this purpose. All the Knoevenagel reactions are performed with nitrogen-based catalysts able to remove an acidic proton from the starting material.[1] Recently, some studies have shown that in many catalytic processes the presence of Schiff bases within metal complexes is an important requirement because the -NH fragment plays an important role in involving atom-transfer intermediates. Herein, we exploited the presence of pyrazolone-based hydrazones as ligands in metal complexes where, in addition, there is a synergistic effect of the metal atom. Several Ru(II), Rh(III), and Ir(III) complexes containing hydrazone ligands were synthesized and characterized, and we explored their catalytic activity toward Knoevenagel condensation applied in tandem reactions. Interestingly, the different metal centre strongly influences the nature of the starting material consistently with their ability to catalyse either de-acetalization or oxidation reactions (Figure 1).

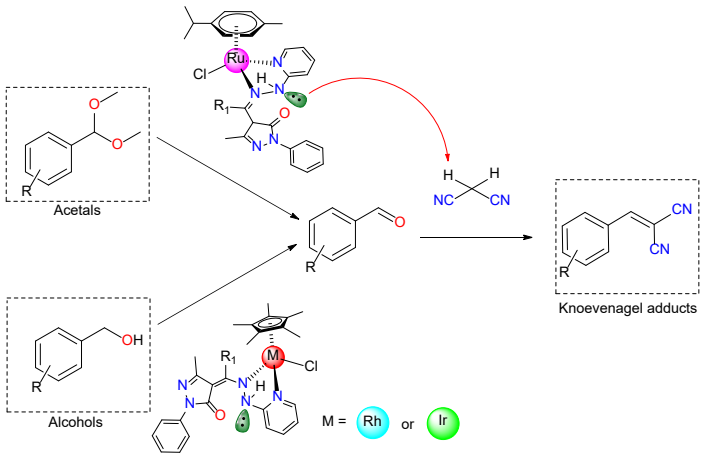

Figure 1: Tandem reaction catalyzed by Ru(II), Rh(III) and Ir(III) complexes

References:

[1] K. van Beurden, S. de Koning, D. Molendijk, J. van Schijndel, Green Chemistry Letters and Reviews, 2020, 13, 349-364.

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INO-PO-034

Cyclic trimidazoles as new ligands for the preparation of luminescent metal complexes and coordination polymers

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Triimidazo[1,2-*a*:1′,2′-*c*:1″,2″-*e*][1,3,5]-triazine (**1**) is a nitrogen rich molecule characterized by an intriguing aggregation induced photophysical behavior comprising an ultralong room temperature phosphorescence (RTUP) in the crystalline state.[1] Based on the presence at the vertexes of a regular triangle of three imidazole nitrogen atoms available for coordination, the potentially of **1** as ligand towards different metal ions have been also investigated.[2-4] Interestingly, these studies revealed the ability of **1** to coordinate as mono-, bi- and tri-dentate, affording luminescent metal complexes and coordination polymers (CPs). The functionalization of **1** with a pyridinic fragment as in **2** expanded the possible coordination modes.[4,5] In fact, **2**, due to the presence of one nitrogen atom on the pyridine ring and another on the imidazolic unit at a proper distance is able to act as chelating ligand and to give molecular or extended coordination structures through the additional nitrogen atoms of the triimidazole moiety. The multidentate nature of **2** has also allowed to isolate, by reaction with CuI in slightly different reaction conditions, two strongly luminescent polymorphs of formula $[Cu_2I_2L]_x$ (x = 2, n), namely a yellow emitting one-dimensional coordination network[6] and a green emitting dimeric complex whose structural and photophysical properties will be here presented.

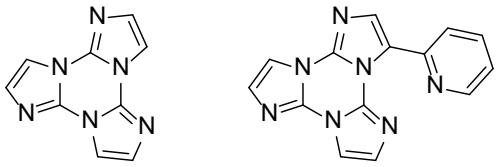

Figure 1: Chemical structures of **1** (left) and its derivative **2** (right).

References:

[1] E. Lucenti, A, Forni, C. Botta, L. Carlucci, C. Giannini, D. Marinotto, A. Previtali, S. Righetto, E. Cariati, J. Phys. Chem. Lett. 2017, 8, 1894−1898

[2] E. Lucenti, E. Cariati, A. Previtali, V. Bold, V. Ch. Kravtsov, M.S. Fonari, D. Marinotto, A. Forni, S. Galli, L. Carlucci, Cryst. Growth Des. 2019, 19, 1567−1575

[3] D. Malpicci, E. Lucenti, A. Forni, D. Marinotto, A. Previtali, L. Carlucci, P. Mercandelli, C. Botta, S. Righetto, E. Cariati, Inorg. Chem. Front. 2021, 8, 1312–1323

[4] E. Cariati, A. Forni, E. Lucenti, D. Marinotto, A. Previtali, S. Righetto, C. Botta, V Bold, V Kravtsov, M.S. Fonari Chem. Asian J. 2019, 14, 853–858

[5] D. Malpicci, D. Maver, D. Maggioni, P. Mercandelli, L. Carlucci, E. Cariati, P. Mussini, M. Panigati, New J. Chem. 2023, 47, 21463–21474

[6] D. Malpicci, D. Blasi, D. Marinotto, A. Forni, E. Cariati, E. Lucenti, L. Carlucci, Crystals 2023, 13, 149-159

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INO-PO-035

Subcritical hydrothermal process for the recovering of polymeric components of car fluff

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The European Green Deal is Europe's growth strategy, which aims to ensure by 2050 a climate neutral, clean and circular economy, where the management of resources is optimised and pollution minimised. The Circular Economy Action Plan contains a commitment to review the legislation on end-of-life vehicles (ELVs) with the aim to promote more circular business models by linking design issues to end-of-life treatment, improving the recycling efficiency.[1]

In this context, it becomes imperative to reevaluate waste streams exploring different approaches for their efficient recycling and reuse. Car fluff (light shredder residues of vehicles) is an inevitable by-product of end-of-life vehicles and it is mainly composed of a heterogeneous mixture of plastics, rubber, textile and fiber material, wood, glass and traces of ferrous and non-ferrous metals.[2] It poses challenges for its disposal and recycle; hence on its environmental impact mitigation as required by the European Union's Regulation.

The hydrothermal liquefaction is an efficient and low-energy-demanding approach potentially capable to solve this problem, it is highly flexible in dealing with both pure waste streams and mixed ones.[3]

The present work aims at developing a sustainable wet-chemistry subcritical hydrothermal process for the recovering of some polymeric components of car fluff which have reactive sites suitable for hydrolysis to depolymerize them into small molecules. Initially, the received car fluff is characterised by FT-IR determining its composition. Therefore, the degradation of polymers is tested in subcritical water varying the experimental parameters (time and temperature of the treatment, presence and amount of catalyst), and the depolymerization products are then characterized.

References:

[1] Circular economy action plan - European Commission. https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en (accessed 2024-03-21).

[2] Morselli, L.; Santini, A.; Passarini, F.; Vassura, I. Automotive Shredder Residue (ASR) Characterization for a Valuable Management. Waste Management 2010, 30 (11), 2228–2234.

[3] Dos Passos, J. S.; Glasius, M.; Biller, P. Screening of Common Synthetic Polymers for Depolymerization by Subcritical Hydrothermal Liquefaction. Process Safety and Environmental Protection 2020, 139, 371–379.

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INO-PO-036

Decoration of polydopamine surfaces with colloidal nanoparticles: a systematic study

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Polydopamine (PDA) is a mussel-inspired polymer enriched in catechol and amine groups, with strong adhesive properties[1]. Lately, it has been widely used as adhesive substrate in different fields, so we decided to study systematically the interactions between PDA and colloidal nanoparticles (NPs). Affinity of NPs for PDA surfaces is expected to depend strongly from surface Z-potential of PDA layers and Z-potential of NPs. As Z-potential is expected to depend from medium pH, we studied the different loading of different NPs as a function of pH of colloidal suspensions of NPs.

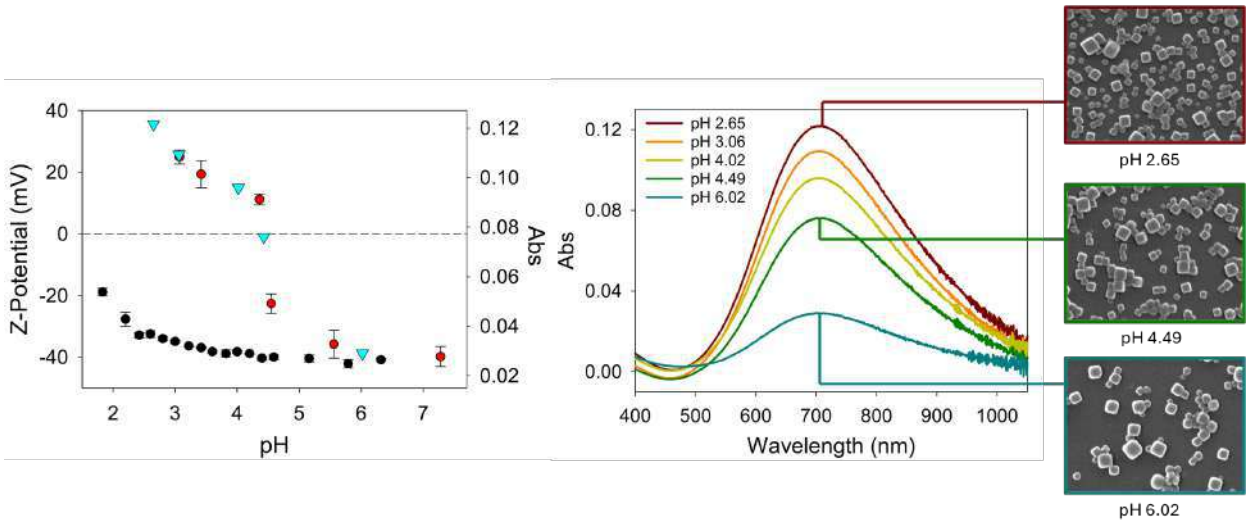

Figure 1: a) Surface Z-Potential of PDA@glass (red dots) and Z-Potential of PBNPs (black dots) at different pH, correlated with the absorbance of PB@PDA@glass obtained at different pH. b) UV-Vis spectra of PB@PDA@glass obtained at different pH and SEM images of the respective sample.

We prepared PDA-coated glass slides (PDA@glass) and grafted on them Prussian Blue NPs (PBNPs), Silver NPs (AgNPs) and Gold NanoStars (GNS), changing the pH of the preparations. We thus demonstrated, using UV-vis spectroscopy, Dynamic Light Scattering and Scanning Electron Microscopy, that the pH controlled difference between z-potentials of PDA and NPs is crucial in determining the amount of grafted NPs.

References:

[1] B.P. Lee, P.B. Messersmith, J.N. Israelachvili, J.H. Waite, 2011, Annu Rev Mater Res 41, 99–132.
[2] V. Ball, 2010, Colloids and Surfaces A: Physicochem. Eng. Aspects 363, 92–96.

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INO-PO-037

Synthesis and catalytic activity of a β-η^1-Pd(II)-thioethyl porphyrazine complex

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Porphyrazines, structural hybrids of porphyrins and phthalocyanines, represent a fascinating class of tetrapyrrolic compounds characterized by unique molecular structure and diverse array of potential applications. In particular, thioalkyl porphyrazines feature alkyl groups substituted with sulfur atoms, adding a distinct chemical functionality to their structure. Their synthesis and functionalization offer intriguing avenues for exploration in fields ranging from materials science to biochemistry. In recent years we disclosed a novel class of asymmetrically aryl substituted thioalkyl porphyrazines endowed with interesting applications in optoelectronics.[1-3] During the preparation of these compounds by Pd catalyzed cross-coupling reactions, we serendipitously isolated the β-η^1-Pd(II)-thioethyl porphyrazine complex **1**, *i.e.* the oxidative addition intermediate between the parent β-bromo porphyrazine and the [Pd(PPh$_3$)$_4$] catalyst. *Meso* ring-metalated porphyrins have been reported in the past,[4] but **1** represents the first example of isolable *βeta* ring-metalated tetrapyrrole. Therefore, we considered worthwhile to investigate its direct preparation and employment as catalytic precursor in cross-coupling reactions of porphyrazines. The results and the crystallographic structure of complex **1** will be reported.

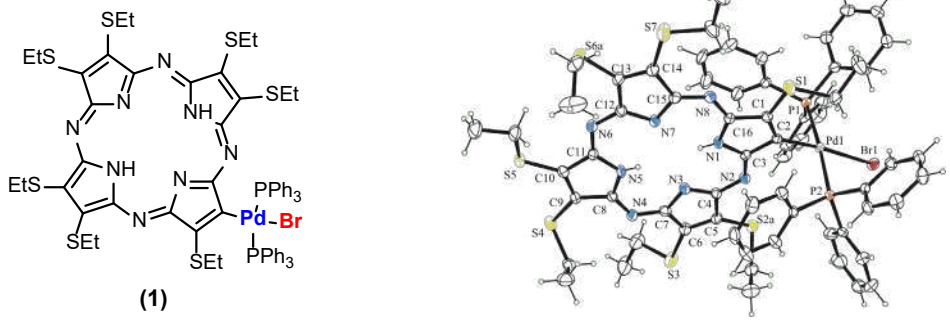

Figure 1: Schematic (*left*) and crystallographic (*right*) structure of compound **1**.

References:

[1] S. Belviso, *et al*. Adv. Funct. Mater. 2018, 28, 1705418.
[2] S. Belviso, *et al*. J. Phys. Chem. C 2019, 123, 13074–13082.
[3] S. Belviso, *et al*. Dalton Trans., 2022, 51, 16453–16464.
[4] D. P. Arnold, *et al*. Chem. Comm, 1998, 2331- 2332

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Micro-Raman detection of inorganic particulate in equine lung section

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Air quality is a main determinant of respiratory health. As for asthmatic people, veterinary species are sensitive to the effect of increased respirable dust[1]. Horses in particular, whose athletic performances concern their owners, are likely exposed to a large burden of inhaled particles originating from the surfaces they work on, with potentially relevant pathologic effects[2]. While little evidence suggests that increased levels of inhaled mineral particles characterize the air of the environments where horses train and perform, no data is currently available on the deposition and distribution pattern of such particles within the equine lungs.

The evaluation of the mineral exposome for understanding the multitude of environmental exposures of inorganic dust continuously over time is crucial[3].

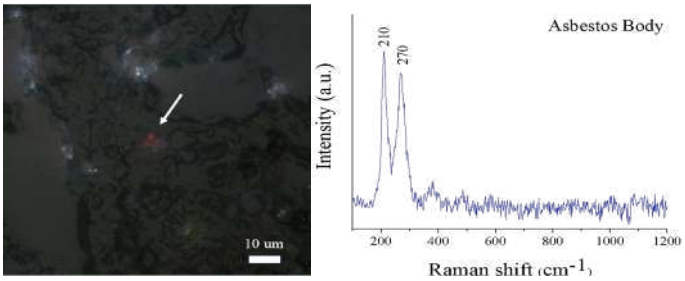

Figure 1. Optical image and Raman spectra of asbestos-body in the lung section[4].

For this reason, understanding the qualitative and quantitative deposition pattern of inorganic dust in the lung is a pivotal step in the comprehension of the respiratory exposure pathway.

This work has been undertaken to describe the qualitative deposition pattern of mineral dust in equine lungs. Post-mortem bilateral lung sections were collected from each lung, following a cranio-caudal and ventro-dorsal gradient.

Observations were conducted with micro-Raman spectroscopy and revealed the presence of different inorganic particles in the range of 2-5 μm in diameter. The main particles found were feldspar (albite), mica (muscovite), titanium dioxide (rutile or mixed phase rutile/anatase), and magnesium calcite (Ca_{1-x}, Mg_x)CO_3. Raman spectrum of an asbestos body, a fiber of asbestos covered with an iron-protein coat, was also recorded (Fig.1). Future studies will be focused on the quantitative determination of the total lung mineral load by digestion of lung tissue of the cranio-caudal sections.

References:

[1] S.L. Raymond, A.F. Clarke, Australian Equine Veterinarian 1998, 16, 21-31.
[2] K.M. Ivester, L. L. Couëtil, N.J Zimmerman, Journal of Veterinary Internal Medicine 2014, 28,1653-1665.
[3] N. Haddad, X.D. Andrianou, K.C. Makris, Current Pollution Report 2019, 5, 378–393.
[4] C. Rinaudo, A. Croce, M. Musa et al., Applied Spectroscopy 2010, 6, 571-7.

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INO-PO-039

Tetrapyrazinoporphyrazines Carrying Externally *o*-Carboranedithiolate Groups. A Route to Potential Bimodal PDT/BNCT Anticancer Drugs

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In our previous extensive studies the synthesis, physicochemical properties and photoactivity as anticancer drugs in photodynamic therapy (PDT) were reported of pentanuclear octa(2-pyridil)tetrapyrazinoporphyrazines complexes, carrying externally eight units of *m*- carborane-1-thiolate (CBT) formulated as $[\{Pd(CBT)_2\}_4Py_8TPyzPzM]\cdot xH_2O$, where $Py_8TPyzPz$ = tetrakis-2,3-[5,6-di(2-pyridyl)pyrazino]porphyrazine and M = $Mg^{II}(H_2O)$, Zn^{II}, Pd^{II} (Figure 1A)[1]. The photosensitizer activity for the generation of singlet oxygen, $^1O_2$, the cytotoxic agent in PDT was explored in DMF solution. These species have high quantum yield values (Φ_Δ = 0.6−0.7) which are higher than those obtained for the parent $[(PdCl_2)_4Py_8TPyzPzM]$, and $[Py_8TPyzPzM]$ complexes[2]. Moreover, the presence of high boron content can open perspectives for their use in Boron Neutron Capture Therapy (BNCT), an experimental radiotherapy studied against aggressive and penetrating cancerous pathologies[3].

In an extension of our work on new TPyzPzs it was thought interesting to open additional perspectives of application in a bimodal anticancer therapy PDT/BNCT. For this purpose new homo/eteropentanuclear tetrapyrazinoporphyrazines having externally four units of 1,2-dithiolate-*o*-carborane, formulated as $[\{Pd(CBdT)\}_4Py_8TPyzPzM]\cdot xH_2O$ (CBdT = 1,2-dithiolate-*o*-carborane; M = $Mg^{II}(H_2O)$, Zn^{II}, Pd^{II}) (Figure 1B), have been synthesized and characterized. The photosensitizer activity for the generation of singlet oxygen, $^1O_2$, was explored for the Zn^{II} and Mg^{II} complexes in DMF. The high Φ_Δ value obtained for the Zn^{II} macrocycle (0.58) falls within the range 0.4-0.7 obtained for numerous phthalocyanines and Zn^{II} porphyrazines. These results qualify the Zn^{II} complex $[\{Pd(CBdT)\}_4Py_8TPyzPzZn]$ as an excellent photosensitizer for the generation of singlet oxygen and in addition its high boron content suggests the possibility to be used as bimodal anticancer agent (PDT/BNCT).

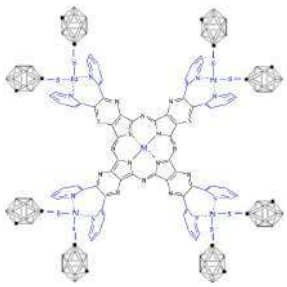

Figure 1A

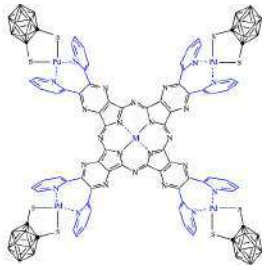

Figure 1B

References:

[1] E. Viola, M.P. Donzello, S. Testani, G. Luccisano, et al., Inorg. Chem. 2019, 58, 1120 – 1133.
[2] M.P. Donzello, E. Viola, C. Ercolani, Z. Fu, D. Futur, K.M. Kadish, Inorg. Chem. 2012, 51, 12548 – 12559.
[3] K. Hu, Z. Yang, L. Zhang, L. Xie, L. Wang, H. Xu, L. Josephson, et al., Coord. Chem. Rev. 2020, 213139.

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Enhancing Electrochemical Performance of Lithium-ion batteries via Coating of Synthesized Single Crystal $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ (NMC-811) Cathode Material.

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Lithium-ion batteries (LIBs) are a well-known and frequently used renewable energy storage technology, especially in the electric vehicle (EV) and bicycle industries as well as energy storage systems (ESS). The energy density constraint of existing LIBs still affects modern EVs despite their widespread use[1]. Technological improvements in batteries, especially in the positive electrodes, are necessary to address this problem. Lithium cobalt oxide (LCO) was a primary component of commercial lithium-ion batteries (LIBs) due to its superior performance. However, due to its toxicity and poor sustainability, scientists are currently exploring alternative options. The utilization of Nickel Manganese Cobalt oxide (NMC) in different compositions, such as NMC-111, NMC-532, NMC-611, and NMC-811, with a lower cobalt percentage, is one of the most promising substitutes. Despite the large capacity offered by NMC and its variants, its capacity tends to lose over time. This issue can be mitigated by dealing with single crystal phases and applying different coatings to these materials[2]. In our research, we synthesized single crystal $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ (NMC-811) using a Sol-gel method. Various coating techniques are found in literature for NMC materials, including atomic layer deposition (ALD), solid-state, and wet method. We opted for the solid-state coating approach for its simplicity and effectiveness in providing protective layer on NMC. This led to an improvement in the stability, conductivity, and overall performance of the cathode material. To assess the structural, morphological, and electrochemical properties of both coated and uncoated single crystal NMC, we employed characterization methods such as X-ray diffraction (XRD), scanning electron microscopy (SEM), and galvanostatic charge-discharge cycling (GCPL). Our findings demonstrate the formation of well-defined single crystal particles with minimal flaws and the desired crystallographic orientation, suggesting potential enhancements in battery performance and longevity. To assess the structural, morphological, and electrochemical measurements of both coated and uncoated single crystal NMC, different characterization techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), and galvanostatic charge-discharge cycling (GCPL) are used. Our findings indicate the formation of well-defined single crystal particles with minimal flaws and the desired crystallographic orientation, suggesting potential enhancements in battery performance and longevity.
Keywords: Lithium-ion batteries (LIBs), Single crystal NMC-811, Sol-gel technique, Coating.

References:

[1] M. Kotal et al. Journal of Energy Storage (2022), 47, 103534.

[2] M. Akhilash, P.S. Salini, B. John et al. Journal of Alloys and Compounds (2021), 869, 159239.

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INO-PO-041

Electrochemical NADH Regeneration Mediated by Pyridine Amidate Iridium Complexes Interconverting 1,4- and 1,6-NADH Regioisomers

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Although there is a huge interest in redox mediators for the selective electrochemical regeneration of 1,4-NADH,[1] only the class of rhodium compounds with bipyridine ligands, initially introduced by the pioneering work of Wienkamp and Steckhan (*Angew. Chem. Int. Ed. Engl.* **1982**, *21*, 782-783), has been developed over the last decades.[2] Here we report the first two progenitors of a new class of redox mediators for indirect NADH regeneration, namely [Cp*Ir(R'-pica)Cl] {pica = R'-picolinamidate = κ^2-R'-pyridine-2-carboxamide ion (–1), **1** R' = H and **2** R' = Me} (Figure 1),[3,4] which exhibit high TOF values (0.51 s^{-1} and 1.34 s^{-1} for **1** and **2**, respectively), production rate up to 3 mmol h^{-1} cm^{-2}, and Faradaic efficiency up to 99% for both complexes in 0.1 M phosphate buffer (pH 7, 298 K). The reaction exclusively leads to a mixture of 1,4-NADH, the desired product, and 1,6-NADH always in a 91:9 molar ratio, independently of the redox mediator, degree of conversion and applied potential. ^{1}H EXSY NMR unequivocally shows that a rapid equilibrium establishes between 1,6-NADH and 1,4-NADH (K_{eq} = 10.1, ΔG^0 = -1.4 kcal mol^{-1}, 298 K), in the presence of **1** and **2**, suggesting that the latter are capable of rapidly interconverting the two regioisomers of NADH, thus allowing to utilize the totality of regenerated NADH.

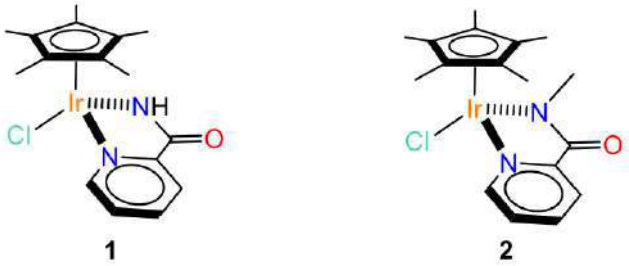

Figure 1: Iridium complexes exploited as redox mediators for electrochemical NADH regeneration.

References:

[1] J. Chapman, A. E. Ismail, C. Z. Dinu, *Catalysts* **2018**, *8*, 1 – 26.
[2] E. Steckhan, *Electroenzymatic Synthesis*, **1994**, 83–111.
[3] A. Bucci, S. Dunn, G. Bellachioma, G. Menendez Rodriguez, C. Zuccaccia, C. Nervi, A. Macchioni, *ACS Catal.* **2017**, *7*, 7788–7796.
[4] G. Menendez Rodriguez, C. Domestici, A. Bucci, M. Valentini, C. Zuccaccia, A. Macchioni, *Eur. J. Inorg. Chem.* **2018**, 2247–2250.

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INO-PO-042

Hard/Soft coupled magnetic nanocomposites for the fabrication of Rare Earth free permanent magnets

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Permanent magnets are crucial elements for the green transition as they allow storing, delivering and converting electrical energy into mechanical and vice versa, which means that improving their performance entails transforming energy in a more efficient and sustainable way. The best magnets are based on rare-earths elements, (RE). However, their status as Critical Raw Materials (CRM) has brought forward the consciousness that it is of great strategic and environmental relevance to develop alternative PMs with reduced or no amount of RE.

Sr or Ba M-type hexaferrites are the most popular magnet in the market thanks to the low production costs, thermal stability, and insulating properties.[1] However, their capability to store energy, described by the energy product, is much smaller than that of the high performing RE magnets (20-40 kJm^{-3} compared to up to 400 kJm^{-3}). Since ferrite magnets are constituted by multidomain grains, large improvements in their performances are expected by exploiting nanometric grains. A further increase of the performances can be obtained by realizing hybrid hard-soft nanocomposites magnetically coupled at the interface.[2]

In this contribution we present the synthesis and discuss the magnetic properties of single crystal, monodomain strontium ferrite nanograins prepared by two different techniques, solid state reaction and sol-gel synthesis. The particles have variable average size in the 50 – 100 nm range and larger coercivity compared to commercial powders. The best obtained ferrite was employed for the fabrication of hybrid nanocomposites using, as the soft phase, iron nanowires. The latter were prepared by chemical reduction of metal salts in aqueous phase and consist of small nanoparticles assembled in a chain-like amorphous superstructure, with a mean diameter of 70-80 nm and length of 4-5 μm.

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References:

[1] C. de Julian Fernandez, C. Sangregorio *et al.* J. Phys. D: Appl. Phys. 2021, 54, 153001.
[2] A. Quesada *et al.* Adv. Electron. Mater. 2016, 1500365-1500372.

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INO-PO-043

Copper complexes with adamantane ring-conjugated ligands as promising agents for the treatment of glioblastoma

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Platinum drugs are the mainstay of the metal-based compounds in the treatment of cancer, even if their use is limited by severe side effects and resistance phenomena. These weaknesses stimulated scientific research to develop new metallodrugs with lower cytotoxicity and acting on different targets. Since copper is a trace element that is essential to all aerobic life forms, and tumour tissues require more copper, Cu complexes may modulate cancer cell survival by generating reactive oxygen species, accumulating excess copper, inhibiting proteasome activity and inhibiting angiogenesis. Cu-based complexes have recently shown interesting antitumor and anti-metastatic properties on several kinds of solid tumours [1].

We designed and synthesized new Cu(I) and Cu(II) complexes and evaluated them as potential agents for the treatment of glioblastoma (GBM) [2]. The bis(pyrazol-1-yl)- and bis(3,5-dimethylpyrazol-1-yl)-acetic acids were selected as bifunctionalizable agents and conjugated to the drug amantadine to obtain the synthesis of the new chelating ligands L^{Ad} and L^{2Ad}. Amantadine was selected because of its recently proven antiproliferative effects in different human tumour cell lines, including hepatocarcinoma, melanoma, and glioblastoma cells. Phosphane co-ligands were employed for the synthesis of the Cu(I) complexes to stabilize copper in the +1 oxidation state and wisely tune solubility properties of the corresponding complexes. The electronic and molecular structures of the new complexes were investigated by X-ray photoelectron spectroscopy, near-edge X-ray absorption and for $[Cu(L^{2Ad})_2]Br_2$ by X-ray diffraction analysis. Interesting results emerged from the biological studies of the new complexes and of the corresponding uncoordinated ligands, investigated for their antitumor potential on different GBM cell lines and for their ability to enhance the chemosensitivity to temozolomide, the standard post-surgical treatment of GBM [2].

Acknowledgements**:** *NextGenerationEU - D.M. 737/2021 "INVIRCuM" University of Camerino FAR 2022 PNR*

References:

[1] C. Santini, M. Pellei, V. Gandin, M. Porchia, F. Tisato, C. Marzano, Chem. Rev. 2014, 114 815 – 862.
[2] M. Caviglia *et al.*, unpublished results.

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INO-PO-044

Molecular Iron Based Water Oxidation Electrocatalysts@Glassy Carbon Lights and Shadows of hybrid catalysis

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Water splitting is considered a sustainable way of obtaining hydrogen but the high overpotential needed in the anodic compartment for oxygen production makes the whole process energetically demanding.[1] To overcome this problem, water oxidation catalysts (WOCs) are required but they are usually based on expensive metals. With the aim of economically viable devices for water splitting and solar fuels production, finding efficient and robust catalysts based on abundant and affordable first-row transition metals is a pivotal point. However, the vast majority of iron WOC catalysts employ sacrificial oxidants and in order to avoid them, electrochemistry offers the alternative. Unfortunately, in the framework of iron electrocatalysts, the few examples reported in literature still show low efficiencies and high overpotential.[2,3]

Recently, our group reported on iron cyclopentadienonic and N-heterocyclic carbene (NHC) complexes that demonstrated to be active, through a stable radical species upon oxidation, in this reaction with competitive activity and low overpotential (TOF of 52 s-1 and η=0,32 V) under basic conditions.[4]

Herein we report on the ligand (NHC) design (Figure 1) towards immobilization on glassy carbon accompanied by characterization (Mossbauer and SQUID) and mechanistic investigation (DFT and EPR studies) on molecular complexes. The peculiar behaviour observed upon immobilization will be also presented and discussed.

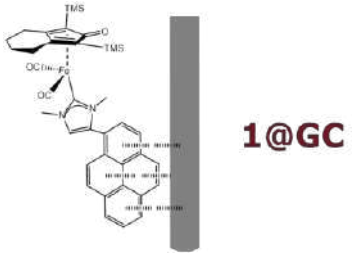

Figure 1. Pyrene functionalized iron electrocatalyst **1@GC** immobilized on Glassy carbon.

References:

[1] J. D. Blakemore, R. H. Crabtree and G. W. Brudvig, Chem. Rev., 2015, 115, 12974–13005.
[2] P. Garrido-Barros, C. Gimbert-Surinach, R. Matheu, X. Sala, A, Llobet, Chem. Soc. Rev., 2017, 46, 6088.
[3] V. K. K. Praneeth, M. Kondo, M. Okamura, T. Akai, H. Izu, S. Masaoka, Chem. Sci., 2019, 10, 4628.
[4] A. Cingolani, I. Gualandi, E. Scavetta, C. Cesari, S.Zacchini, D. Tonelli, V. Zanotti, P. Franchi, M. Lucarini, E. Sicilia, G. Mazzone, D. Nanni and R. Mazzoni, Catal. Sci Technol., 2021, 11, 1407-1418.

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Self-assembled complex promotes cell proliferation and stem cell self-renewal through redox signaling in in vivo model

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Transition metal complexes have attracted much attention because of their rich and peculiar chemical and spectroscopic properties that have found applications in different fields and even as therapeutics.[1] In this field, Pt(II) complexes have been extensively studied. However, even though the emission of platinum complexes has been extensively investigated, the use as luminescent probes, for cellular imaging, has been still poorly investigated. This application requires water solubility of the complexes, and it is limited by the quenching exerted by dioxygen in water and biological fluids because of the long lived luminescent excited state. This severe drawback could however be overcome by exploiting the high tendency of such square planar compounds to self-assembly in supramolecular structures. In this regard, our research group has already demonstrated the aggregation induced emission for Pt(II) complexes[2,3] in different media. In this contribution we describe the synthesis and characterization of luminescent amphiphilic platinum compound, soluble in water, based on a N^N^N pyridil-triazolate functionalized with an ancillary ligand and its behaviour in vivo. An invertebrate freshwater polyp, *Hydra vulgaris*, was treated with the bright orange phosphorescent complexes at only 20 μM concentration

Figure 1: In vivo fluorescence imaging showing a living *Hydra* 24 h post incubation with YAC_2

The compounds self-assembly in vivo and in particular accumulate in the tentacles of the animal. Interestingly, preliminary results suggest not only the use of these compounds for bioimaging and cell tracking but also as enhancer of cell proliferation. Studies are in progress to rationalize such important results.

References:

[1] K.J. Franz et al. *Chem. Rev*. **2019**, 119, 2, 727–729
[2] A. Aliprandi et al. *Nature Chemistry*, **2016**, 10-15
[3] A. Aliprandi, et al. *Isr. J. Chem.*, **2019,** *59*, 892 -897

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Octacoordinated iron(II) complex with neutral *bis*-tetrazolylpyridyl ligands and solvent molecules as solid-state-trapped intermediate in solution conversion

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2,6-*bis*(2-(methyl)-2H-tetrazol-5-yl)pyridine, Me_2btp, related to the most known *bis*-pyrazolylpyridyl R-bpp derivatives (R = variable substituents),[1–3] was employed as neutral tridentate *mer*-coordinating ligand for iron(II). Metalation of Me_2btp with iron(II) perchlorate revealed a non-trivial chemistry with the selective crystallization of $[Fe^{HS/LS}(Me_2btp)_2](ClO_4)_2{\cdot}MeCN{\cdot}2.75H_2O$ ($\mathbf{2}^{HS/LS}{\cdot}MeCN{\cdot}2.75H_2O$) as red rods through accurate solvent polarity control, with half of the iron(II) in the high spin (HS, $S = 2$) state and the second half in the low spin (LS, $S = 0$) state. $\mathbf{2}^{HS/LS}{\cdot}MeCN{\cdot}2.75H_2O$ slowly converts in solution into the co-crystal $[Fe^{LS}(Me_2btp)_2][Fe^{HS}(Me_2btp)(MeCN)_2(H_2O)](ClO_4)_4{\cdot}MeCN$ ($\mathbf{2}^{LS}{\cdot}\mathbf{3}^{HS}{\cdot}MeCN$) through the unprecedented octacoordinated species $[Fe(Me_2btp)_2(MeCN)(H_2O)](ClO_4)_2{\cdot}H_2O$ ($\mathbf{1}{\cdot}H_2O$) as intermediate species trapped in the solid state.[4] The combined use of different spectroscopic techniques, single-crystal X-ray diffraction experiments and magnetic measurements, together with theoretical calculations, will be presented in this contribution.

Acknowledgment: Italian Ministero dell'Università e della Ricerca (MUR), the Royal Society of Chemistry through the RSC Research Fund grant nr. R19-0504 entitled '*Nitrogen-donor ligands for new molecular iron(II) spin crossover complexes and cobalt(II) single-molecule magnets*', the Dipartimento di Scienze Chimiche e Geologiche of the Università degli Studi di Modena e Reggio Emilia through the Fondo Dipartimentale per la Ricerca year 2020 (FDR2020 linea ricerca) and year 2021 (FDR2021 linea dottorato).

References:

[1] N. Bridonneau, L. Rigamonti, G. Poneti, D. Pinkowicz, A. Forni and A. Cornia, *Dalton Trans.*, 2017, **46**, 4075–4085.
[2] M. A. Halcrow, Ed., *Spin-crossover materials: properties and applications*, Wiley, Chichester, West Sussex, United Kingdom, 2013.
[3] L. Marchi, S. Fantuzzi, A. Cingolani, A. Messori, R. Mazzoni, S. Zacchini, M. Cocchi and L. Rigamonti, *Dalton Trans.*, 2023, **52**, 7684–7694.
[4] Luca Rigamonti, Lorenzo Marchi, Valentina Fiorini, Stefano Stagni, Stefano Zacchini, Dawid Pinkowicz, Katarzyna Dziedzic-Kocurek, Alessandra Forni, Francesco Muniz Miranda and Rita Mazzoni, *Dalton Trans.*, 2024, **53**, 3490-3498.

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INO-PO-048

Enhancing Chronic Wound Healing: Injectable Hydrogels incorporating Cerium-Doped Mesoporous Bioactive Glasses

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Bioactive glasses (BGs) have traditionally been applied in hard tissue regeneration due to their ability to induce apatitic layer (HA) formation upon exposure to biological fluids. However, research is focusing on expanding their application field to soft tissue regeneration, particularly for chronic wounds.[1] This study investigates the integration of cerium-doped mesoporous bioactive glasses (Ce-MBGs) into alginate/agarose injectable hydrogels to develop delivery systems with enhanced antioxidant properties for chronic wound healing.[2-3]
Ce-MBGs were synthesized via a modified sol-gel EISA method with 0-3.6 mol% CeO_2, then incorporated into an optimized thermoresponsive alginate/agarose hydrogel. The HA formation was monitored via FT-IR and XRDP analyses after soaking in simulated wound fluid (SWF). These results suggested that the hydrogel matrix slowed the HA formation ability of Ce-MBGs, decreasing the possibility of wound calcination. Additionally, ICP-OES analyses demonstrated that the hydrogel matrix did not hinder the ionic release: Ce-MBGs with or without hydrogel exhibited similar Ca, P and Si leakage up to 3 days. It was also verified that the hydrogel did not interfere with Ce antioxidant properties, since all Ce-containing samples maintained their H_2O_2 scavenging ability. If Ce-MBGs were loaded with a mixture of natural polyphenols, the composite hydrogels also exhibited a fast O_2^- dismutation ability.
These findings underline the potential of Ce-MBG-containing injectable hydrogels as promising platforms for chronic wound management. Therefore, future investigations will delve into the drug releasing ability of this composite system and assess the hydrogel cytocompatibility.

References:

[1] S. Kargozar, R.K. Singh, H. Kim, F. Baino, Acta Biomater. 2020, 115, 1 - 28.
[2] G- Lusvardi, F. Fraulini, S. D'Addato, A. Zambon, ACS Biomater. Sci. Eng. 2022, 8, 2890 - 2898.
[3] Q. Zeng, Y. Han, H. Li, J. Chang, J. Mater. Chem. B 2015, 3, 8856 - 8864.

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INO-PO-050

Large Pores Mesoporous Bioactive Silica: a New Candidate for Delivery of Big Therapeutics Molecules. A Study of its Behavior in Terms of Drug Loading/Release and Bioactivity

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Large Pores Mesoporous Silica (LPMS) could be an innovative support suitable to accommodate big pharmaceutical molecules, shield them and maintain their biological activity. Large pores allow the loading of bioactive molecules inside the structure, their stabilization and protection.[1] Indeed, for Classical Mesoporous Silica (MS) only pore blocking occurs. To obtain a synergistic effect between a proper structure and bioactive/pharmaceutical activity, ions with a physiological effect can be added, such as Ca^{2+} (for bioactive activity) and Ga^{3+} (for anticancer action).[2] LPMSs have been synthesized (Figure 1) starting from an acidic water solution of tetraethyl orthosilicate reacting with pore agents (Pluronic® F127 and mesitylene), performing hydrothermal and microwave-assisted reactions. Time and surfactant optimization was performed.

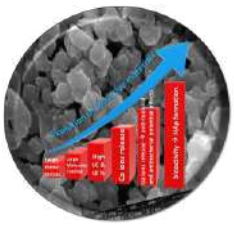

Figure 1: LPMS structure, evolution, and features.

Pore structure characterization has been performed using N_2 adsorption/desorption and Hg-porosimetry, demonstrating that LPMSs have pores in the range of 20–60 and 200–600 nm. Nisin (antibacterial peptide) has been used for load and release tests. Tests performed highlight a doubled loading and releasing for LPMSs if compared to MSs. To confirm the maintenance of the structure of LPMSs, Scanning Electron Microscopy images were acquired before and after release tests. Ca and Ga release in Simulated Body Fluid has been studied through inductively ICP-OES, showing a high release of these ions achieved with LPMSs. The bioactivity of Ca-containing structures has been confirmed using FT-IR, SEM-EDS, and XRDP. In conclusion, LPMSs showed better loading and releasing properties compared with classical MS and better release in terms of active ions. It has also been demonstrated that LPMSs have bioactive behavior.

References:

[1] D. Carrozza, G. Malavasi, E. Ferrari, Materials, 2023, 16 (11), 4151-4172.
[2] D. Carrozza, E. Ferrari, G. Malavasi, Materials, 2024, 17 (2), 373-389.

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Exploring functionalized [Fe(EDTA)]$^-$ complexes and their supramolecular adducts

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All the FDA-approved contrast agents (CAs) are Gd(III)-based complexes (GBCAs) and they are used in 40% of the tens of millions of Magnetic Resonance Imaging scans performed each year. Recently, concerns regarding their economic, environmental and clinical impact have spurred interest in exploring alternative CAs, notably those utilizing endogenous ions like Fe(III). Initial studies suggest that Fe(III) chelates, administered at higher doses than GBCAs, exhibit comparable efficacy in typical clinical settings. However, understanding the mechanisms underlying water proton relaxation enhancement by Fe(III) complexes and their structural features is still an open challenge.[1,2] In this study, we investigated Fe(III) complexes with derivatives of EDTA functionalized on the acetic arms with one (EDTA-BOM) or two (EDTA-BOM$_2$) benzyloxymethyl groups. The objective is to explore the effects of ligand modification on the overall efficacy (relaxivity, r_1) of these systems for contrast enhancement. In fact, an increase in the relaxivity of these probes is expected because of the elongation of the molecular tumbling, provided by the increasing molecular mass. Moreover, the lipophilic nature of the BOM substituents allows non-covalent interaction with different substrates (β-cyclodextrin, poly-β-cyclodextrin and human serum albumin), which can further increase their efficacy. For these reasons, we present the ^{1}H and ^{17}O NMR relaxometric characterization of these two novel complexes and their supramolecular adducts, for which we also investigated their thermodynamic stability, kinetic inertness and redox behaviour.

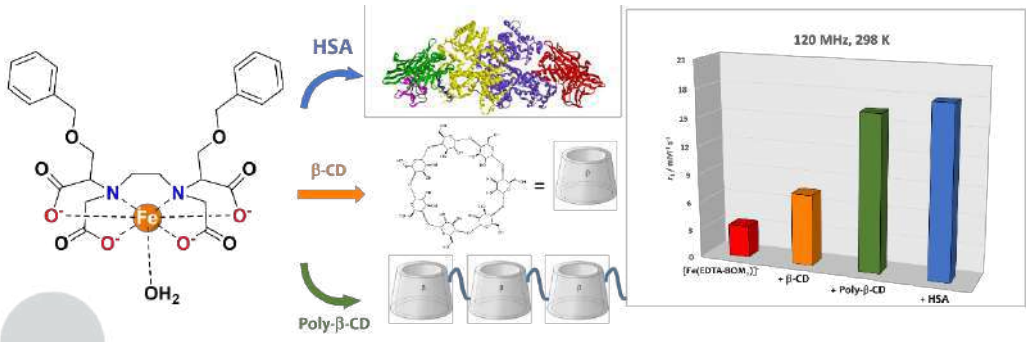

Figure 1: Some of the investigated systems and their r_1 values (120 MHz, 298 K).

References:
[1] Z. Baranyai *et al.* Chem. Sci. 2021, 12, 11138–11145
[2] R. Uzal-Varela *et al.* Inorg. Chem Front. 2023, 10, 1633–1649

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INO-PO-052

Assessing the impact of donor groups on the coordination and magnetic properties of monohydrated Fe(III) complexes for MRI applications

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In response to recent safety concerns surrounding Gd-based contrast agents (GBCAs), there has been a surge in research aimed at identifying alternative options for magnetic resonance imaging (MRI)[1]. Trivalent iron (Fe^{3+}) complexes have emerged as promising candidates due to the element's widespread natural occurrence and well-understood metabolic pathways[2], suggesting the potential for the development of safer and more sustainable MRI contrast agents. Previously, our research group investigated the structural and magnetic properties of $[Fe(EDTA)]^-$ and $[Fe(CDTA)]^-$ complexes, serving as model systems for monohydrated Fe(III)-chelates for use as MRI probes[3]. Building upon this groundwork, the current study delves into the impact of complex charge on water exchange kinetics, thermodynamic stability, and kinetic inertness. To explore this, we synthesized four CDTA-amide ligands, each featuring substitutions of one or two carboxylic groups with diethylamine or butylamine functionalities. These alterations resulted in Fe(III) complexes with either neutral or positively charged characteristics. Investigating the water exchange rates (k_{ex}) involved a combination of ^1H relaxometric studies and ^{17}O NMR chemical shifts and relaxation rates. In addition, we evaluated the thermodynamic stability and kinetic inertness of the complexes using potentiometry, UV-Vis spectrophotometry, and capillary zone electrophoresis. As anticipated, altering the charge of the complex leads to a modulation of k_{ex}, aligning with observations made previously for Gd(III) and Mn(II) chelates. Furthermore, the incorporation of amide donor groups has been found to reduce the stability of the complexes, albeit maintaining a relatively high level. These discoveries offer valuable insights for the prospective development of advanced MRI probes.

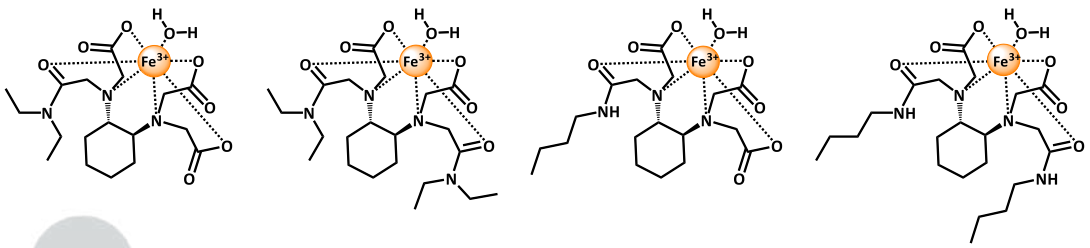

Figure 1: Chemical structures of CDTA-amide derivatives. From left to right: CD3A-DEA, CD2A-DEA_2, CD3A-BUT, CD2A-BUT_2.

References:

[1] K. Schmidt, M. Bau, G. Merschel, N. Tepe, *Sci. Total Environ*. **2019**, *687*, 1401–1408

[2] P. Boehm-Sturm, A. Haeckel, R. Hauptmann, S. Mueller, et al., *Radiology* **2018**, *286*, 537–546

[3] Z. Baranyai et al., *Chem. Sci*. **2021**, *12*, 11138–11145

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Ferritin-Au(I) bioconjugates as anticancer agents

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Human heavy-chain ferritin (HuHf) is a recombinant protein composed of 24 H-subunits, forming a nanocage with a hollow globular structure. The H-chain is recognized by the transferrin receptor-1 (TfR1), overexpressed in many cancer cell lines. HuHf is a suitable nanocarrier due to its versatility, excellent safety profile and nano-range size[1]. Gold compounds are potential anticancers with antiproliferative and proapoptotic properties[2]. Here, I worked on the development of human heavy chain ferritin conjugates with different gold(I) compounds, i.e. Auranofin[3], Aurothiomalate and a monocarbene, for the production of ferritin-based nanocarriers and their selective delivery toward cancer cells. Five human-H chain ferritins were expressed in *E. coli* cells: the wild type, three different mutants, where I replaced with Alanine one or two cysteines (C130A, C90AC102A and C90A) and a ^{19}F labelled- human ferritin (5-F-Trp93). I exploited the use of recombinant wild type HuHf for the targeted delivery of the gold(I) compounds, the three mutants to determine their binding sites on the protein and the ^{19}F-labelled ferritin as a probe for cellular uptake via ^{19}F NMR studies. For all the HuHf-gold(I) adducts: ESI-MS spectrometry (measuring the disassembled subunits) confirmed the adducts formation and provided information on the chemical nature of the species present in solution. ICP determined the total amount of gold per cage. Also, biological experiments were performed to evaluate the cytotoxicity of the free drugs and their bioconjugates with ferritin against A2780 ovarian cancer cells; moreover, the cytotoxicity of the free compounds was evaluated together with the TfR1 expression in four different cell lines i.e. U87MG glioblastoma cells, MCF-7 breast cancer cells, HCT-116 colorectal cancer cells and MRC-5 fibroblast cells.

References:

[1] B. Bhushan, S. U. Kumar, I. Matai, A. Sachdev, P. Dubey and P. Gopinath, *J. Biomed. Nanotechnol.*, 2014, **10**, 2950–2976.
[2] S. Nobili, E. Mini, I. Landini, C. Gabbiani, A. Casini and L. Messori, *Med. Res. Rev.*, 2010, **30**, 550–580.
[3] L. Cosottini, L. Massai, V. Ghini, S. Zineddu, A. Geri, M. Mannelli, S. Ciambellotti, M. Severi, T. Gamberi, L. Messori and P. Turano, *J. Drug Deliv. Sci. Technol.*, 2023, **87**, 104822.

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Purification of water contaminated with arsenic using a bio-inspired porous membrane with selective As-sequestering properties

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The presence of arsenic as contaminant in water for drinking and irrigation is a worldwide issue. This, particularly, where groundwater is the prevalent source. Several technologies have been proposed to address this issue and remove arsenic from water.

The successful development of a porous membrane designed using a bio-inspired and multidisciplinary approach is here presented. This membrane has been tested successfully on model solutions and real groundwater samples. This membrane is able to selectively remove arsenic in both As(V) and, the more toxic and less easy to remove, As(III) oxidation states.

The high selectivity avoids demineralization making the decontaminated water suitable for human use without further processing.

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Functionalization of Metallorganic Catalysts for CO_2 Electroreduction

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Functionalization is a procedure to anchor a catalyst on a support, to improve its catalytic behaviour, in our case toward the conversion of carbon dioxide into valuable products[1].

Catalysts are usually required to lower the working potential for the reduction of carbon dioxide and also to enhance the selectivity toward one product or to move the possible products into more valuable ones.[2] In our research, we focused on a functionalization with diazonium salt, as shown in Figure 1, on a carbon substrate named Carbon Cloth[3].

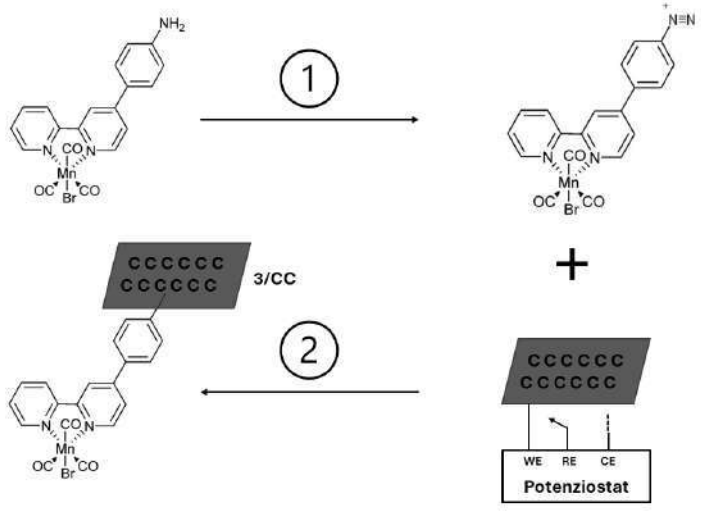

Figure 1: Scheme of the functionalization of the catalyst on Carbon Cloth

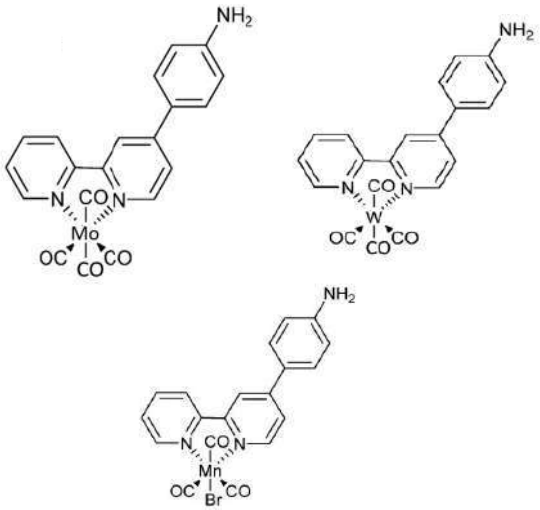

Figure 2: Example of three bipy metal electrocatalysts

Different catalysts were studied with this method, all of them belong to the bipyridine complexes, as shown in Figure 2 with different metals. For Manganese we observed a great improvement in TON and Faradic Efficiency after the functionalization for the production of CO[3]; Tungsten gave production of liquid products such as methanol and formate and Molybdenum produced a very high quantity of methanol in water[4].

References:

[1] L. Rotundo, A. Barbero, C. Nervi, R. Gobetto, *Catalysts* **2022**, *12*, 1448.
[2] E.A. Palade, R. Gobetto, C. Nervi, *Inorg. Chim. Acta* **2024**, in press.
[3] J. Filippi, L. Rotundo, R. Gobetto, H.A. Miller, C. Nervi, A. Lavacchi, F. Vizza, *Chemical Engineering Journal* **2021**, *416*, 129050.
[4] A. Barbero, C. Nervi, R. Gobetto, Manuscript in preparation.

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INO-PO-056

Carbazole-cyclic triimidazole: when fluorophores' connectivity makes the difference

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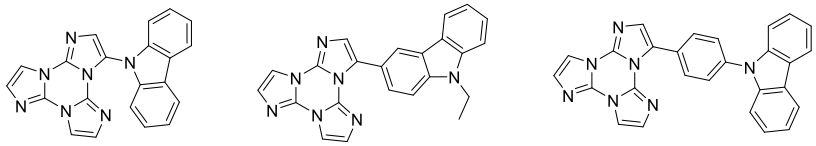
Cyclic triimidazole (**TT**) has recently revealed as an intriguing scaffold for the preparation of new fully organic room temperature phosphorescent (RTP) materials, luminescent coordination complexes, polymers and bio-probes.[1] **TT** displays at room temperature Crystallization Induced Emissive behaviour with a solid state photoluminescent quantum yield equal to 30% due to concomitant fluorescence and ultralong phosphorescence (up to 1 s).[1a]

A new recently reported family of **TT**-Carbazole compounds has been prepared with different connections between the two units, namely a C_{TT}-C_{Cz} bond in **TT-(C)-Cz** or a C_{TT}-N_{Cz} one in **TT-(N)-Cz** and a phenyl spacer in **TT-Ph-Cz**.[2] The three compounds display in diluted solution, films and powders, excitation-dependent emissive behavior with both short and long-lived emissions. Remarkably, **TT-(N)-Cz** and **TT-Ph-Cz** have been isolated in different polymorphs displaying a structural and crystalline grade-dependent photophysics. Moreover, **TT-Ph-Cz** crystallizes as MeOH-solvated (monoclinic) and de-solvated (triclinic and orthorhombic) forms characterized by distinctive emissive features. Notably, triclinic and monoclinic phases are able to interconvert through Single-Crystal to Single-Crystal transition (desolvation) and MeOH uptake (vapochromism) restoring emissive properties. The multifaceted emissive behavior of **TT-Ph-Cz** is enriched by dual fluorescence (clearly visible in viscous solvents) and phosphorescence, RTP from aqueous aggregate and mechanochromism leading to an interesting stimuli-responsive high-performance single-component luminescent material.



TT-(N)-Cz TT-(C)-Cz TT-Ph-Cz

References:

[1] a) E. Lucenti, A. Forni, C. Botta, L. Carlucci, C. Giannini, D. Marinotto, A. Pavanello, A. Previtali, S. Righetto, E. Cariati, *Angew. Chem. Int. Ed.* **2017**, *56*, 16302-16307; b) E. Lucenti, A. Forni, C. Botta, L. Carlucci, C. Giannini, D. Marinotto, A. Previtali, S. Righetto, E. Cariati, *J. Phys. Chem. Lett.* **2017**, *8*, 1894-1898; c) A. Previtali, W. He, A. Forni, D. Malpicci, E. Lucenti, D. Marinotto, L. Carlucci, P. Mercandelli, M. A. Ortenzi, G. Terraneo, C. Botta, R. T. K. Kwok, J. W. Y. Lam, B. Z. Tang, E. Cariati, *Chem. Eur. J.* **2021**, *27*, 16690-16700.

[2] a) D. Malpicci, A. Forni, C. Botta, C. Giannini, E. Lucenti, D. Marinotto, D. Maver, L. Carlucci, E. Cariati, *Dyes Pigm.* **2023**, *215*, 111274; b) D. Malpicci, A. Forni, C. Botta, C. Giannini, E. Lucenti, D. Marinotto, D. Maver, L. Carlucci, E. Cariati, *Chem. Eur. J.* **2023**, *29*, e202300930.

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INO-PO-057

Structure and photochemical properties of single nickel atoms on the surface of carbon nitride

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Current research in the field of solar energy conversion is focusing on photocatalysts constituted by earth-abundant inexpensive elements and with good absorption properties in the visible range. These properties are key to foster a greener and sustainable photochemistry. Carbon nitride (CN) is a semiconductor which has raised much interest over the past few years because it possesses all these features and has proved to be active in a variety of chemical processes [1]. Recent studies have shown that it is possible to couple the visible-light-activated photoredox activity of CN with the nickel-based catalysis, which is involved in the synthesis of high-value chemicals [2]. Though this Ni-CN system is frequently described as a single-atom catalyst, a site-specific characterization of the active species is still lacking, as well as a description of the mechanism underlying the supposed energy transfer between the light-excited CN semiconductor and the nickel species.

I will present an investigation of the coordination environment of nickel species on CN and the evolution of their oxidation state upon light excitation of the CN semiconductor or in the presence of chemical reductants (H_2, CO, C_2H_4) [3]. In all cases evidence is provided for the formation of reduced paramagnetic Ni(I) single ion species. Electron paramagnetic resonance spectroscopy (EPR) provides a detailed description of the coordination environment and redox activity allowing to probe the electron transfer from CN to nickel and to pinpoint the excitation wavelengths able to optimize this process under reactive conditions.

References:

[1] A. Actis, P. Fornasiero, M. Chiesa, E. Salvadori, ChemPhotoChem 2024, e202300203.
[2] M. Marchi, G. Gentile, C. Rosso, M. Melchionna, P. Fornasiero, G. Filippini, M. Prato, ChemSusChem 2022, 15, e202201094.
[3] M. Marchi, E. Raciti, S. Manoj Gali, F. Piccirilli, H. Vondracek, A. Actis, E. Salvadori, M. Chiesa et al., Advanced Science 2023, 10, 2303781.

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INO-PO-058

Direct oxidation of cyclohexane to adipic acid on Fe-Co based catalysts

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AA is a widely used chemical with a wide range of commercial uses, as the manufacturing of polyamides, plasticizers, polyurethanes, and other products of relevant importance. Industrially, AA is obtained in a two-step oxidation of cyclohexane. The first step is the oxidation of cyclohexane to cyclohexanone and cyclohexanol (KA-oil), which proceeds through a radical mechanism starting from the activation of C-H bond performed at 150°C and 10-20 bar of air in the presence of an homogeneous cobalt-manganese catalyst. In the second step, KA oil is oxidized to AA by HNO_3. The resultant formation of N_2O and NO_x makes the process not environmentally friendly, leading to serious environmental pollution [1]. Therefore, efforts to develop a greener method capable of directly converting cyclohexane to adipic acid under sustainable conditions is needed. In this view, the replacement of homogeneous catalyst with an heterogynous one would be beneficial facilitating the recovery and the reuse of the catalytic system.

In this study we investigated the direct oxidation of cyclohexane to adipic acid by molecular oxygen and transition metal-based heterogeneous catalysts. In particular, Co and Fe have been selected considering they easily switch between II and III oxidation states, favouring the single electrons exchange required for the C-H bond activation [2]. Fe, Co, and bimetallic Fe-Co supported on different reducible and non-reducible oxides, i.e. Al_2O_3, TiO_2, SiO_2 and CeO_2, have been synthesized by sol-immobilization method [3], a suitable technique for obtaining similar metal dispersion regardless the support. Catalytic tests performed at 120°C and 4 bar of O_2 showed that Fe-Co bimetallic catalysts are able to produce adipic acid directly from cyclohexane differently from the monometallic counterparts, proving the cooperative effect between the two metals. Moreover, we revealed a strong support effect being CeO_2 supported catalyst the most active (AA production 0,074 mmol/h). The effect Fe:Co molar ratio was also investigated, proving a full characterization to disclose the reasons on the basis of the different catalytic behaviour.

References:

[1] A. Vomeri, M. Stucchi, A. Villa, C. Evangelisti, A. Beck, and L. Prati, "New insights for the catalytic oxidation of cyclohexane to K-A oil," *Journal of Energy Chemistry*, vol. 70, pp. 45–51, Jul. 2022, doi: 10.1016/j.jechem.2022.02.008.

[2] Y. Liu and J. Wang, "Multivalent metal catalysts in Fenton/Fenton-like oxidation system: A critical review," *Chemical Engineering Journal*, vol. 466. 2023. doi: 10.1016/j.cej.2023.143147.

[3] A.Villa, L.Prati "Gold Colloids: From Quasi-Homogeneous to Heterogeneous Catalytic Systems" , *Account of Chemical Research*, 2014, 47 (3), 855–863.

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Design of novel catalysts for the sustainable synthesis of DME

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Effects of climate change and the depletion of oil reserves require the use of clean alternatives to common chemicals and fuels made from fossil sources. Industrial innovation has recently adopted the responsible practice of reducing waste and energy consumption to match economic and environmental sustainability. In this view, dimethyl ether (DME) recently gains increased interest. Besides, being a well-known propellant and coolant, it is an alternative clean fuel for diesel engines, which simultaneously is capable of achieving high performance and low emission of CO, NO_x and particulates in its combustion [1].

Industrially, DME is presently produced from syngas ($CO+H_2$) in a two-steps process, in which methanol is obtained and then converted to DME in another reactor. The sustainability of the process could be strongly enhanced by producing DME directly from CO_2, which is still a great challenge. Hence, this work investigated the possibility to produce DME from CO_2 [2], developing appropriate bifunctional catalysts for a possible one-step reaction, i.e. catalyst able to convert CO_2 to MeOH and dehydrate MeOH to DME.

As the transformation of CO_2 to MeOH is a well-known and studied transformation operated in the presence of ($CuO/ZnO/Al_2O_3$) mixed oxide, we first investigated the dehydration of alcohol to the corresponding ether for the selection of appropriate support for redox component. Different acidic materials have been tested under standard conditions (180°C and 5 bar N2) as dehydrating agent of alcohol to obtain the corresponding ether. Commercial zeolite like ZSM-5 and mordenite (Degussa), Nb_2O_5, Al_2O_3, Fe_2O_3, ZrO_2, SiO_2 results poorly active. However, by increasing the acidity of oxides with the introduction of sulphonic groups we were able to obtain a neat increasing of the dehydrating activity. Unfortunately, the stability of the sulphonic groups under the actual reaction conditions was poor and we observe a rapid deactivation of modified catalyst. We then turn toward a structural change of oxide instead of a simple functionalization. We then synthesized SiO_2·Al_2O_3 at different internal ratio by Flame Spray Pyrolysis and WO_2-modified ZrO_2 prepared by microemulsion technique. Preliminary results confirmed the activity and the stability of these mixed oxide in the conversion of iPrOH to $(iPr)_2O$ with a productivity of 7,3 mmol/h.

Next steps will be the investigation in a flow reactor.

References:

[1] Zoha Azizi, Mohsen Rezaeimanesh, Tahere Tohidian, Mohammad Reza Rahimpour, Dimethyl ether: A review of technologies and production challenges, Chemical Engineering and Processing, Vol.82 (2014) 150–172.
[2] Ng, K. L.; Chadwick, D.; Toseland, B. A. Kinetics and modelling of dimethyl ether synthesis from synthesis gas. Chem. Eng. Sci. 1999, 54, 3587.

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INO-PO-060

Melanin-like polymers with chemical responsiveness for living cell display technology

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Living cells, through their intrinsic nature, can work as natural platforms exhibiting a multitude of functional groups or biomolecules. The application of an engineered chemical surface onto these cells enables bacteria, mammalian and human cells, yeasts, and microalgae to recognize their environment and incorporate both *cell-to-cell* and *cell-to-environment* interactions useful for different applications ranging from industrial to biomedical.[1]

The scientific research here has been focused on the development of a strategy to universally decorate living cells with the use of melanin-like sticky organic polymers. Polydopamine (PDA), a poly-hydroxy-indole specie, has recently been used to achieve self-assembling coating onto living cells, giving them the capability both to continue living/dividing and increase cell resistance under harsh environmental conditions.[2]

This technology is simple, one pot, yielding to allow a highly reactive surface capable to react with other xeno-functional groups to change the chemical reactivity on the living cell surfaces. Our studies are focused on the possibility to co-polymerize dopamine with boronic acid units to obtain engineered cells with new functionalities such as addressing both free and membrane-bound saccharide moieties over cell surface, holding the potential for broad biology and biomedicine.

Other studies are conducted to enhance properties of diatoms in the field of bioremediation. Co-polymerization of dopamine with polyamines trigger the pollutants removal from aqueous environment, and increase the specificity of the chemical type of these (e.g. emerging small molecules, microplastics).[3]

Moreover, redox responsive melanin-like polymers were also synthesized *via* co-polymerization thiol-bearing moieties with dopamine, to add disulfide bridges to the polymer bulk. In this way these bioinspired polymers resulted cleavable under specific redox inputs, ready to be removed after capturing pollutants.

References:

[1] M. Lo Presti, D. Vona, MRS Communications 2021, 11, 213 – 225.
[2] D. Vona, S.R. Cicco, Photochemical & Photobiological Sciences 2022, 21, 949 – 958.
[3] A. Aresta, S.R. Cicco, Separations 2022, 9(8), 194.

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LabXAS: a new table-top instrument for in-lab XANES/EXAFS measurements

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X-Ray Absorption Near Edge Structure (XANES) and Extended X-Ray Absorption Fine Structure (EXAFS) spectroscopies are powerful techniques used to characterize the oxidation state of the absorbing atom and its coordination to the ligands. However, the need of an intense and tuneable-in-energy x-ray beam has limited the use of these techniques to synchrotron facilities, thus precluding their wide spreading. Giving access to XANES/EXAFS facilities to a broader community of physicists, chemists and material scientists would be extremely beneficial as XANES/EXAFS could provide them with an immediate feedback on the quality of the products of their research.

Recently, the development of novel laboratory x-ray sources with modern technology has favoured the rise of compact, but extremely expensive XANES/EXAFS spectrometers[1,2]. Within the NEXT-GAME and MUSA projects, we have designed a XANES/EXAFS spectrometer, called LabXAS, based on the use of a conventional but micro-focused x-ray source with suitable brilliance. Besides the source, the spectrometer also comprises a Johansson-type Ge(nn0) crystal analyser and a silicon drift detector, installed in vacuum and arranged on a Rowland circle. The instrument will work in transmission, within the energy range spanning from 3 to 15 keV. LabXAS is intended to minimize the costs, the size and the mechanical complexity of existing laboratory XANES/EXAFS spectrometers, while reaching measurement performances comparable to available instruments. Ultimately, it aims to provide a fast access to XANES/EXAFS characterization of novel, freshly synthesized materials, in particular for studies in the field of the next-generation batteries and catalysis. In this talk, we will give a general overview of the LabXAS instrument by presenting the innovative design solutions and the targeted performances, and we will finally discuss the most appealing applications for the community of chemists.

References:

[1] A. P. Honkanen, et al., Review of Scientific Instruments (2019), 90.
[2] G. T. Seidler, et al., Review of Scientific Instruments (2014), 85.

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INO-PO-062

Building Multisite Hydrocarbyl Ligands in Diiron Carbonyl Complexes Pointing to Catalytic Applications

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Specific diiron complexes, derived from commercial $[Fe_2Cp_2(CO)_4]$ (Cp = η^5-C_5H_5), have emerged as versatile frameworks for the construction of functionalized organometallic architectures. Taking advantage of the facile substitution of up to three carbonyl ligands and the synergistic interplay between the two iron centres, these complexes enable the assembly of small molecular entities via non-traditional reaction pathways.[1] Cyano-amino-allylidene complexes (**1**) can be synthesized through a sequence of regio- and stereo-selective reactions, being tolerant towards diverse functional groups (esters, pyridyl, thiophenyl, ferrocenyl, etc.).

Within complexes of type **1**, the interaction between the amine nitrogen lone pair and the terminal carbonyl ligand promotes the thermally-induced displacement of this CO. The resulting derivatives with multisite ligands have been evaluated for their catalytic activity in the hydroboration reaction of aldehydes and in the coupling reaction of CO_2 with epoxides under mild conditions.

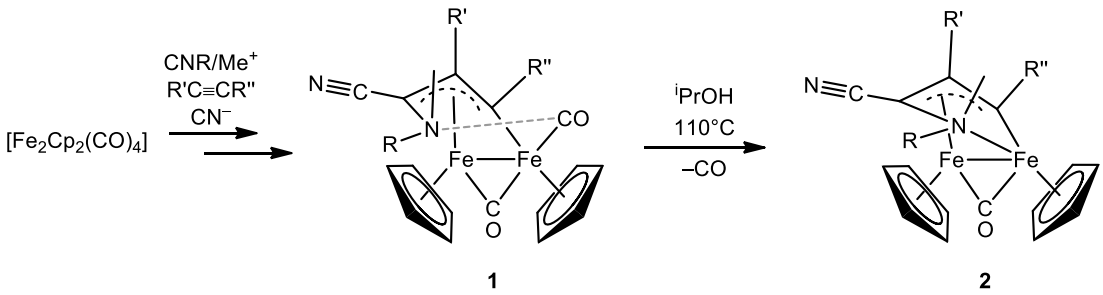

Figure 1: Synthesis of cyano-amino-allylidene complexes (**1**) and their thermal decarbonylation (**2**).

References:

[1] L. Biancalana, F. Marchetti, Coord. Chem. Rev. 2021, 449, 214203.

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TI_3C_2 MXene heterojunctions for enhanced photocatalytic properties in hydrogen photoproduction

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The hydrogen production can be performed in different ways: electrolysis, thermo-splitting, and photo-splitting. [1] The methods just mentioned use different types of energy to decompose water into hydrogen and oxygen, even though the efficiencies are really different. Indeed, the efficiencies of these systems are generally 70% when electricity is used, 40% when heat is used, and about 0,5% when light is the source of energy. With the idea of developing efficient green processes to produce hydrogen, among the quoted mechanisms photolysis results be a very interesting and feasible option since harvesting solar energy would directly produce H_2. The efficiency of the technology is still very low, due to several factors that depend on the reaction itself and for the catalyst used.

In the recent past MXene (Ti_3C_2) [2] has been used as a cocatalyst in possible combination with other synthesized semiconductors for an enhanced photocatalytic heterojunction. This material shown a 2D structure and is also interesting the presence of many functional groups that can be tuned by changing the synthesis. It exhibits absorption in the visible spectrum, boasts conductivity comparable to metals, and maintains an ideal Fermi level for hydrogen production when interacting with water.

In this study, the synthesis of this compound was always executed starting using Ti_3AlC_2 as precursor, trying different etching processes. Different semiconductors were also synthesized paying particular attention to different factors such as energy gap, the position of valence and conduction band, and sustainability aspects. All the synthetize materials were then characterized with XRD, SEM and UV-Vis analyses.

In the end, the photocatalytic performances of the materials were tested for the production H_2 by using different LED source (characterize by different wavelengths) to evaluate the performances.

[1] C. M. Kalamaras and A. M. Efstathiou, “Hydrogen Production Technologies: Current State and Future Developments,” Conference Papers in Energy, vol. 2013, pp. 1–9, Jun. 2013.

[2] L. Biswal, R. Mohanty, S. Nayak, and K. Parida, “Review on MXene/TiO2 nanohybrids for photocatalytic hydrogen production and pollutant degradations,” Journal of Environmental Chemical Engineering, vol. 10, no. 2. Elsevier Ltd, Apr. 01, 2022.

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Subcritical Hydrothermal Synthesis of Low- and High-Entropy Spinel Oxides for Oxygen Evolution Reaction

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Spinel oxides based on earth-abundant transition metals, such as Cr, Mn, Fe, Ni, Cu, and Zn, have emerged as promising alternatives to 'platinum group metals'-based catalysts in fuel cells and electrolysers, particularly for their application in the oxygen evolution reaction (OER).[1]

A novel and promising approach for developing high performance OER-catalysts involves high-entropy spinel oxides (HESO). These materials, characterised by a single phase spinel crystal structure with multiple metal cations, generally exhibit superior catalytic performance and increased stability compared to conventional binary spinel oxides.[2]

This project aims at optimising a low temperature, sustainable, water-based synthetic route for spinel oxides through the subcritical hydrothermal treatment of an oxalate suspension of the metal cations present in the final structure.[3] In particular, low entropy spinel oxides with the formula $NiFe_{2-X}M_XO_4$, (X = 0.25, 0.50, 1.00 and M = Mn or Cr) were synthesised to investigate the influence of Fe substitution on the structural and catalytic properties of the materials. Furthermore, four HESOs were synthesised: $(Cr_{0.2}Mn_{0.2}Fe_{0.2}Co_{0.2}Ni_{0.2})_3O_4$, $(Cr_{0.2}Mn_{0.2}Fe_{0.2}Ni_{0.2}Cu_{0.2})_3O_4$, $(Cr_{0.2}Mn_{0.2}Fe_{0.2}Ni_{0.2}Zn_{0.2})_3O_4$, $(Mn_{0.2}Fe_{0.2}Ni_{0.2}Cu_{0.2}Zn_{0.2})_3O_4$. Although some samples exhibited a pure crystalline spinel structure immediately after the hydrothermal treatment (150-200°C, 24 h), as confirmed by PXRD analyses, others required a subsequent annealing step (300-500°C) to achieve crystalline purity. Stoichiometries were determined through ICP-AES analyses, demonstrating good agreement with expected values and confirming the successful incorporation of the cations within the crystal lattice.

Currently, electrochemical tests (linear sweep voltammetry measurements) are ongoing on the synthesised materials to assess their electrochemical behaviour. These results will be pivotal in identifying the most promising stoichiometries for future evaluations, where the materials will be tested as electrocatalysts for OER in water electrolysers.

[1] Roger, I.; Shipman, M. A.; Symes, M. D. *Nat Rev Chem* **2017**, *1* (1), 1–13
[2] Stenzel, D.; Zhou, B.; Okafor, C.; Kante, M. V.; Lin, L.; Melinte, G.; Bergfeldt, T.; Botros, M.; Hahn, H.; Breitung, B.; Schweidler, S. *Frontiers in Energy Research* **2022**, *10*.
[3] Dolcet, P.; Diodati, S.; Zorzi, F.; Voepel, P.; Seitz, C.; Smarsly, B. M.; Mascotto, S.; Nestola, F.; Gross, S. *Green Chem.* **2018**, *20* (10), 2257–2268

INO-PO-065

Amyloid fibrils as innovative catalysts for advanced functional materials

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A fascinating class of nanostructures known as amyloid fibrils has garnered significant attention in the field of nanotechnology. Recent discoveries are now changing our vision of self-assembling peptide structures from disease related entities to functional tools for diverse biotechnological and material science applications.[1,2] Particularly interesting are catalytic amyloids, which allow to combine the benefits of enzymatic and heterogeneous catalysts within peptide-based nanostructures. In this context, our research focuses on developing functional nanomaterials combining amyloid-like nanofibrils and artificial metalloenzymes, showcasing their potential in flow biocatalysis.

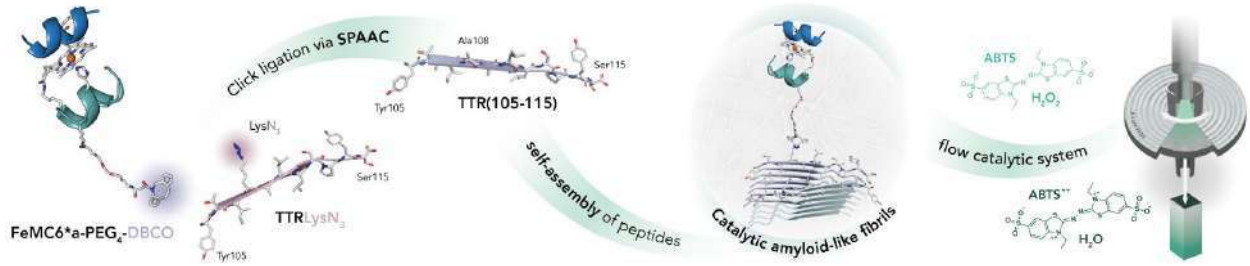

Figure 1: Schematic representation of the conjugation strategy and its application.

For this purpose, we have selected the TTR(105-115) peptide, derived from human transthyretin, which is able to form non-toxic fibrils with unique structural properties.[3] Exploiting click chemistry (SPAAC, illustrated in Figure 1), the synthetic miniaturized peroxidase FeMC6*a[4] has been covalently bonded to TTR(105-115)-based fibrils. Subsequently, FeMC6*a@fibrils were implemented in a flow catalytic system by simple immobilization onto a PVDF filter membrane. This amyloid-functionalized filtering device demonstrated remarkable performance, enabling up to 40 reaction cycles of substrate (ABTS) oxidation. This approach not only enables enzyme recycling, but also facilitates the separation of reaction products. Overall, this research provides a starting point for exploring the catalytic capabilities of amyloid fibrils in various applications.

References:

[1] G. Wei, Z. Su, N. Reynolds, P. Arosio, I. W. Hamley, E. Gazit, R. Mezzenga, Chem. Soc. Rev. 2017, 46, 4661–4708.
[2] T. P. J. Knowles, R. Mezzenga, Adv. Mater. 2016, 28, 6546 – 6561.
[3] A. Fitzpatrick, G. Debelouchina, M. Bayro, D. Clare, M. Caporini, V. Bajaj, C. Jaroniec, L. Wang, V. Ladizhansky, S. Müller, C. Macphee, C. Waudby, H. Mott, A. Simone, T. Knowles, H. Saibil, M. Vendruscolo, E.V. Orlova, R. Griffin, C. Dobson, Proc. Natl. Acad. Sci. 2013, 110, 5468–5473.
[4] G. Zambrano, M. Chino, E. Renzi, R. Di Girolamo, O. Maglio, V. Pavone, A. Lombardi, F. Nastri, Biotechnol. Appl. Biochem. 2020, 67, 549–562.

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INO-PO-066

Copper indium sulfide quantum dots enabling quantitative visible light photoisomerisation of (E)-azobenzene dyes

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Azobenzene derivatives are one of the most studied photochromic systems, garnering significant attention in different fields such as photopharmacology and photoresponsive materials[1,2]. However, azobenzenes rely on UV light to generate the metastable (Z) isomer, limiting their use in the previously mentioned fields. The rare cases showing large ratios of the (Z) isomer under visible light irradiation need either the use of a photosensitizer or structural modifications of the azobenzene compound[3]. Our work has focused on investigating various hybrid architectures involving azobenzene and quantum dots. We design an azobenzene with a dihydrolipoic acid chain that is grafted onto the surface of $CuInS_2$ quantum dots (CIS-QDs) (Figure 1). Interestingly, all these hybrid systems show quantitative photoisomerization to the (Z) isomer under visible light irradiation (e.g., 533 nm), with no observable back photoisomerization. We demonstrated that this peculiar effect was also noticed for physical mixtures of CIS-QDs and azobenzene dyes, revealing that this phenomenon can be ascribed to a direct interaction of the (Z) isomer N=N function with CIS-QDs. We showed that this interaction drastically decreases the intensity of the absorption bands of the (Z) isomer in the visible spectrum, shifting the photostationary state to the (Z) isomer, preventing its back photoisomerisation.

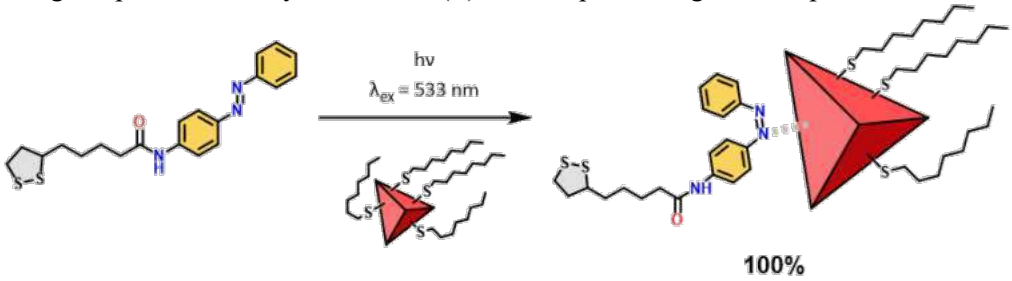

Figure 1: Isomerization process of an azobenzene derivative in the presence of CIS-QDs under visible light irradiation.

Acknowledgement:
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References:

[1] M. J. Fuchter, J. Med. Chem 2020, 63, 11436–11447.
[2] A. Goulet-Hanssens, F. Eisenreich, S. Hecht, F. Eisenreich, S Hecht, S. Hecht, Adv Mater 2020, 32, 1905966.
[3] J. Gemen, J. R. Church, T.-P. Ruoko, N. Durandin, M. J. Białek, M. Weißenfels, M. Feller, M. Kazes, M. Odaybat, V. A. Borin, R. Kalepu, Y. Diskin-Posner, D. Oron, M. J. Fuchter, A. Priimagi, I. Schapiro, R. Klajn, Science 2023, 381, 1357–1363.

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Tungstate and bromide dicationic ionic liquids with rigid spacers: an experimental and computational study on their structure-properties relationship

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The inclusion of catalytically or electrochemically active metal-based systems in ionic liquids (ILs) is attracting a growing interest due to the versatility of this approach and the potential applications in a variety of fields.[1] Molybdate and tungstate-based ILs have been reported in literature as effective catalysts for the cycloaddition of CO_2 to epoxides,[2,3] and other authors have also reported encouraging results concerning the use of tungstate-based ILs for the catalysis of CO_2 reaction with a variety of substrates. Among ILs, dicationic ionic liquids (DILs), which display a positive ion consisting of two cationic moieties covalently connected to each other, represent quite interesting systems from a structural point of view. The type and length of the spacer chain is in fact capable of influencing both the conformation and the reactivity of the DIL, representing a further element of tunability with respect to monocationic structures.[4] Nevertheless, at the best of our knowledge, no literature papers have yet considered tungstate based-DILs.

A panel of DILs with different rigid xylyl spacers (ortho, meta, para) and different anions (bromide and tungstate) has been synthesised and characterized through different experimental and computational techniques. Analogies and differences between the systems have been analysed using information derived from their DFT structures, semiempirical molecular dynamics, thermal behaviour, and catalytic properties versus the CO_2 cycloaddition to epichlorohydrin. The results have shown an interesting correlation between structure, flexibility, properties and catalytic activity.

References:

[1] Md.G. Ahmad, K. Chanda, Coord Chem Rev 2022, 472, 214769.
[2] N. Bragato, A. Perosa, M. Selva, G. Fiorani, R. Calmanti, Green Chemistry 2023, 25, 4849–4860.
[3] R. Calmanti, M. Selva, A. Perosa, Molecular Catalysis 2020, 486, 110854.
[4] J.L. Anderson, R. Ding, A. Ellern, D. W. Armstrong, J Am Chem Soc 2005, 127, 593–604.

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INO-PO-068

Ruthenium Complexes as Versatile Scaffolds for Anticancer Drugs Development

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Metal complexes are widely used in anticancer therapies, since they offer a wide range of tuning variables, including choice of metal, kind of ligands, coordination geometry, and a variety of oxidation states. This versatility permits to be notable drug design platforms.[1,2]

Clinically approved metallodrugs such as cisplatin, carboplatin and oxaliplatin are currently used to treat severe neoplastic diseases. Due to their versatile biochemical properties, Ruthenium compounds have emerged as promising anticancer alternatives to Platinum. Several types of Ru-based anticancer agents have been developed so far and some of them have undergone clinical trials. They can act by interacting with DNA or proteins, by producing reactive oxygen species to induce oxidative stress, ultimately affording cancer cells death.

A novel class of Ruthenium complexes has been designed by incorporating ligands such as CO, triphenylphosphine, hydride, and a variety of N- and O-donor chelate ligands, including non-steroidal anti-inflammatory drugs, hydroxy-stearic acids, pyrrole- or indole- derivatives. The selection of ligands was based on the purpose of enhancing therapeutic effectiveness of Ruthenium species against cancer cells, while retaining the option of further modification, by substituting the remaining hydride unit with N-donating ligands. Two distinct mechanisms, involving unprecedented chelate ligand exchange from k^2-(O,O) to k^2-(N,O) dihapto fashion mode, have been proposed and supported by DFT calculations.

NMR binding evaluations have been performed to test metal interactions to calf thymus DNA or human serum albumin biological targets. The results exhibit the organometallic species to bind by weak interactions with PPh_3 apical ligands. Preliminary biological evaluations *in vitro* MTT assays on different human cancer cell lines have shown promising anticancer activity by inhibition of cell viability and proliferation.

[1] L. Massai, J. Fernàndez-Gallardo, A. Guerri, A. Arcangeli, S. Pillozzi, M. Contel, L. Messori, *Dalton Trans*., **2015**, 44, 11067-11076
[2] B. S. Murray, P. J. Dyson, *Curr. Opin. Chem. Biol.* **2020**, 56, 28–34

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Mini-protein design: tailoring metalloprotein function for electron transfer and catalysis

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Metalloproteins display countless kinds of activities, despite employing a limited number or metal ions. From an inorganic chemist's perspective, they can be considered as a special kind of coordination compounds, featuring a complex macromolecular ligand that dictates the properties of metal ions through specific arrangements of aminoacids.[1] Deciphering the intricate mechanisms of metalloprotein function has been a central topic of research. Advances in de novo protein design have significantly contributed to the process, while facilitating the tailoring of enzymes for specific applications.[2] In this field, we have designed small, yet functional, peptide-based models housing different metal sites.[3-5] Our efforts have been recently directed to reproduce the structural and redox properties of the rubredoxin $Fe(Cys)_4$ center within a miniaturized protein scaffold, named METPsc1.[6] Notably, FeMETPsc1 exhibits one the highest reduction potentials among the rubredoxin family, thanks to precise introduction of hydrogen bonds in the second coordination sphere. FeMETPsc1 was able to perform at least 12 reversible redox cycles, prompting us to build a synthetic electron transfer chain by matching FeMETPsc1 with another mini enzyme, ZnMC6*a, as a photosensitizer.
Further, we have obtained the crystal structure of METPsc1 in its zinc and cobalt complexes, showing perfect agreement with the designed model. Our current research is focused on evaluating the effect of metal ion substitution in the METPsc1 scaffold, with the aim of achieving a thorough spectroscopic characterization and expanding the versatility of this mini-protein towards energy-related catalysis. Altogether, these studies open new avenues for exploiting artificial metalloproteins into complex electron transfer and catalytic processes, suggesting a promising direction for nanoscale multi-component mini-protein devices.

References:

[1] L. Leone, M. De Fenza, A. Esposito, O. Maglio, F. Nastri, A. Lombardi, *J. Pept. Sci* **2024** (accepted for publication).
[2] K. J. Koebke, T. B. J. Pinter, W. C. Pitts, V. L. Pecoraro, *Chem. Rev*. **2022**, 122, 12046–12109.
[3] M. Chino, L. Leone, O. Maglio, D. D'Alonzo, F. Pirro, V. Pavone, F. Nastri, A. Lombardi, *Angew. Chem. Int. Ed.* **2017**, 56, 15580-15583.
[4] L. Leone, D. D'Alonzo, O. Maglio, V. Pavone, F. Nastri, A. Lombardi, *ACS Catal.* **2021**, 11, 9407–9417.
[5] F. Pirro, S. La Gatta, F. Arrigoni, A. Famulari, O. Maglio, P. Del Vecchio, M. Chiesa, L. De Gioia, L. Bertini, M. Chino, F. Nastri, A. Lombardi, *Angew. Chem. Int. Ed.* **2023**, 62, e202211552.
[6] M. Chino, L. F. Di Costanzo, L. Leone, S. La Gatta, A. Famulari, M. Chiesa, A. Lombardi, V. Pavone, *Nat. Commun.* **2023**, 14, 2368.

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INO-PO-070

Lanthanide activated KY_3F_{10} nanoparticles for optical thermometry

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Fluoride based nanoparticles (NPs) activated with trivalent lanthanide ions (Ln^{3+}) have been extensively investigated in the last years for their interesting luminescence properties in the UV, Visible and Near Infrared (NIR) optical regions. These NPs are particularly interesting for applications in nanomedicine, in particular as optical probes or sensors in the biological windows (700-950 and 1000-1350 nm ranges).

In this contribution, we focus on KY_3F_{10} NPs activated with luminescent Ln^{3+} ions (as Pr^{3+}, Nd^{3+}, Tm^{3+}, Er^{3+}, Yb^{3+}), also considering core@shell architectures[1] (Figure 1).

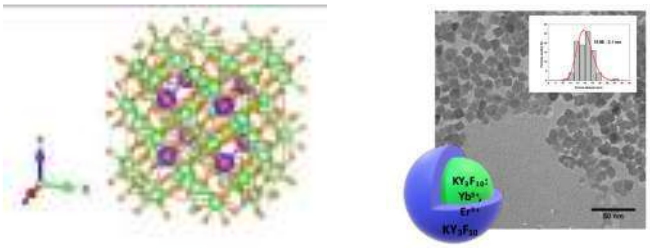

Figure 1: Crystal structure (K, violet; Y, green; F, yellow); architecture, TEM image and size analysis for representative core@shell nanoparticles.

KY_3F_{10} NPs have been prepared as water colloids with a "green chemistry", microwave (MW) assisted hydrothermal technique, using hydrophilic citrate groups as capping agents, which confer excellent colloidal stability in physiological buffers dispersion. Stokes and Anti-Stokes emissions in the UV-Visible-NIR regions have been measured by excitation with laser radiations. Energy transfer processes among Ln^{3+} ion couples (e.g. Yb^{3+}-Nd^{3+} or Yb^{3+}-Er^{3+}) have been exploited to investigate the performances of the Ln^{3+} doped KY_3F_{10} NPs as optical thermometers. In particular, the intensity of emission bands originating from the Ln^{3+} ions have been employed to study the thermometric properties, for evaluating the absolute and relative thermal sensitivities as well as temperature uncertainties of the NPs, using ratiometric methods. The obtained values clearly suggest a promising use of the KY_3F_{10} NPs as nanothermometers in biomedical applications.

References:

[1] C. Cressoni, A. Speghini et al. ACS Appl. Mater. Interfaces 2023, 15, 12171−12188.

INO-PO-073

Green Zinc/Galactomannan-based hydrogels push up the photovoltage of Quasi Solid Aqueous Dye Sensitized Solar Cells

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In the present work, we implement environmentally friendly water-based Quasi-Solid Electrolytes (QSE) for Dye Sensitized Solar Cells (DSSCs), displaying an unprecedent open circuit voltage (VOC) as high as 750 mV. The production of the hydrogel for QSE-DSSCs is achieved by exploiting the concept of fully green design and fabrication, through the selection of components such as the natural polysaccharide galactomannan (GM), the biocompatible zinc salts, and the employment of eco-friendly synthetic procedures to afford the hybrid gelating agents. In the process, moderate temperature (< 40 °C) and only aqueous solutions are employed. Depending on the type of the initial salt, either zinc hydroxysulfate lamellae or zinc oxide nanoparticles are created within the gel matrix, with a more extended nanoporous structure in the latter case (See Figure 1). Upon addition of the redox mediator I^-/I_3^- and ensuing assembling of the device, aqueous QSE-DSSCs are achieved with state-of-the-art PhotoConversion Efficiency. The latter couples a 2% efficiency (limited by charge diffusion as proved by Electrochemical Impedance Spectroscopy) with a good Average Visible Transmittance (AVT) (See Figure 1), and Light Utilization Efficiency (LUE), a couple of coveted features in wave-selective or semi-transparent devices [1].

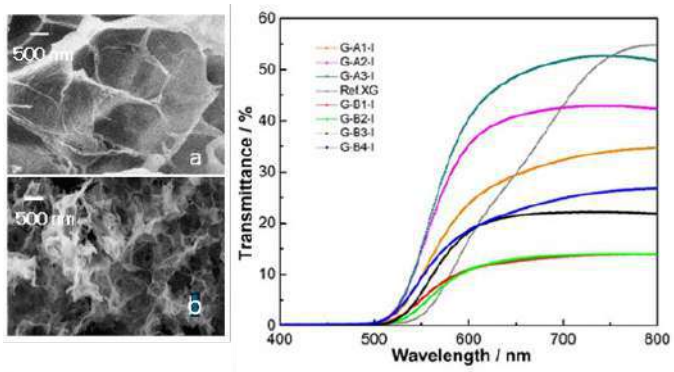

Figure 1: SEM images of the QSE (left). AVT of the devices (right).

Reference: [1] A. Y. S. Zarate, L. Gontrani, S. Galliano, E.M. Bauer, D.T. Donia, C. Barolo, M. Bonomo, M. Carbone *Solar Energy*, 22 (2024) 112460.

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INO-PO-074

Pesticides detection through ZnO-based fluorescent nanoprobes

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In modern agriculture, the application of chlorinated pesticides plays a critical role in managing pests affecting crops, herbs, and spices. However, the extensive use of these organochlorines rises concerns regarding potential residues in food products and their impact on human health[1]. In response, regulatory bodies have established maximum residue levels to ensure adherence to safety standards. Conventional detection methods, like high-performance liquid chromatography, though effective, involve labour-intensive and costly processes. Considering this, is worth exploring alternative techniques for faster, on-field detection. A potentially successful approach is fluorescence-based detection, involving intrinsic fluorophores. Zinc oxide is suitable for these methods, as it is safe and biocompatible. A surface functionalization of the ZnO nanoparticles (NPs) ensures the interaction between the former and the pesticides, resulting in a quenching or enhancing of the fluorescence signal intensity, thus providing the detection[3,4]. In a previous related paper (3-aminopropyl) trimethoxysilane (APTMS) was used as the coating agent and its interaction with the organochlorine penconazol was studied[2]. In this current study, the potential of various amino-silanes is explored. Also, a double functionalization is performed, using tetraorthosilicate (TEOS) to increase the dispersibility of the NPs in aqueous solutions; and then the amino-silane as the outermost layer providing the -NH_2 tail that serves as a hook for the -Cl of organochlorines.

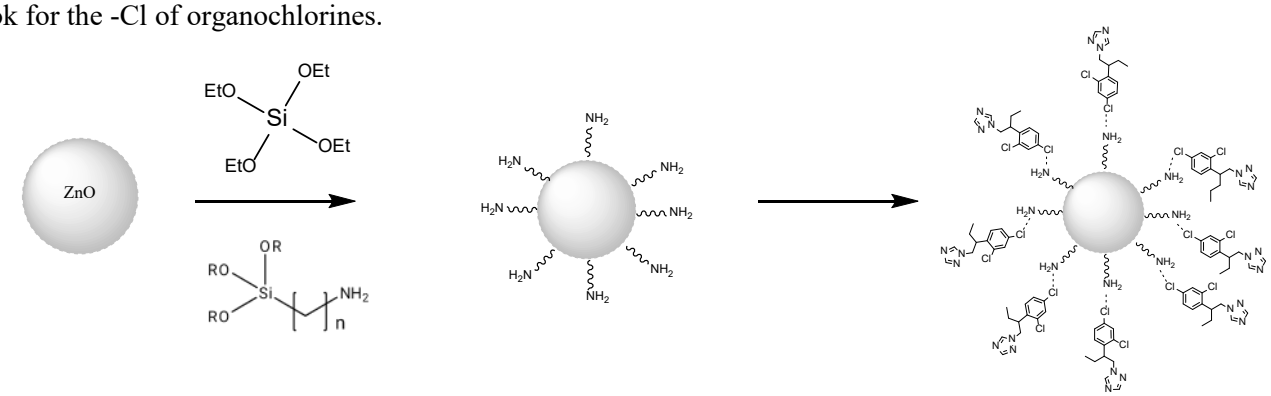

Figure 1: Scheme of the functionalization of ZnO NPs and their interaction with the chlorinated pesticed penconazol.

References:

[1] F. Almeida, V. S. Brauer, Biomolecules 2019, 9(10), 521-542.
[2] E.M. Bauer, G. Bogliardi, C. Ricci, D. Cecchetti, T. De Caro, S. Sennato, A. Nucara, M. Carbone, Materials 2022, 15, 8050-8067.

INO-PO-075

Fluorescence properties of DES borne nanometric ZnO: temperature and structure effects

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In this contribution, we describe the fluorescence properties of high purity nanometrical ZnO synthesized by precipitation in type-IV zinc nitrate-urea Deep Eutectic Solvent, a system inherently endowed with nano-homogeneities in its internal structure[1], that can be easily prepared by mixing the solid components with only little heating and limited workout procedures. The observed photo luminescence (PL) is remarkably brilliant and detailed investigations pointed out that the emitted radiation has quantum yield values that decrease when temperature is increased across a broad range, being very high at low temperature (77 K) but still appreciable up to 373 K. Such behaviour is perfectly reversible upon cooling and can be profited to assess external temperature with quite good confidence[2]. In order to gain further insight on such response property, a series of Raman studies was performed, whose vibrational patterns were assigned according to the crystal structure revealed by XRD experiments. Additionally, the dependence on the system morphology was investigated with FE-SEM microscopy, that depicts different nanoscopical structural arrangements, unveiling the presence of nano lamellar moieties embedded into larger mesoporous domains.

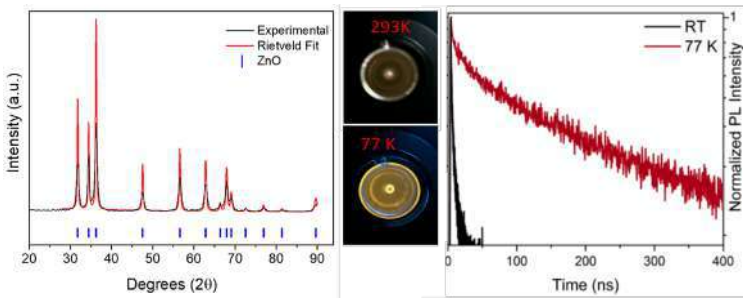

Figure 1: ZnO NPs: XRD pattern (left); PL at RT and 77 K: visual trace (center), lifetime (right).

References:

[1] L. Gontrani, D.T. Donia, E. M. Bauer, P. Tagliatesta, M. Carbone, Inorg. Chim. Acta 2023, 545, 121268.
[2] S. L. Shinde, K. Kar Nanda, Angew. Chem. Int. Ed., 2013, 52, 11325 –11328.

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Fabrication of new functional high-performing clay-based fabrics for environmental parameters detection

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Nowadays environmental pollution deriving from anthropological activities is a serious threat to the well-being of ecosystem and its inhabitants, representing the main cause of mortality in the world. The presence of emerging and common pollutants in air, water and soil is a cause of worry and discussion. Effective monitoring methods are indispensable for assessing environmental quality and identifying pollution sources. One of the most powerful analytical tools for determining environmental contaminants is chromatography, which allows for qualitative and quantitative analysis. However, these approaches require qualified staff, expensive instrumentation, and time-consuming sample preparation. In this regard, nanotechnologies represent potential for the development of sensor for environmental applications, thanks to their unique features such as high surface area (surface/volume ratio), catalytic capacity, reactivity and easy functionalization to chemically modulate their properties.[1] In particular, devices based on functional nanomaterials may represent a valid alternative to traditional techniques, compared to which they generate fast responses, addressing at the same time the actual need to use systems with a low environmental impact.[2] Recently, the scientific community is focusing on the development of optical sensor systems for the detection of environmental parameters and contaminants such as heavy metals. In particular, colorimetric sensors exhibit promising potential for the detection of metallic ions, anions, organic dyes, drugs, pesticides, and other toxic pollutants thanks to their easy fabrication, quick detection, high sensitivity, and naked-eye sensing.

In this work, a user-friendly adsorbing system that may either respond colorimetrically to the presence of various environmentally parameters (such as pH) is developed using different chromophores. In particular, a hybrid material based on functionalized clay is produced and used to immobilize seven distinct organic dyes and applied on cotton fabrics. All starting materials and final products have been characterized by means of different chemical-physical and morphological techniques. Finally, their successful employment for the pH variation detection will be shown, together with preliminary tests for pH variations and heavy metal revealing.

References:

[1] M.R. Plutino, E. Guido, C. Colleoni, G. Rosace, *Sensors Actuators B* **2017**, *238*, 281–291.
[2] S. Sfameni, G. Rando, M.R. Plutino, et al., *Molecules* **2022**; *27*, 5709.

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e-CCM TECHNOLOGY: TRASFORMING CO_2 INTO BUILDING MATERIALS

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Carbon Capture and Utilization (CCU) technologies, i.e. those that use CO_2 as a feedstock and convert it into value-added products (e.g. fuels, chemicals, building materials), are receiving increasing attention. The CCU is also seen to decrease the costs associated with the reduction of GHG emissions by valorizing the products and this is often considered an advantage over the geological storage of CO_2 (CCS).

Among the CCU approaches, mineral carbonation (MC) has the highest environmental benefits as it involves the permanent fixation of CO_2 in form of inorganic carbonates, stable, inert and non-toxic phases. MC processes can be applied on natural (mineral) or synthetic (industrial wastes, by-products) substrates if they have a sufficiently high content of reacting elements (calcium, magnesium and/or iron) to justify the otherwise onerous process. Minerals such as Olivine [$Mg_{2-x}Fe_xSiO_4$], Serpentine [$Mg_3(Si_2O_5)(OH)_4$], Wollastonite [$CaSiO_3$] are well studied for these processes since they have a high CO_2 uptake, nominally ranging from 0.38 $kg_{CO2}/kg_{Wollastonite}$ to 0.63 $kg_{CO2}/kg_{Olivine}$).

In this context, Eni has developed the e-CCM technology which consists of the *ex-situ* mineral carbonation of Olivine, a mineral widely available in outcrops often exploited industrially to produce materials for the steel, metallurgical and building industries. The rate of carbonation is strongly influenced by P_{CO2}, temperature, average particle size of the mineral, and, in lower extent, by the composition of the aqueous phase. Other phenomena may negatively influence the overall rate of the reaction, the most important being the formation of passivating layers of amorphous silica and/or carbonates that, covering the surface of the particles, constitute barriers to the diffusion of reagents and products, thus slowing down the entire carbonation process. Working with rocks mined from different outcrops located in Northern Italy and Norway, with an average Olivine content of 85 wt% and nominal CO_2 uptake of to 0.50 kg_{CO2}/kg_{rock}, we have selected a reactor suitable to manage a reaction that is only apparently simple, involving different gas-liquid-solid equilibria, and optimized the reaction conditions to obtain an almost complete carbonation (> 95%) within 3 - 4 hours, under moderate P_{CO2} (70 - 90 bar). In addition to this result, which ranks among the best reported in the literature, a further important turning point is represented by having discovered that, after simple treatments, the product (consisting mainly of $Mg(Fe)CO_3$ and amorphous SiO_2), develops pozzolanic properties never reported before for similar materials. This paves the way for applications of the mineralized product as a pozzolanic addition in the formulation of cements, limiting the production of clinker, which has a very high hard-to-abate carbon footprint.

References:

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INO-PO-078

Heck reaction between free base 2-Br-Porphyrin and vinyl-ferrocene derivatives. A comparative study, electrochemical and spectroscopic characterization of *β*-functionalized *alpha* and *trans*-vinyl-ferrocene porphyrin derivatives.

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The marriage of porphyrins with ferrocene affords new materials with improved photo- and electrochemical properties for photovoltaics, NLO, fluorescent switches and electrochemical-based devices[1-2], but, if on one hand the introduction of ferrocene in the *meso*-porphyrin positions was well and extensively studied, the difficulty to introduce the ferrocenyl moiety in the *β*-porphyrins positions has limited their application.

In line with our previous work[3], here we report on a comparative study to investigate the regioselectivity of the Heck reaction between free base 2-Br-Porphyrin and vinylferrocene derivatives. In the mild reaction condition adopted, using $Pd(dba)_2/AsPh_3$ as catalytic system, the vinylferrocene showed a peculiar selectivity towards the formation of the *alpha*-isomer rather than the *trans*-isomer. This aspect allowed us to investigate by an electro- and photochemical point of view the properties of the new 2-vinylferrocenyl-substituted porphyrin *alpha*-isomers compared to the respective *trans*-isomers, outlining the importance of the type of *β*-C-C bond in the electron-transfer processes.

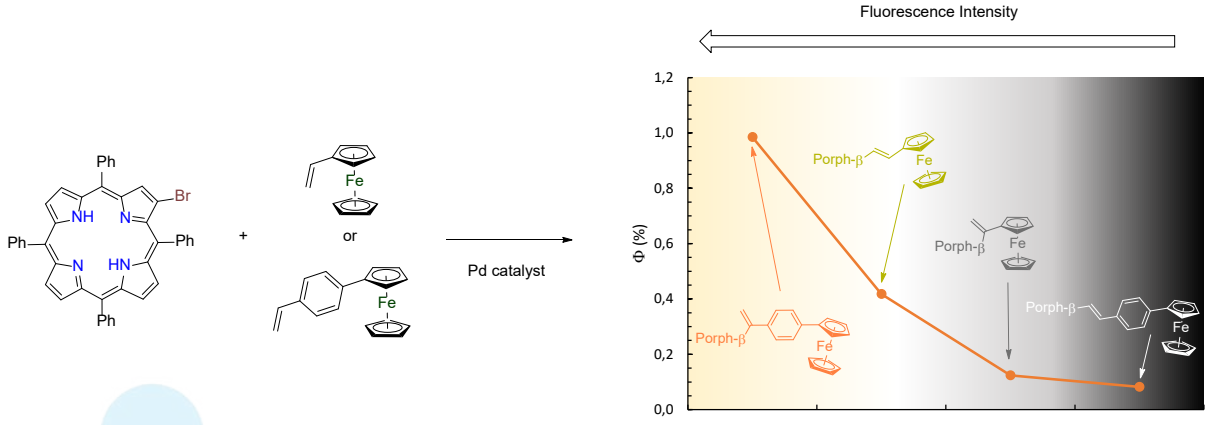

Figure 1: Heck reaction (left) and residual porphyrin fluorescence in the different isomers (right)

References:

[1] C. Bucher, C. H. Devillers, J.-C. Moutet, G. Royal, E. Saint-Aman *Coordination Chem. Rev.* 2009, **253**, 21-36.
[2] B. M. J. M. Suijkerbuijk and R. J. M. K. Gebbink *Angew. Chem. Int. Ed.* 2008, **47**, 7396-7421.
[3] P. Tagliatesta, A. Lembo and A. Leoni *New J. Chem.* 2013, **37**, 3416-3419.

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INO-PO-079

Deposition of fungicide and Bacillus spores containing coatings for encapsulating seeds by Aerosol Assisted Atmospheric Pressure Plasma tecnique

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Cereals can be colonized, throughout the whole crop cycle, by fungal pathogens, including mycotoxigenic species and among these one of the most important is *F. graminearum*, causal agent of different cereal diseases such as Fusarium Head Blight. *Fusarium graminearum* represents both a phytopathological problem and a toxicological risk for human and animals. To date, fungicides represent the most effective strategy to protect cereals against Fusarium species. However, in the last years, as requested by the European Green Deal, more eco-friendly strategies should replace the use of chemicals in agriculture. In this scenario, selection of biocontrol agents and Low Temperature Plasma (LTP) processes recently developed for applications in Agriculture and Food technologies are very promising.[1, 2]

Experiments were conducted on the deposition of barrier films containing fungicides or bacterial spores in a DBD (Dielectric Barrier Discharge) reactor by means of Aerosol Assisted Atmospheric Pressure Plasma Deposition (AA-APPD). With this approach, high fungicide effect with a small quantity of chemicals and less pollution of soil and water is expected. The chemical composition and the morphology of barrier film have been characterized by means of WCA measurements, FTIR, SEM and profilometer. Coating chemistry and morphology and activity against *F. graminearum* have been tested on glass discs, and the viability of the Bacillus spores as well.

Good activity against fungi has been observed both for coatings embedding the fungicide or including the Bacillus spores. Very interestingly the latter retained the viability upon the deposition process. In the case of coatings containing prothioconazole an anti-fungine activity higher than the pure pesticide has been found. Preliminary results showed that Aerosol Assisted Atmospheric Pressure Plasma can represent a good ecofriendly tool for seed coating. Activities aimed to optimize the deposition on maize and wheat seeds of nanocomposite film containing fungicides or bacteria spores, are ongoing.

Acknowledgements: this research activity is partly funded by Progetti@CNR "Cold Plasma Processes and Technologies for Sustainable Agriculture and Food Processing" and ON FOODS, PNRR Mission 4 Component 2 Investment 1.3, Theme 10

References:

[1] M. Masiello et al., Int. J. Mol. Sci., 22 (17) (2021), 9301. DOI:10.3390/ijms22179301.

[2] C. Lo Porto, et al., Plasma Process Polym., 16 (6), (2019), 190022. DOI: 10.1002/ppap.201900022.

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Surface engineering via Atomic Layer Deposition of chitosan sponges for application in cooperative photocatalysis

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Cooperative photo-redox catalysis is a cost-effective and sustainable approach allowing the tackling of two major societal challenges: water stress and energy shortage. In the cooperative photoredox approach, (non-)selective oxidation of organic pollutants is exploited for solar fuels production integrated in a light-driven photoredox system, valorising the contaminants in a circular economy approach.

To this aim, we engineered low-cost and bio-derived sorbents, i.e., chitosan-based sponges, integrating photoactive materials to couple the photocatalysis with the excellent sorption properties for water remediation. Specifically, chitosan-based polymers were adopted as porous sponges and non-porous thin films and atomic layer deposition (ALD) was chosen to integrate the photo-active materials.

ALD is a powerful method for the deposition of thin films on 3D porous materials, due to its processing capabilities such as the angstrom-level thickness control and conformal deposition. Zinc oxide (ZnO) was chosen as a starting photoactive material for its well-known photocatalytic and antibacterial properties, representing a good candidate for the above-mentioned applications.

The growth of the ZnO on both chitosan thin films and sponges was studied by means of spectroscopic ellipsometry, XPS, UV-vis Spectroscopy and FTIR. The measured band gap and the chemical composition confirmed the growth of ZnO. Moreover, the photocatalyst was found to grow within the matrix of the sponges up to at least tens of micrometres. Due to the chemisorptive nature of ALD, the growth model suggested a strong integration of the oxide into the bio-polymer matrix, with properties resembling a ZnO/chitosan nanocomposite. Moreover, it was observed that only 10 ALD cycles, resulting in a nominal ZnO of 2 nm, greatly increased the stability of chitosan sponges in water media, enabling pollutants removal.

The adsorption of Direct Blue 78 was studied as a function of the ALD ZnO cycles. Higher direct anionic dye removal from solution was measured for the ALD ZnO/chitosan nanocomposite compared to the pristine chitosan sponges.

ALD was the key-enabling technology for the production of ZnO-based photo-active organic-inorganic hybrid bio-based sponges, setting the first step towards a cooperative photo-redox system.

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Reaction with water vapor defines surface reconstruction and toxic activity of fractured quartz particles

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Respirable crystalline silica (RCS) remains the leading cause of occupational respiratory disease worldwide and continues to prompt extensive research into its mechanisms of toxicity. Surface characteristics of silica, notably the occurrence of specific silanol groups, the "nearly-free silanols" (NFS), have emerged as pivotal factors in triggering the molecular initiating event of silica toxic pathways[1]. NFS are formed during fracturing of crystalline silica and exhibit a unique arrangement that facilitates the interaction with zwitterionic phospholipids in cell membranes, resulting in their disruption. The amount of NFS can be modified through physico-chemical processes that lead to different surface reconstruction pathways, that in turn modulate the degree of toxicity observed with different silica specimens[2].

To clarify the impact of the silica surface reconstruction on cell membrane damage, quartz was milled in different molecular environments that combined the absence and presence of molecular water vapor and oxygen. Water- and oxygen-free environment ($-H_2O/-O_2$) mainly generated silyl surface radicals (E' centers). Oxygen-rich environment ($-H_2O/+O_2$) favored the peroxyl and surface-bound superoxide radicals, with respect to E' centers. Water-rich environments ($+H_2O/\pm O_2$), on the contrary, reduced the number of electronic defects, and converted them in diamagnetic species, likely surface silanols. Only quartz milled in water-free environments ($-H_2O/\pm O_2$) exhibited highly reactive surface that immediately interacted with water vapor and acquired a membranolytic activity. On the contrary, quartz milled in water-rich environments ($+H_2O/\pm O_2$) showed a negligible membranolytic activity. Mechanistically, E' centers, that largely dominate the surface of quartz milled in water-free environment, seems to be responsible for the generation of the membranolytic silanol species, after reaction with water vapor[3].

The identification of specific silanol configurations that can interact with phospholipid and induce membrane damage may pave the way for a comprehensive toxicity model extended to particles of several metal oxides and minerals with hydroxylated surfaces.

References:

[1] Pavan et al., Proc Natl Acad Sci U S A, 2020, 117(45), 27836-46
[2] Pavan et al., Int J Mol Sci, 2023, 24(14), 11482
[3] Bellomo et al., Small, 2023

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INO-PO-082

Synthesis and catalytic properties of CeO_2 nanoparticles for ROS production or scavenging

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CeO_2 nanoparticles (NPs) are interesting materials for possible applications in biomedicine as wound and bone healing, cancer therapy, and other diseases involving oxidative stress.[1] An intriguing aspect of these NPs is the presence of both Ce^{3+} and Ce^{4+} ions[2] which confers the peculiar ability to both scavenge and produce OH· radicals through redox processes. CeO_2 NPs have been synthetized using several methods,[3] but the preparation of stable colloidal suspensions in water or biological buffers, needed to be used as therapeutic agents, is not trivial. In this contribution, we investigate the synthesis of water-dispersed CeO_2 NPs employing different preparation conditions, from room temperature to higher ones, by microwave-assisted technique, and with different reaction times. The effect of precursors and capping agents (e.g. the citrate group) concentrations on both the colloidal and the redox properties of the CeO_2 NPs have been evaluated. A possible doping with Tb^{3+} ions has been also investigated to exploit the Ce^{3+} to Tb^{3+} energy transfer, serving as a quick tool to probe the presence of Ce^{3+} under different conditions.[4]

The synthesized materials have been characterized by means of X-Ray powder diffraction, Raman spectroscopy and Dynamic Light Scattering. Investigations on the catalytic properties of CeO_2 NPs have been carried out by indirectly following Reactive Oxygen Species (ROS) generation through UV-Vis and fluorescence spectroscopy, exploiting the Fenton reaction to degrade a sample dye or directly tune the Ce^{3+}/Ce^{4+} ratio.

References:

[1] Y. Huang, *et al.* Adv. Healthcare Mater. 2023, 12, 2300748.
[2] R. Wang, *et al.* ACS Sens. 2023, 8, 4442 – 4467.
[3] S. Pundir, *et al.* IOP Conf. Ser.: Earth Environ. Sci. 2023, 1110, 012030.
[4] X. Wang, *et al.* RSC Adv. 2013, 3, 3623 – 3630.

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Towards building-integrated photovoltaics: highly transparent and colourless luminescent solar concentrators based on bright Eu^{3+} supramolecular cages

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Achieving seamless installation of photovoltaic (PV) devices into buildings requires versatile technologies that can maximise the energy output while preserving the functionality and aesthetics of the existing architectural element. Luminescent solar concentrators (LSCs) are now emerging as powerful tools to turn glazing systems into energy-producing building components. An LSC is conventionally comprised of a glassy or polymeric slate embedded or coated with luminescent species, which light emission can be stimulated by sunlight and collected at the edges of the panel by thin PV cells, to be then converted into electrical power.

Our study reports *i)* the synthesis of strongly emitting $[Eu_2L_4]^{2-}$ cages, where the ligands L are bis-β-diketones capable of sensitizing the Eu^{3+} ion through the benzolytrifluoroacetone (btfa) moiety, *ii)* the preparation of planar LSCs in form of tiles or films having 5 x 5 cm^2 active area by embedding the cages into PMMA, and *iii)* the study of the LSC-PV devices obtained by edge-coupling the LSCs with monocrystalline Si PV cells. The photophysical properties of the luminophores have been fully characterized before and after embedding into the host medium. Measured average visible transmission (AVT), colour rendering index (CRI) and CIELAB coordinates are all well within the industrial standards for glass destined to neutral colour applications, denoting excellent transparency ad aesthetic quality. LSC-PVs have been characterized under simulated AM1.5G illumination. Thanks to increased light absorption, LSCs containing higher luminophore loadings yield better power conversion efficiency (PCE), while maintaining unaltered transparency and colour neutrality. Finally, we compared the fabricated LSC-PVs to other Eu^{3+}-based concentrators present in literature, finding similar performances in terms of PCE, while using a 10 to 100 times lower content of europium in our devices.

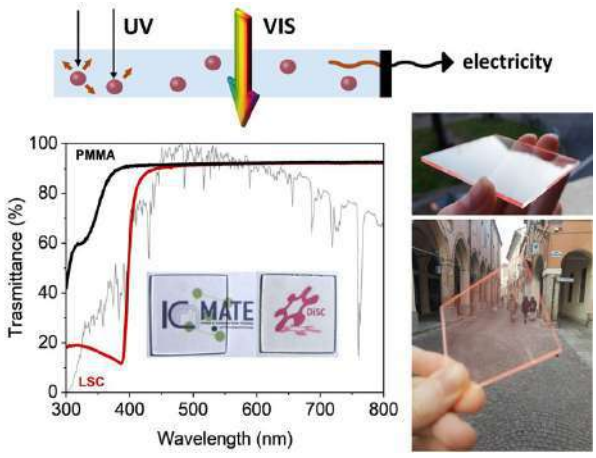

Figure 1: Working principle of a planar LSC embedded with UV-absorbing luminophores (top), transmittance spectrum of one of the proposed Eu^{3+}-based LSCs and of plain PMMA superimposed to AM1.5G spectrum (bottom left), digital photographs of the concentrators under natural daylight (bottom right).

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INO-PO-084

Synthesis and characterization of new curcumin and bisdemethoxycurcumin conjugates for novel bioactive Ru(II)-arene complexes

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Curcumin and bisdemethoxycurcumin, bioactive ingredients extracted from the rhizome of the plant *Curcuma longa*, have shown interesting medicinal properties such as anti-cancer activity. However, their clinical application is restricted by low bioavailability due to the low absorption and low water solubility, rapid metabolism, and clearance. In this respect, highly promising approaches dealing with the bioavailability issue involve the coordination of a metal center and structural modifications. Recently, some Ru(II) and Os(II) complexes incorporating palmitic bioconjugates of curcuminoids showed enhanced cytotoxic effects on both cis-platin sensitive and resistant ovarian carcinoma cell lines (AC2780 and AC2780cisR).[1] Herein is reported the synthesis and characterization of new ester-conjugates of curcumin and bisdemethoxycurcumin to investigate if their Ru(II) related compounds could lead to improved efficacy. Ru(II) half-sandwich complexes, synthesized using appropriately modified bidentate curcuminoid ligands (Figure 1), have been studied as antitumor agents.

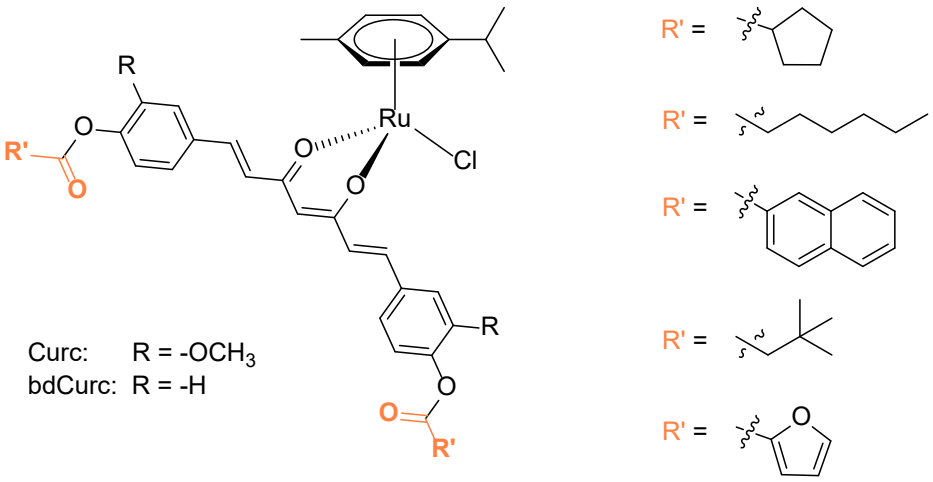

Figure 1: Organometallic Ru(II)-p-cymene complexes with curcuminoid conjugates

References:

[1] N. Pagliaricci, R. Pettinari, F. Marchetti, C. Pettinari, L. Cappellacci, A. Tombesi, M. Cuccioloni, M. Hadiji, P.J. Dyson, *Dalton Trans.* **2022**, *51*, 13311-13321

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Improving the pyrolysis yields of biochar from agrifood wastes for hydrogen storage: the action of fungi

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Waste recycling has become a priority in recent years' policies, representing a cornerstone of the Circular Economy model aimed at making the economic system sustainable. Circular principles find ample application in the agri-food supply chain, encompassing agricultural production, processing, and consumption. Recent estimates indicate that waste production from the agri-food sector in Europe amounts to approximately 87 million tonnes, equivalent to 171 kg per capita, with around 20% attributable to the agricultural sector. All these waste materials contain cellulose, hemicellulose, and lignin-carbon bioresources, all substances considered promising for energy storage[1]: in particular, they are seen as suitable candidates if obtained in the appropriate chemical and morphological form through pyrolysis steps. Pyrolysis is a thermal decomposition process that converts organic materials into carbon-rich solids (biochar), condensable liquids (bio-oil), and non-condensable volatile substances (gas) by applying heat in an oxygen-free environment[2].

In our research group, cereals and vegetables waste from Lombardy region (Italy) are considered as good source of C for hydrogen storage. The time and temperature of pyrolysis are undergoing optimization to enhance the chemical and morphological characteristics of the obtained materials. Since the yield for biochar production is still low (maximum 25%), the implementation of a pre-treatment process for biomass/vegetable waste, aimed at making cellulose and hemicellulose components easily accessible, could lead to a higher final yield. One green option is the use of white rot fungi, capable of degrading lignin, cellulose and hemicellulose in lignocellulosic materials. In particular, lignin is a component that proves to be challenging to degrade during pyrolysis. Fungi can assist in breaking down lignin into water (H_2O) and carbon dioxide (CO_2)[2,3] due to their extracellular oxidase. In this study, the capability of six lignicolous fungal strains to colonize different vegetal wastes was tested. The effectiveness of fungal pre-treatment on waste to increase the efficiency of the pyrolysis process was evaluated. Preliminary results pointed out an increase in the solid C production yield during pyrolysis (from 27% up to 40%) for rice bran, the most promising waste from cereals matrices in terms of hydrogen storage gravimetric capacity and kinetics.

References:

[1] M. A. Yahya et al., Sustain. Energy Rev., 2015, 46, 218–235.
[2] A. N. Amenaghawon et al., Environ. Dev. Sustain. 2021, 23 (10), 14324–14378.
[3] T. Manavalanet al. Curr. Microbiol. 2015, 70 (4), 485–498.

INO-PO-086

Electrochemiluminescent compounds in confined space

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Electrochemiluminescence (ECL) – the production of molecular excited states without light excitation but through the recombination of charges – is a well-known process. This method presents diverse advantages due to the absence of excitation light, thus resulting in a sensitive enhancement of the signal-to-noise ratio.[1] Thus, ECL can be exploited for the design of diagnostic tools and it is used extensively in immunoassays. As ECL emitters the most well known compounds are ruthenium and iridium compounds. However more recently also organic molecules have been reported. The emission of heavy metals compounds is strongly influenced by the quenching due to the presence of dioxygen in solution and many attempts have been made to protect the complexes by such detrimental process, such as denritic compounds and encapsulation in silica particles.

The use of the confinement of the emitters in scaffold and nanoparticles can also improve their solubility and stability in aqueous environments, such as biological ones.[2]

Here we report a set of organic and organometallic compounds which have been chemically and spectroscopically characterized. Their ECL and emission properties have been performed in solution and compared with their behavior once they are encapsulated in silica nanostructures that possessing different porosity can affect the photophysical properties and ELC signal.

References:

[1] E. Longhi, J.M. Fernandez-Hernandez, A. Iordache, R. Fröhlich, H.P. Josel, L. De Cola, Inorg. Chem., 2020, 59, 7435-7443.

[2] E. A.Prasetyanto, Y. Atoini1, L. Donato, C.W. Hsu, L De Cola, Frontiers in Chemistry, 2022, 10, 2296-2646

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Atomically Precise Rh-In Carbonyl Nanoclusters: Synthesis, Characterization and Crystal Structures

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The chemistry of homo-[1] and hetero-metallic[2,3] rhodium carbonyl clusters has been widely investigated in the last decades. In order to further widen the chemistry of heterometallic rhodium compounds, we investigated the reactivity of the $[Rh_7(CO)_{16}]^{3-}$ cluster precursor with $InCl_3$, obtaining the new Rh-In carbonyl species $[Rh_6(CO)_{15}InCl_3]^{2-}$ and its dimeric version $[\{Rh_6(CO)_{15}InCl_2\}_2]^{2-}$. Furthermore, we synthesised the In-centred icosahedral $[Rh_{12}In(CO)_{28}]^{3-}$ cluster, which parallels the species belonging to the $[Rh_{12}E(CO)_{27}]^{n-}$ family (E = Sn, Ge, Sb, Bi), with which it shares the electron counting (170 cluster valence electrons) and the metal structure.[4]

These new Rh carbonyl clusters have been characterised by IR spectroscopy and ESI-MS spectrometry and their molecular structures fully established by single-crystal X-ray diffraction studies.

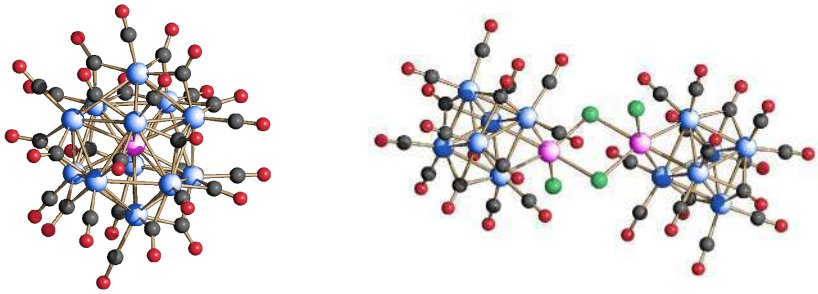

Figure 1: Molecular structures of $[Rh_{12}In(CO)_{28}]^{3-}$ and $[\{Rh_6(CO)_{15}InCl_2\}_2]^{2-}$. Rh is depicted in blue, In in magenta, Cl in green, C in grey, and O in red.

References:

[1] D.S. Dolzhnikov, M.C. Iapalucci, G. Longoni, C. Tiozzo, S. Zacchini, C. Femoni, Inorg. Chem. 2012, 51, 11214 – 11216.
[2] C. Femoni, M.C. Iapalucci, S. Ruggieri, S. Zacchini, Acc. Chem. Res. 2018, 51, 2748 – 2755.
[3] G. Bussoli, C. Cesari, C. Femoni, M.C. Iapalucci, S. Ruggieri, S. Zacchini, Atomically Precise Nanochemistry, Wiley 2023, 10, 309 – 330.
[4] C. Cesari, C. Femoni, T. Funaioli, M.C. Iapalucci, I. Rivalta, S. Ruggieri, S. Zacchini, J. Chem. Phys. 2021, 155, 104301.

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INO-PO-090

C-H bond activation in laccases investigated with molecular modelling

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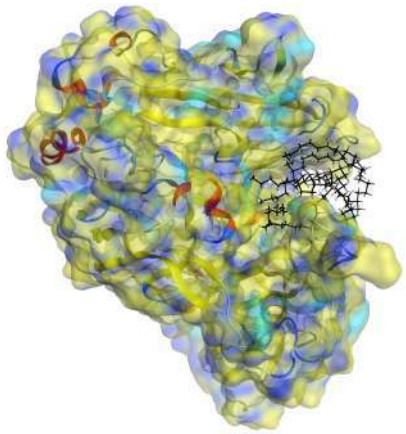
It is known that laccases, both bacterial and fungal, catalyze the activation of Csp2-H bonds through monoelectronic oxidation[1], the mechanism of which is not fully known in detail. This process is generally assisted by a mediator, which is a small molecule with a higher redox potential than laccase and a strong affinity with it. Recent experimental results highlight that some laccases would also be able to oxidize Csp3-H bonds and moreover in the absence of a mediator. What could be the molecular-level mechanism of this process? A possible approach is to study the oxidation process at the classical and quantum molecular modeling level using a model aliphatic and aromatic hydrocarbon substrate linked to the laccase binding pockets.



References:
[1] I. Bassanini, EE Ferrandi, S. Riva, D. Monti,. Catalysts. 2021; 11, 1-30.
[2] J. Zampolli, M. Mangiagalli, D. Vezzini, M. Lasagni, D. Ami, A. Natalello, F. Arrigoni, L.Bertini, M. Lotti, P. Di Gennaro, Environmental Technology & Innovation. 2023, 32, 103273
[3] A. Rovaletti, L. De Gioia, P. Fantucci, C. Greco, J. Vertemara, G. Zampella, F. Arrigoni, L. Bertini, Int. J. Mol. Sci. 2023, 24, 6368

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Understanding intermolecular interactions: carbon nanofibers from low and lowest molecular weight polyphenols

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Carbon nanofibres (CNFs) are seen as one of the most promising materials when it comes to high performance applications. Yet, CNFs are *de facto* only produced fossil-based resources, mainly in the form of polyacrylnitrile precursors.[1] Renewable resources such as the natural polyphenolic lignin are yet struggling to convincingly perform in this field, despite interesting findings in the recent years.[2]

Being interested to shed light into this intriguing problem, we set out to use our very detailed structural knowledge regarding natural polyphenols to mechanistically study the importance of structural features for winning intermolecular interactions such as to rationalise fibre formation.

To this end, two technical lignins, namely softwood kraft lignin (S-KL) and wheat straw organosolv lignin (WS-OSL) were fractionated by a single-step solvent extraction. The starting lignins and the resulting fractions were thoroughly characterized by means of quantitative ^{31}P nuclear magnetic resonance and quantitative ^{1}H-^{13}C heteronuclear spin quantum coherence spectroscopy, gel permeation chromatography, as well as thermal analysis. Pure low molecular weight fractions of the two technical lignins were converted into fibrous matrices using optimized spinning solutions and electrospinning process parameters. Uniform and bead-free fibres in both random and aligned mode were confirmed by scanning electron microscope analyses. Fibres could be processed to obtain well-defined thermostablised and carbonized fibres on the basis of the pure low MW fractions.

The accumulated insights could be converted into a set of rationales, on the basis of which it became generally possible to determine natural polyphenols most suitable for CF formation. These rationales were ultimately tested generating for the first time electrospun nanofibers from tannic acid (TA) and mono- and dimeric proanthocyanidin, which could equally well be thermostabilised and carbonised to CNFs.[3]

References:

[1] X. Zhou, Y. Wanga, C. Gong, B. Liu, G. Wei, Chem. Eng. J. 2020, 402, 126189.
[2] X. Huang, Y. Li, Z. Li, *et al.*, Biomass Conv. Bioref. 2024, DOI:10.1007/s13399-024-05387-7.
[3] P. Giannì, M. Gigli, Francesco Basoli, Reza Ebrahimi Majdara, C. Crestini, H. Lange, *unpublished results*, 2024.

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Doped CeO_2/g-C_3N_4 nanocomposite as photocatalyst for H_2 production

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The emergence of hydrogen economy with the current scenario of the need to switch to cleaner and greener forms of energy sources is seen to be inevitable. However, the production cost of green hydrogen is seen to be higher than blue or grey hydrogen in the energy market, especially in Europe[1]. One of the important factors that need to be considered for accessing proper large-scale production of hydrogen apart from the reactor geometry and configuration set-up includes mainly the catalyst. Herein, a catalyst synthesized with the idea of building blocks was tested for the H_2 evolution reaction. The synergistic effect of heterojunction formation between CeO_2 and g-C_3N_4 was taken into account with modification in the ceria lattice by introducing some rare-earth (RE) metals (Nd, Pr, Gd, Y). The catalyst was synthesized by a co-precipitation method with calcination at 400˚C. Further, heterojunction formation was confirmed with characterization techniques such as HR-TEM, Raman, XRD where cubic-fluorite nanoparticles of ceria were formed ~ 5nm with a composite formation with g-C_3N_4. Photocurrent measurements showed impressive e^-/h^+ separation in case of CeO_2/g-C_3N_4. Further, Raman analysis with F_{2g} peak broadening in the case of the RE doped ceria was seen along with UV-DRS showing extended absorption of $Pr_{0.2}Ce_{0.8}O_{2-\delta}$/g-$C_3N_4$ and $Nd_{0.2}Ce_{0.8}O_{2-\delta}$/g-$C_3N_4$ as compared to the undoped composite proving the inclusion of the RE ions.

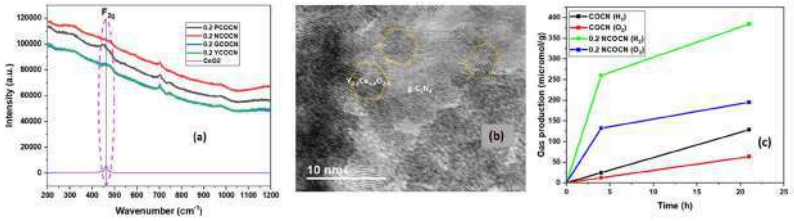

Figure 1: (a) F_{2g} broadening in Raman analysis. (b)HR-TEM image. (c) Overall water splitting.

Testing these materials for H_2 production clearly showed 10 times higher production of hydrogen in case of $Nd_{0.2}Ce_{0.8}O_{2-\delta}$/g-$C_3N_4$ as compared to CeO_2/g-C_3N_4 through overall water splitting with both the catalysts producing stoichiometric amounts of H_2 and O_2. Also, using TEOA as a sacrificial agent, higher production of H_2 for $Nd_{0.2}Ce_{0.8}O_{2-\delta}$/g-$C_3N_4$ (406 $\mu molg^{-1}h^{-1}$) as compared CeO_2/g-C_3N_4 (329 $\mu molg^{-1}h^{-1}$) was observed.

References:

[1] IntelliNews, "Hydrogen production and demand to grow in 2024, but only slowly" Feb, 2024. (accessed Mar 2024)

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INO-PO-094

Towards a More Sustainable and Circular Production of Hydrogen

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The paradigms of circular economy include for sure the production of sustainable energy but also the valorization of materials that are currently solely seen as waste. Nowadays, sewage sludge (SS) is one of the most abundant waste produced by municipalities and industries, but it can also be a source of valuable chemicals, including some interesting energy vectors[1].

The significant concentration of ammonia in SS[2] is appealing for this purpose: its oxidation does not produce any carbon containing species and it has much lower energy demand compared to water oxidation[3], thus it represents an innovative and circular way to produce hydrogen.

In this work, we investigated a composite system based on metal nanostructures grown on nickel foam (NF) and others supports for the (photo)electrochemical ammonia oxidation reaction (AOR). Both platinum and more earth-abundant metals such as Ni and Cu were deposited by different synthetic approaches in solution (*e.g.*, static and pulsed electrodeposition and hydrothermal method) to have high dispersed nanostructures. They were characterized from morphological, crystallographic and (photo)electrochemical point of view.

Moreover, (photo)electrolytic experiments were performed to investigate and compare the stability and selectivity for AOR. Our results showed that Pt has some evident tendency to poisoning while materials based on less noble metals could show longer stability.

References:

[1] A. Rioja-Cabanillas, D. Valdesueiro, P. Fernández-Ibáñez, J. Byrne, Journal of Physics: Energy 2020, 3, 012006.
[2] E. P. Bonnin, E. J. Biddinger, G. G. Botte, Journal of Power Sources 2008, 182, 284–290.
[3] N. M. Adli, H. Zhang, S. Mukherjee, G. Wu, Journal of The Electrochemical Society 2018, 165, J3130–J3147.

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ORG-MD-01

The Oxygen Paradox, a lifelong challenging dance

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The use of sustainable oxidants, i.e. O_2 or H_2O_2 easily available and safe reagents, has been the guideline in more than four decades of research.[1] In most cases the best results were achieved using vanadium catalysis but recently our interest has also turned to photo(electro)catalysis.

Efficient metal- (V and Mo) catalyzed oxybromination of alkenes inspired by the activity of haloperoxidases enzymes is one of the finest achievements of the group. A two-phase system, where a brominating intermediate is formed in water from the metal catalyst, H_2O_2 and Br^-, has been developed. The peroxometal complex then oxidizes the substrate dissolved in the organic phase. Observed yields and selectivities, together with replacement of Br_2 with Br-, provide a procedure of sustainable synthetic interest. Indeed, excellent results were obtained with aromatics, alkenes and alkynes. To render our system even more interesting from the sustainability point of view, we modified it substituting molecular chlorinated solvents with ILs. Again, excellent results in terms of reaction rates and selectivities have been obtained with alkenes and alkynes. Our procedure was equally efficient in the bromination of toluene and similar substrates; the reaction proceeds under mild conditions, and solventless functionalization can be also carried out.

Over the years, we elucidated mechanistic details of vanadium based catalytic systems performing, inter alia, NMR, electrochemical and spectroscopic experimental studies as well as theoretical calculations. These studies allowed to establish correlation between the nature of the ligands bound to vanadium centre and catalytic activity in benchmark oxidations.

More recently we synthesized a fully conjugated pentacyclic quinoid class of compounds named KuQuinones (KuQs), molecules close to naturally occurring polycyclic quinones. KuQs show interesting features both as photosensitive material on semiconductive oxides, as well as in biomedical applications, as they showed a significant antiproliferative activity against tumor cell lines.

The use of organic photocatalysts is an appealing and sustainable strategy to promote chemical processes, to this aim use of 1-hexylKuQuinone (KuQ) as metal-free photocatalyst for selective thioethers oxidation to sulfoxides was pursued.[2] The broad and intense absorption spectrum in the visible range and the low reduction potential constitute suitable features for photocatalytic and photoelectrocatalytic applications of KuQs.

References:

[1] F. Sabuzi, G. Pomarico V. Conte, P. Galloni, Catalysis Series No. 41 Vanadium Catalysis, Chap.5, M. Sutradhar, J. A. L. da Silva, A. J. L. Pombeiro (eds), Royal Society of Chemistry 2021, 97-110
[2] M. Forchetta, F. Sabuzi, L. Stella, V. Conte, P. Galloni, J. Org. Chem. 2022, 87, 14016−14025.

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ORG-MD-02

Handcrafting Function-Rich Molecules: an Amazing Opportunity to Serve Life Sciences

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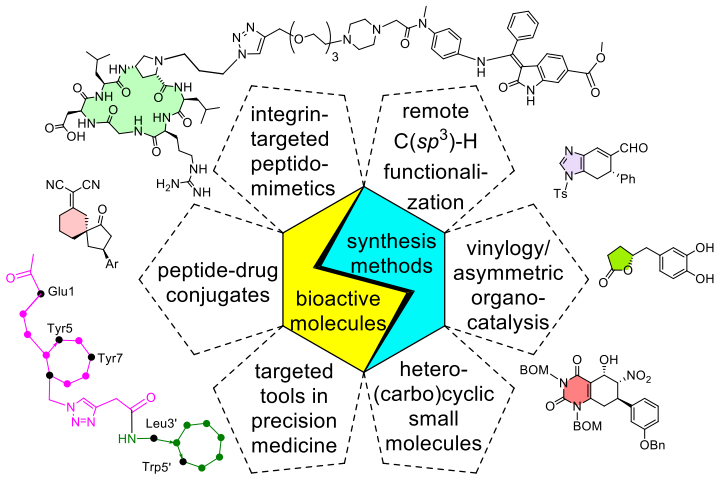
Over the past century, synthetic organic chemistry has made crucial contributions to the discovery and development of important life-saving drugs, improving the health and wellbeing of people worldwide. Most of these achievements have been possible by drawing heavily from the ever-growing arsenal of ingenious methods and technologies involving diverse sectors of fundamental chemistry, chemical bond construction, and three-dimensional control. Intertwining biomedicine-addressed synthesis ventures with methodology-centred synthetic approaches has been the leitmotiv of our research over the past years, with abounding opportunities to serve life sciences arising from the confluence of basic and applied research.

The lecture will present research results from our laboratories along this double path (see Figure). On one hand, we shall focus on handcrafting novel bioactive peptidomimetics, their incorporation into covalent (or nanosized) conjugates, and their use as proof-of-concept tools in the field of targeted antiviral, antiangiogenic, antitumor, and antifibrotic therapy.[1] On the other hand, the merger between the vinylogy concept with organo- (and photo)catalysis will be illustrated, as applied to the asymmetric synthesis of diverse collections of richly functionalized hetero(carbo)cyclic small molecules.[2]



References:

[1] K. Bugatti, A. Sartori, L. Battistini, J. Ruzzolini, C. Nediani, C. Curti, F. Bianchini, F. Zanardi, *Eur. J. Org. Chem.* **2022**, e202200765.

[2] C. Curti, G. Rassu, M. Lombardo, V. Zambrano, L. Pinna, L. Battistini, A. Sartori, G. Pelosi, F. Zanardi, *Angew. Chem. Int. Ed.* **2020**, *59*, 20055–20064.

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ORG-MD-03

New Catalytic Approaches Towards the Synthesis of Organic Compounds

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Catalysis has a fundamental role to solve arduous tasks in synthetic chemistry and is thus involved in the global economy in many industrial fields. In fact, in the last 50 years, catalysis has seen enormous progress in the development of optimized large-scale productions within the area of pharmaceutical, agrochemical and petrochemical industry. Moreover, a catalytic approach presents multiple benefits for business and sustainability compared to stoichiometric processes. These include cost reduction, time and energy saving, waste reduction, carbon-footprint minimization, among others. In this context, our research activity aims at designing and developing novel catalytic organic transformations which address unsolved problems in synthetic chemistry. The final goal is therefore the production of effective, inexpensive and safe catalytic systems that will find widespread use in modern organic synthesis. To this end, we effectively employed aromatic molecules as photocatalytic systems to drive the synthesis of relevant organic compounds. As a matter of fact, the great structural variety of these molecules combined with the easy fine-tuning of their electronic properties has unlocked new possibilities for the generation of reactive intermediates under mild operative conditions.[1-4] In addition, we worked on the development of novel nano-catalytic organic transformations. In particular, we design new carbon-based nano-organocatalytic systems, namely carbon nitrides and carbon dots.[5-10] These materials have been efficiently used to drive relevant organic reactions, including enantioselective transformations, under mild operative conditions.

References:

[1] C. Rosso, J. D. Williams, G. Filippini, M. Prato, C. O. Kappe, Org. Lett., 2019, 21, 5341-5345.
[2] C. Rosso, S. Cuadros, G. Barison, P. Costa, M. Kurbasic, M. Bonchio, M. Prato, L. Dell'Amico, G. Filippini, ACS Catalysis, 2022, 12, 4290-4295.
[3] S. Cuadros, C. Rosso, G. Barison, P. Costa, M. Kurbasic, M. Bonchio, M. Prato, G. Filippini, L. Dell'Amico, Org. Lett., 2022, 24, 2961-2966.
[4] G. Gentile, B. Bartolomei, J. Dosso, N. Demitri G. Filippini, M. Prato, Chem. Commun., 2024, 60, 602-605.
[5] C. Rosso, G. Filippini, M. Prato, ACS Catalysis, 2020, 10, 8090-8105.
[6] C. Rosso, G. Filippini, A. Criado, M. Melchionna, P. Fornasiero, M. Prato, ACS Nano, 2021, 15, 3621-3630.
[7] G. Filippini, F. Amato, C. Rosso, G. Ragazzon, A. Vega-Peñaloza, X. Companyó, L. Dell'Amico, M. Bonchio, M. Prato, Chem, 2020, 6, 3022-3037.
[8] G. Filippini, F. Longobardo, L. Forster, A. Criado, G. Di Carmine, L. Nasi, C. D'Agostino, M. Melchionna, P. Fornasiero, M. Prato, Sci. Adv., 2020, 6, eabc9923.
[9] M. Marchi, E. Raciti, S. M. Gali, F. Piccirilli, H. Vondracek, A. Actis, E. Salvadori, C. Rosso, A. Criado, C. D'Agostino, L. Forster, D. Lee, A. C. Foucher, R. K. Rai, D. Beljonne, E. A. Stach, M. Chiesa, R. Lazzaroni, G. Filippini, M. Prato, M. Melchionna, P. Fornasiero, Adv. Sci. 2023, 10, 2303781.
[10] A. Actis, M. Melchionna, G. Filippini, P. Fornasiero, M. Prato, E. Salvadori, M. Chiesa, Angew. Chem. Int. Ed., 2022, e202210640.

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ORG-PZ-01

Chemical tailoring of graphene materials for environmental applications: from lab-to-fab to market exploitation

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In this presentation, I will discuss selected case studies showcasing chemically modified graphene materials and their applications in water purification, electrochemical sensors, and carbocatalysis. I will detail our recent findings on design strategies and covalent functionalization techniques aimed at creating new materials for: i) enhanced adsorption of emerging contaminants such as PFAS and antibiotics from drinking water [1], ii) electrochemical transduction for early detection of pesticides in water [2], and iii) CO_2 capture and utilization in chemical transformations [3]. Additionally, I will describe the development of polymer-graphene membranes [4] and composites produced also through the upcycling of industrial plastic waste [5], and their application in new water filtration systems. These advancements, along with ongoing technology transfer and validation processes from laboratory scale to industrial production and commercialization, will also be covered [6].

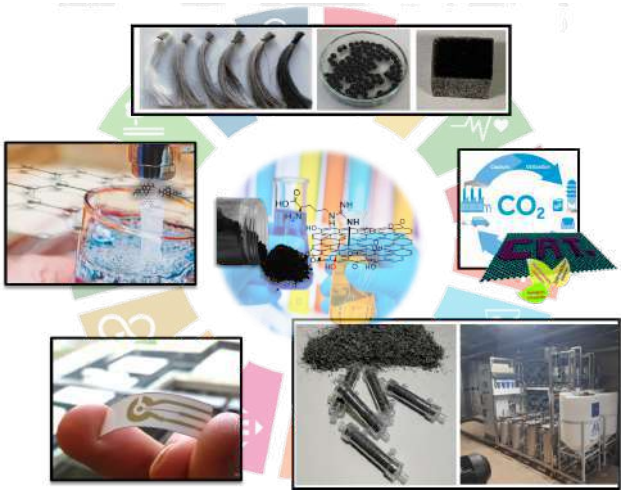

Figure 1: Chemically modified graphene oxide materials and technologies for environmental applications.

References:

[1] S. Mantovani, T. D. Marforio, S. Khaliha, *et al., RSC Env. Science and Engineering*, **2023**, 1030;
[2] G. Moro, S. Khaliha, A. Pintus, *et al., Materials Today Chemistry*, **2024**, 101936;
[3] A. Pintus, S. Mantovani, A. Kovtun, *et al., Chem. Eur. J.,* **2023**, e202202440;
[4] M. Zambianchi, S. Khaliha, A. Bianchi, *et al., J. Membr. Sci*., **2022**, 120707;
[5] S. Khaliha, F. Tunioli, L. Foti, *et al., Environmental Science: Water Research & Technology,* **2024**, DOI: 10.1039/d3ew00900a;
[6] a) Patents M. Melucci *et al.*, PCTIB2019058300; EP21207308; c) https://liferemembrance.eu

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ORG-PZ-02

One-Pot Asymmetric Organocatalysis: Multipurpose Tool to Access Carboxylic Acid Derivatives

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The development of new methodologies for the catalytic asymmetric synthesis of carboxylic acid derivatives is a central topic in organic chemistry, given their recurrent presence as key motives in bioactive compounds.[1] In this lecture, our results on the application of one-pot strategies to prepare privileged classes of heterocyclic compounds and acyclic products will be illustrated. The sequential organocatalysed reactions, involve ester surrogates as the reagents or electron-poor epoxides as the intermediates, providing the products in an efficient way (Figure 1).[2]

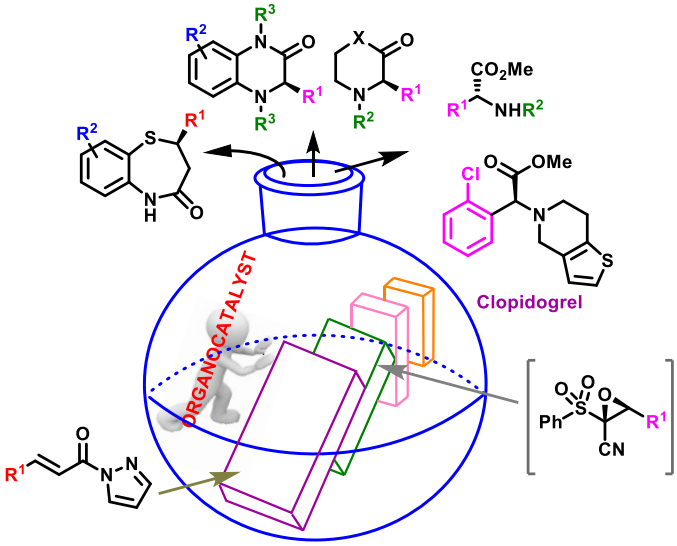

Figure 1: One-pot asymmetric routes to carboxylic acid derivatives.

As a demonstration of the synthetic utility of the protocols, antidepressant drug Thiazesim, a key intermediate to potent antiemetic drug Aprepitant and antiplatelet drug Clopidogrel, have been prepared.

References:

[1] G. De Simoni, G. Faita, P. Quadrelli, Chem. Rev. 2015, 115, 9922 – 9980.
[2] a) S. Meninno, C. Volpe, A. Lattanzi, Chem. Eur. J. 2017, 23, 4547 – 4550; b) C. Volpe, S. Meninno, C. Crescenzi, M. Mancinelli, A. Mazzanti, A. Lattanzi, Angew. Chem. Int. Ed. 2021, 60, 23819 – 23826; c) S. Meninno, A. Lattanzi, J. Org. Chem. 2023, 88, 7888 – 7892; d) V. Battaglia, S. Meninno, A. Lattanzi, Eur. J. Org. Chem. 2023, 26, e202300744.

ORG-PZ-03

Unveiling the potential of synthetic nucleic acid analogs as versatile tools for enhancing human health

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In recent years, besides being the building blocks of life, nucleic acids revealed their enormous potential in diagnostics[1,2] and therapy.[3,4] Not only do they often represent the target for personalized medicine intervention, but they also hold immense potential as targeted drugs.[5] This power lies within their unique properties resulting from nucleobase sequence and structural polymorphism. Researchers have unlocked new possibilities by synthesizing short nucleic acid fragments, called oligonucleotides, incorporating chemical modifications on the sugar, the nucleobase, or both to confer them with specific properties useful for applications in medicine, diagnostics, and even for the creation of new biomaterials.[6,7] In this contribution, I will review the foundation and our recent findings on the design, synthesis, and structural characterization of modified nucleosides, nucleotides, and oligonucleotides. This knowledge paves the way for developing powerful and innovative new tools for fighting diseases, diagnosing health conditions, and potentially even building new materials for biological applications.

References:

[1] R. Moretta, M. Terracciano, N. Borbone, G. Oliviero, C. Schiattarella, G. Piccialli, A.P. Falanga, M. Marzano, P. Dardano, L. De Stefano, I. Rea, Nanomaterials 2020, 10, 2233.
[2] T. Crisci, A.P. Falanga, M. Casalino, N. Borbone, M. Terracciano, G. Chianese, M. Gioffrè, S. D'Errico, M. Marzano, I. Rea, L. De Stefano, G. Oliviero, Nanomaterials 2021, 11, 523.
[3] N. Borbone, G. Piccialli, G.N. Roviello, G. Oliviero, Molecules 2021, 26, 986.
[4] N. Borbone, I. Piccialli, A.P. Falanga, V. Piccialli, G.N. Roviello, G. Oliviero, Int. J. Mol. Sci. 2022, 23, 4359.
[5] E. Cesaro, A.P. Falanga, R. Catapano, F. Greco, S. Romano, N. Borbone, A. Pastore, M. Marzano, F. Chiurazzi, S. D'errico, G. Piccialli, G. Oliviero, P. Costanzo, M. Grosso, PLoS ONE 2022, 17, e0266090.
[6] N. Borbone, J. Amato, G. Oliviero, V. D'Atri, V. Gabelica, E. De Pauw, G. Piccialli, L. Mayol, Nucleic Acids Res. 2011, 39, 7848 – 7857.
[7] M. Marzano, S. D'Errico, F. Greco, A.P. Falanga, M. Terracciano, D. Di Prisco, G. Piccialli, N. Borbone, G. Oliviero, Int. J. Biol. Macromol. 2023, 253, 127062.

ORG-PZ-04

Expect the Unexpected: How Understanding Reaction Mechanisms Can Lead to More Efficient Production Processes in the Fine Chemical Industry.

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My presentation will discuss how detailed investigations on reaction mechanisms, kinetic and thermodynamic could positively impact on new larger scale production processes.

Examples will be from my multiyear experience in the small molecules field in the pharmaceutical as well as in the fine chemical industry.

In particular, the presented case studies will span from pure speculative investigations to evolve in the full understanding of the reaction kinetics and thermodynamics and finally transferred into production plant. Environmental and circular economy considerations will also be part of the discussion.

In addition, the multidisciplinary approach to problem solving and the cross-sectors interactions will be also included in the presented work.

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ORG-PZ-05

Artificial Water Channels in Quantasome Photosynthetic Systems

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In the design of bioinspired artificial photosystems, the implementation of water channels, to reproduce the protein environment around the PSII, plays an essential role for efficient catalysis.[1] This study presents a synthetic strategy for the introduction of this feature in the artificial quantasomes (**QS**), a water-splitting photosystem made of bis-cationic perylenebisimides (**PBI**) and deca-anionic tetraruthenate polyoxometalates (**Ru_4POM**).[2,3,4] A click-chemistry approach was employed to install hydrophilic bis-azido polyethylene glycol bridges (**PEG_n**) between the PBI units, obtaining **QS_{PEG}-n** with cross-linked units and hydrophilic water channels. **QS_{PEG}-n** are characterized by a more porous structure featuring distinct water channels, as evidenced by SAXS analysis and LF-NMR experiments. Among the series, **QS_{PEG}-6**, emerges as the best performing photosystem, bearing PEG chains that provide an optimal combination of porosity, water interaction, and photocatalytic properties, with a 4-fold increase in photocurrent output compared to the unmodified quantasome (**QS-0**). These results highlight the essential role of water channels in the construction of PSII biomimetic systems and propose the **QS_{PEG}-6** as a promising candidate in bioinspired photocatalysis.

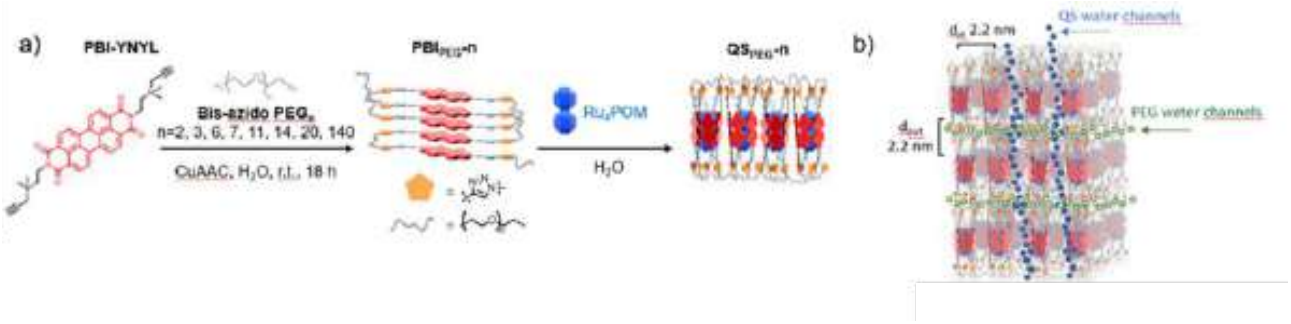

Figure 1. a) Synthesis of **PBI_{PEG}-n** and self-assembly of **QS_{PEG-n}** in water. b) Water channels in the quantasome structure.

References:
[1] F. Rigodanza et al. Nat. Chem., 2019, 11, 146–153 [2] F. Rigodanza et al. JACS. 2022, 144, 31, 14021–14025 [3] Hussein R. et al. Nat. Commun. 2021, 12, 6531 [4] F. Rigodanza et al. Chem.Eur.J. 2024, e202303784

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ORG-PZ-06

Rapid and scalable photocatalytic C(sp^2)–C(sp^3) Suzuki−Miyaura cross-coupling of aryl bromides with alkyl boranes

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Transition metal-catalyzed cross-coupling reactions have demonstrated remarkable fidelity, but their success has introduced a bias for "flat" molecules design.[1]

In recent years, there has been notable progress in the application of light-mediated methods to introduce sp^3-hybridized carbons into biologically relevant scaffolds, enhancing compatibility with 3D-shaped protein targets. In essence, photoredox catalysis is working as a guiding light to escape from flatland.

Herein, we present a powerful approach for the photocatalyzed B-alkyl Suzuki−Miyaura cross-coupling between alkyl boranes and aryl bromides (Figure 1).[2] Alkyl boranes are prepared from feedstock alkenes via regioselective hydroboration, allowing for the transfer of a wide array of primary alkyl fragments onto the arene ring thanks to a photocatalyst/nickel dual catalytic system.

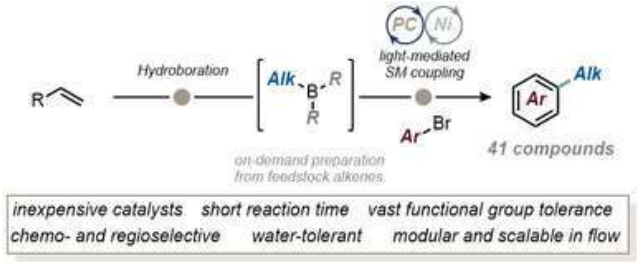

Figure 1: Rapid and scalable photocatalytic C(sp^2)–C(sp^3) Suzuki−Miyaura cross-coupling of aryl bromides with alkyl boranes.

Our approach marks the inaugural instance wherein alkyl boranes are used as substrates in photoredox catalysis. It eliminates the need for expensive catalytic systems and sensitive organometallic compounds, operating efficiently at room temperature within just 30 minutes. Moreover, we demonstrate the advantageous translation of the present protocol to continuous-flow conditions, enhancing scalability, safety, and overall efficiency of the method. This versatile approach offers significant potential for accelerating drug discovery efforts by enabling the introduction of complex aliphatic fragments in a straightforward and reliable manner.

References:

[1] F. Lovering, J. Bikker, C. Humblet, J. Med. Chem. 2009, 52, 6752 – 6756.
[2] T. Wan, L. Capaldo, J. Djossou, A. Staffa, F. de Zwart, B. de Bruin, T. Noël, ChemRxiv 2023, DOI: 10.26434/chemrxiv-2023-4g3xz.

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Exploring the Boundless Utility of Chelation Agents: From Therapeutics to Catalysis

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Hydroxypyranones and hydroxypyridinones are important oxygen- or nitrogen-containing heterocyclic nuclei for creating metal chelation agents.[1] Their rapid and efficient binding of hard metals in aqueous media has enabled a plethora of applications in biological, pharmacological, and chemical contexts. Some of these derivatives have recently drawn much attention, such as the hexadentate tris(3-hydroxypyridin-4-one) (THP) based ligand. Because of its strong affinities for oxophilic trivalent metal ions, THP complexes the Fe^{3+} cations at very low concentrations, opening up new uses as bifunctional chelators for the radiometal gallium-68 (^{68}Ga). At room temperature, neutral pH, and micromolar ligand concentrations, THP-bioconjugates bind ^{68}Ga quickly and quantitatively, making them suitable for kit-based radiosynthesis of ^{68}Ga positron emission tomography (PET) radiopharmaceuticals.[2–4] Following their functionalization with other molecules or materials, like cyclodextrins and halloysite, they have also been explored recently for use in catalysis and antibacterial medication development.[5] Different of the newly reported applications will be examined in this communication.

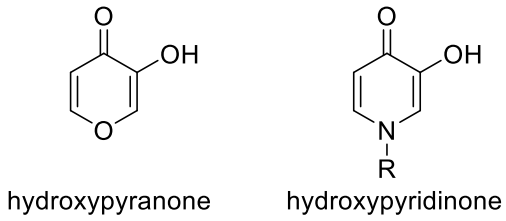

Figure 1: Chemical structures of hydroxypyranone and hydroxypyridinone.

References:

[1] A. Cilibrizzi, V. Abbate, Y. Chen, Y. Ma, T. Zhou R.C. Hider. Chemical Reviews 2018, 118, 7657 – 7701.
[2] G. Floresta, G.P. Keeling, S. Memdouh, L.K. Meszaros, R.T.M. de Rosales, V. Abbate. Biomedicines 2021, 9, 4, 367.
[3] G. Floresta, S. Memdouh, T. Pham, M.T. Ma, P.J. Blower, R.C. Hider, V. Abbate. A. Cilibrizzi, Dalton Transaction 2022, 51, 12796 – 12803.
[4] M. Failla, G. Floresta, V. Abbate. RSC Medicinal Chemistry 2023, 14, 592 – 623.
[5] C. Zagni, V. Patamia, S. Dattilo, V. Fuochi, S. Furnari, P.M. Furneri, S.C. Carroccio, G. Floresta, A. Rescifina, Materials Advances 2024, 5, 3675 – 3682.

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ORG-PZ-08

Azides Manipulation: Danger is not our Middle Name

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Azides play a pivotal role in organic synthesis, as they allow to introduce a variety of key functional groups in synthetic scaffolds of interest. These include amines, triazoles, tetrazoles, isocyanates, etc.[1,2] Regardless of azides role in the synthesis -whether only azide-based reagents are used or the azide moiety is also present in the resulting product- this type of chemistry generally involves significant safety risks.[3] Main concerns are linked to azides general toxicity and explosivity. In addition to this, each azide bears the potential to form hydrazoic acid (HN_3) upon decomposition, which is even more dangerous than its precursors.[4]

Despite these caveats, azides are often manipulated, especially at small and medium scale, with insufficient precautions and knowledge about the involved risks.[5,6] At Dipharma, we have extensive experience in the safety evaluation for scale-up of chemical processes involving azides, with multi-ton productions per year of various intermediates and APIs exploiting this type of chemistry. In this presentation, we will provide a general overview about the dos and don'ts in azides manipulation based on this expertise. These will cover the main incompatibilities, some rule-of-thumbs to evaluate the dangers that may be encountered and some strategies to tame the highlighted dangers. These will be supported by tailored examples from our product portfolio, giving a taste of the chemical space that can be accessed at scale when making good use of azides chemistry.

References:
[1] S. Bräse; C. Gil; K. Knepper; V.N. Zimmermann, Angew. Chem Int. Ed. 2005, 44, 5188 – 5240.
[2] E. F. V. Scriven; K. Turnbull, Chem. Rev. 1988, 88 (2), 297 – 368
[3] J.-P. Hagenbuch, Chimia, 2003, 57 (12), 773 – 776
[4] J. Wiss, C. Fleury, C. Heuberger, U. Onken, M. Glor, OPRD 2007, 11 (6), 1096-1103
[5] N. P. Peet, P. Weintraub, «Azide explosions discussed further,» *C&EN,* 14 March 1994
[6] V. J. Hruby, L. Boteju, G. Li, «Explosion with sodium azide,» *C&EN,* p. 2, 11 October 1993.

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Carbon Nanodots: a bright trip from individual particles to superstructures

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Carbon Nanodots (CNDs) are defined as carbon nanoparticles with size below 10 nm which possess intriguing properties like tunable light-emission and rich-surface chemistry. In recent years, our group has focused on the bottom-up synthesis of CNDs, particularly, starting from *ad hoc* molecular precursors we demonstrated the possibility to tailor the photoluminescent, chiral, and redox properties of these materials, unlocking their use in different fields.[1] In particular, one of the latest research efforts was devoted to the optimization of chiral and catalytically active CNDs able to promote several kinds of organic reactions, promoting the role of these materials as a new generation of catalysts.[2] We have also contributed to the development of reliable synthetic and purification strategies for the preparation of these nanoparticles, exploiting combined characterization techniques to study their purity and composition.[3] Having in hand a reproducible and versatile synthetic method for CNDs allowed to recently use these materials as starting units to develop new kinds of superstructures.[4] Specifically, a covalent interconnection of CNDs was proposed by the use of click chemistry. To this aim, the superficial groups of the particles were exploited as anchoring points to install 'clickable' moieties. Then, a click reaction between the prepared building blocks was tested affording the formation of covalent superstructures. As a step further, the use of rigid aromatic linkers for the CND connection has been explored, moving towards the production of novel porous 3D networks.

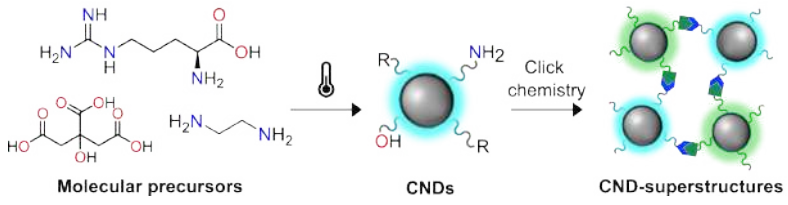

Figure 1: Synthesis of CNDs and following assembly.

References:

[1] F. Arcudi, L. Đorđević, M. Prato, *Acc. Chem. Res.* **2019**, *52*, 2070–2079.
[2] B. Bartolomei, V. Corti, M. Prato, *Angew. Chemie - Int. Ed.* **2023**, *62*, e202305460.
[3] B. Bartolomei, A. Bogo, F. Amato, G. Ragazzon, M. Prato, *Angew. Chemie - Int. Ed.* **2022**, *61*, e202200038.
[4] B. Bartolomei, M. Sbacchi, C. Rosso, A. Günay-Gürer, L. Zdražil, A. Cadranel, S. Kralj, D. M. Guldi, M. Prato, *Angew. Chemie - Int. Ed.* **2024**, *63*, e202316915.

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ORG-PZ-10

Ring-opening reactions of unstrained cyclic aminals with Grignard reagents

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Cyclic aminals such as imidazolidines and hexahydropyrimidines are common scaffolds in natural products, medicinal chemistry, and agrochemicals[1a-c]. A special case of cyclic aminals of particular importance is given by 1,3,5-triaryl-1,3,5-triazinanes which behave as a stable formaldehyde-derived imine offering a large variety of reactions for the preparation of nitrogen containing compounds.[2] Considering the limited literature regarding the use of organometallic reagents in combination with cyclic aminals[3a,b] and the long-lasting interest of our laboratory in ring-opening reactions of heterocyclic compounds with organometallic reagents,[4a,b] we developed a nucleophilic ring opening of unstrained cyclic aminals by the use of Grignard and cuprates reagents to give diversely substituted 1,2- or 1,3-diamines which are important building blocks in organic synthesis due to their presence in natural products, medicines, and ligands in transition-metal catalysis and organocatalysis.[5,6]

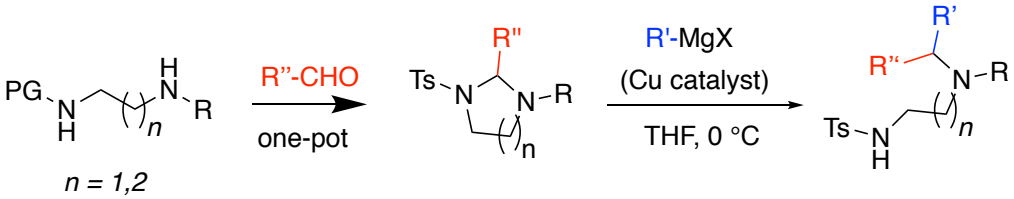

Figure 1. Ring-opening reaction of protected cyclic aminals with Grignard reagents.

Computational DFT data point to the formation of a transient iminium ion intermediate that is energetically accessible only with PG = Ts in which the Lewis acidity of the cationic component of the organometallic reagent triggers the ring-opening process by coordination.

References:

[1] a. Jiao, R. H.; Xu, S.; Liu, J. Y.; Ge, H. M.; Ding, H.; Xu, C.; Zhu, H. L.; Tan, R. X. *Org. Lett.* 2006, **8**, 5709− 5712. b. Jiang, X. X.; Wang, Y. Q.; Zhang, G.; Fu, D.; Zhang, F. T.; Kai, M.; Wang, R. *Adv. Synth. Catal.* 2011, **353**, 1787−1796. c. Kang, T.; Gao, S.; Zhao, L.-X.; Zhai, Y.; Ye, F.; Fu, Y. *J. Agric. Food Chem.* 2021, **69**, 45-54.
[2] Che, J.; Niu, L.; Jia, S.; Xing, D.; Hu, W. *Nature Comm.* 2020, **11**, 1511.
[3] a. Ashweek, N. J.; Coldham, I.; Haxell, T. F. N.; Howard, S. *Org. Biomol. Chem.* 2003, **1**, 1532-1544. b. Katritzky, A. R.; Singh, S. K.; He, H.-Y. *J. Org. Chem.* 2002, **67**, 3115-3117.
[4] Review: Pineschi, M. Eur. *J. Org. Chem.* 2020, 2643-2649.
[5] X. Ji and H. Huang, *Org. Biomol. Chem.*, 2016, **14**, 10557-10566.
[6] C. Jentgens, R. Hofmann, A. Guggisberg, S. Bienz and M. Hesse, *Helv. Chim. Acta*, 1997, **80**, 966-978.

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Chalcogens: a Powerful Tool for Helicenes Construction, Organocatalysis and Materials

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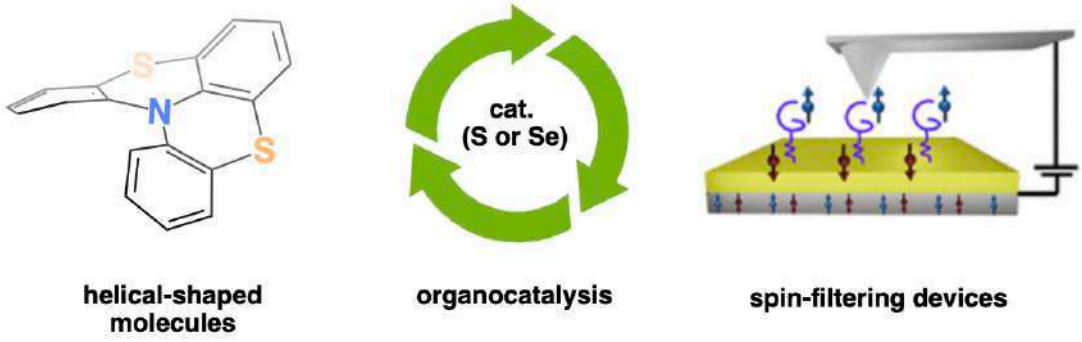
Over the years, chalcogen chemistry proved a powerful tool in tackling challenges in many fields, ranging from medicinal chemistry to catalysis and materials. Herein we present a peculiar example of thia [4]helicenes in which sulfur has a crucial role in their exceptional configurational stability,[1] allowing an efficient optical resolution approach,[2] and in the modulation of their red-ox potential.[3,4] The exploitation of chalcogen-mediated organocatalytic routes led both to the isolation of thiahelicenes in enantioenriched form,[5] and to the enantioselective construction of other pharmaceutically relevant heterocycles.[6] Furthermore, we report the application of these thiahelicenes in the development of novel spintronic devices,[7,8] in which sulfur seems to play a key role in the spin-filtering process, highlighting the utility of chalcogen chemistry in material science.



References:

[1] G. Lamanna, C. Faggi, F. Gasparrini, A. Ciogli, C. Villani, P. J. Stephens, F. J. Devlin, S. Menichetti, *Chem. Eur. J.* **2008**, *14*, 5747 – 5750.

[2] M. Lupi, M. Onori, S. Menichetti, S. Abbate, G. Longhi, C. Viglianisi, *Molecules* **2022**, *27*, 1160.

[3] R. Amorati, L. Valgimigli, A. Baschieri, Y. Guo, F. Mollica, S. Menichetti, M. Lupi, C. Viglianisi, *ChemPhysChem* **2021**, *22*, 1446 – 1454.

[4] M. Lupi, S. Menichetti, P. Stagnaro, R. Utzeri, C. Viglianisi, *Synthesis* **2021**, *53*, 2602 – 2611.

[5] M. Lupi, O. Salmi, C. Viglianisi, S. Menichetti, *Adv Synth Catal* **2023**, *365*, 1705 – 1712.

[6] C. C. Cunningham, J. L. Panger, M. Lupi, S. E. Denmark, *In preparation*.

[7] N. Giaconi, A. L. Sorrentino, L. Poggini, M. Lupi, V. Polewczyk, G. Vinai, P. Torelli, A. Magnani, R. Sessoli, S. Menichetti, L. Sorace, C. Viglianisi, M. Mannini, *Angew. Chem. Int. Ed.* **2021**, *60*, 15276 – 15280.

[8] N. Giaconi, L. Poggini, M. Lupi, M. Briganti, A. Kumar, T. K. Das, A. L. Sorrentino, C. Viglianisi, S. Menichetti, R. Naaman, R. Sessoli, M. Mannini, *ACS Nano* **2023**, *17*, 15189 – 15198.

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Azolium-based organocatalysts immobilized on bamboo as recyclable and sustainable mediators for C-O bond formation reactions

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The present work proposes novel heterogeneous catalysts based on triazolium and imidazolium derivatives for C-O bond formation reactions. Homogeneous organocatalysts were anchored onto pre-treated bamboo as natural porous materials by varying the linkers (Figure 1).

The growing demand of green approaches in chemical synthesis led the research to explore new possibilities in terms of inert matrixes for heterogenization of molecular catalysts. The use of natural porous materials enhances the sustainability of the process in this regard.[1]

In detail, the immobilization of 1-Methylimidazole and 1-methyl-1,2,4-triazole onto bamboo has been investigated by exploiting the reactivity of silanes and isocyanates for anchoring the organocatalysts with linkers of different length and polarity.

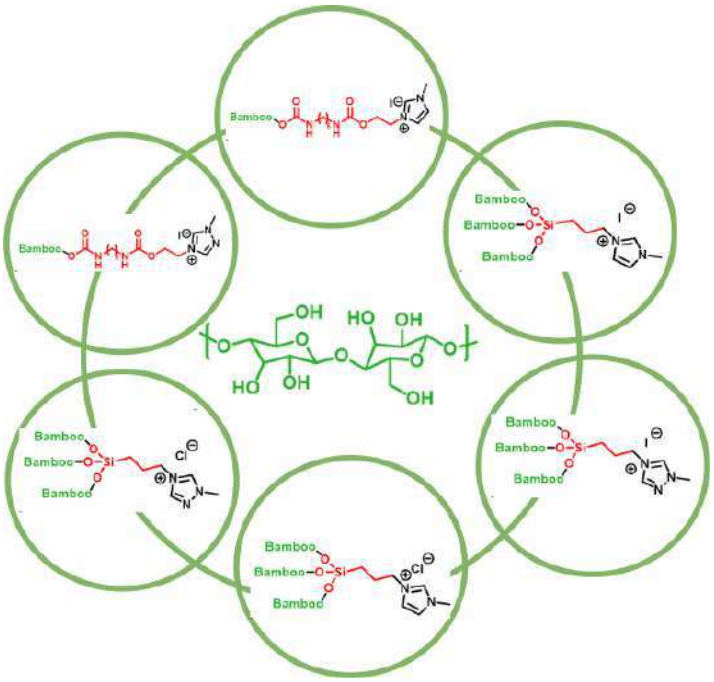

Figure 1: Heterogeneous organocatalysts immobilized onto bamboo with different linkers.

A preliminary study on cyclic carbonates synthesis from epoxides and CO_2 has been performed with the novel bamboo-based organocatalysts, while further studies in batch and flow conditions are currently underway.

References:

[1] B. G. Palma, et al, Catalysis Today 381 (2021), 280-287

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ORG-OR-002

Enzymatic Synthesis of New Acetoacetate–Ursodeoxycholic Acid Hybrids as Potential Therapeutic Agents and Useful Synthetic Scaffolds as Well

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Molecular hybridization has been recognized as an emerging strategy to pursue, for multi-target drugs therapy, especially when traditional combination treatments fails.[1] Ursodeoxycholic acid (UDCA) and acetoacetate are natural compounds present in the human intestine and blood, respectively. Nowadays, it is widely known that both compounds possess the ability to influence a variety of cellular processes involved in the etiology of various diseases, playing a relevant role either as bioactive moieties or drug delivery scaffolds.[2] Herein, we describe a synthetic strategy to selectively derivatize the hydroxyl groups of the bile acid with acetoacetyl moieties. These new compounds were obtained via a simple chemo-enzymatic approach, which exploits the selectivity of the lipase B from Candida antarctica. 3α-acetoacetoxy UDCA was obtained (60% isolated yield) via the regioselective transesterification of methyl acetoacetate with UDCA. 3α,7β- bis-acetoacetoxy UDCA was obtained instead by thermal condensation of methyl acetoacetate and UDCA (80% isolated yield). This bis-adduct was finally converted to the 7β-acetoacetoxy UDCA (82% isolated yield) via CAL-B catalyzed regioselective alcoholysis of the ester group on the 3α position. In order to demonstrate the value of the above new hybrids as UDCA-based scaffolds, 3α-acetoacetoxy UDCA was converted into the corresponding 4-phenyl-3,4-dihydropyrimidin-2-(1H)-one derivative in 65% isolated yield exploiting the multicomponent Biginelli reaction.

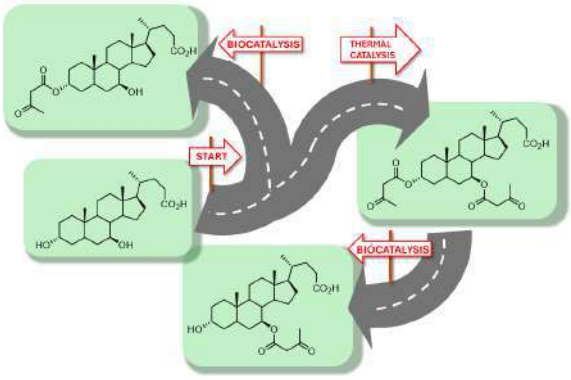

Figure 1: Schematic representation of the UDCA's esters

References:

[1] Alkhzem, A.H.; Woodman, T.J.; Blagbrough, I.S. Design and Synthesis of Hybrid Compounds as Novel Drugs and Medicines. *RSC Adv.* 2022, *12*, 19470–19484.
[2] Faustino, C.; Serafim, C.; Rijo, P.; Reis, C.P. Bile Acids and Bile Acid Derivatives: Use in Drug Delivery Systems and as Therapeutic Agents. *Expert Opin. Drug Deliv.* 2016, *13*, 1133–1148.

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Divergent Total Synthesis of Tricyclic Clavine Alkaloids via Metal-Free Reductive Coupling

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The actual trend toward "increasing sustainability" calls for a modular, convergent, and versatile platform to form C−C bonds that do not require a metal catalyst. In 2009, Barluenga and Valdés reported the first metal-free C(sp^3)–C bond-forming coupling between tosylhydrazones (highly versatile and safe precursors for *in situ* carbene and diazo compounds formation in the presence of only a base) and aryl boronic acids.[1] Since then, this transformation has shown considerable usefulness in medicinal chemistry and diversity-oriented synthesis,[2] whereas its applications for the total synthesis of natural products, their analogues, and beyond, is undeveloped.[3] In this context, we present here the metal-free reductive coupling of aryl, alkenyl, and alkyl boronic acid with *N*-arylsulfonylhydrazone derivative of *N*-Boc protected 4-amino Uhle's ketone[4] for the asymmetric synthesis of natural, e.g. (-)-6,7-secoagroclavine,[5] and non-natural analogue of tricyclic clavines alkaloids (Figure 1).

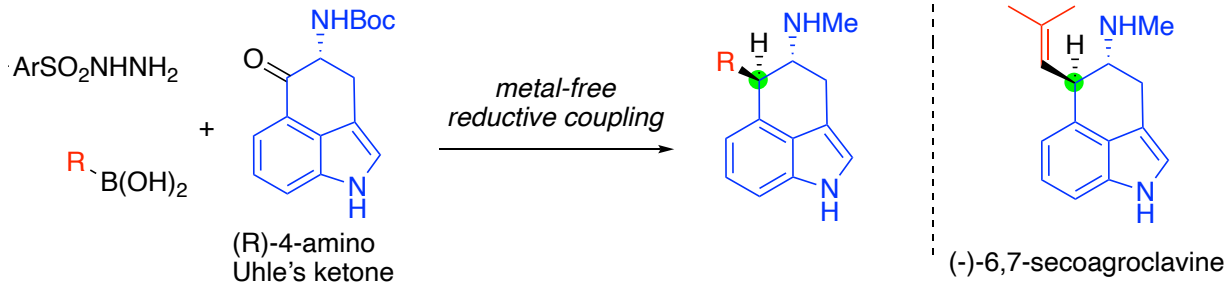

Figure 1: metal-free reductive coupling approach to the divergent syntheses of tricyclic clavine alkaloids.

This work was supported by the Italian Ministry for University and Research (MUR, PRIN 2020, 2020AEX4TA project).

References:

[1] J. Barluenga, M. Tomás-Gamasa, F. Aznar, C. Valdés, *Nat. Chem.* **2009**, *1*, 494–499.
[2] a) M. Paraja, M. Plaza, C. Valdés, *Synlett* **2017**, *28*, 2373-2389; b) D. Arunprasath, B. Devi Bala, G. Sekar, *Adv. Synth. Catal.* **2019**, *361*, 1172–1207; c) R. Singhal, S. P. Choudhary, B. Malik, M. Pilania, *ChemistrySelect*, **2022**, *7*, e20220013, d) Z. Bao, J. Wang, *Synlett* **2023**, *34*, 2071-2084.
[3] R. A. Shenvi, *ACS Cent. Sci.* **2024**, Article ASAP, DOI: 10.1021/acscentsci.3c01518.
[4] F. Bartoccini, A. Regni, M. Retini, G. Piersanti, *Org. Biomol. Chem.* **2021**, *19*, 2932–2940.
[5] F. Diotallevi, F. Bartoccini, G. Piersanti, *Eur. J. Org. Chem. 2024*, e202400035.

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Low Environmental Impact Synthesis of γ-Lactones through Photoinduced Baeyer-Villiger Oxidation of Cyclic Ketones

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Five-membered cyclic esters, better known as γ-lactones, are recurring motifs contained in a wide range of biomolecules.[1] Despite the abundance of synthetic approaches concerning their preparation, the oxidation of cyclic ketones through the Baeyer-Villiger (BV) reaction still represents an efficient and widely applied process.[2]

In this project, a new chemo- and regioselective protocol for the atom-efficient photo-oxidation of functionalized cyclobutanones[3] has been developed, to access γ-lactones in good to excellent yields, using anthraquinone and molecular oxygen at atmospheric pressure, as a source of reactive oxygen species, under visible light conditions, in the presence of TFA. The scope of the reaction was studied using both 2- and 3-substituted cyclobutanones, as well as enantiopure ketones obtain full preservation of its stereochemical identity after the oxidation. The process furnishes in most cases the desired compounds with high purity after simple filtration of the catalyst, reducing the production of solvents waste.

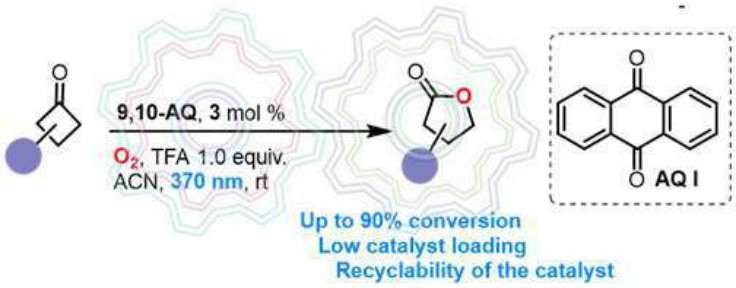

Figure 1. Photoinduced oxidation of cyclobutanones to γ-lactones.

References:
[1] S. Schulz, S. Hötling, Nat. Prod. Rep. 2015, 32, 1042-1066.
[2] G.-J. Ten Brink, I. W. C. E. Arends, R. A. Sheldon, Chem. Rev. 2004, 104, 4105-4124
[3] A. Frongia, C. Girard, J. Ollivier, P. P. Piras, F. Secci, Synlett 2008, 18, 2823-2825.

ORG-OR-005

Multi-enzymatic nanoreactors for the synthesis of privileged scaffolds

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Inspired by nature, considerable efforts have been made in developing enzymatic cascade nanoreactors. We recently demonstrated the efficacy of lignin nanoplatforms in enhancing the performance and stability of multi-enzymatic cascade reactions. [1-2]The immobilization of enzymes was obtained by using concanavalin A (Con A) as a spacer to bind the carbohydrate region of glyco-enzymes, thus favouring the correct orientation of the active sites. First example of application of Con A mediated lipase/tyrosinase cascade reaction systems included the one-pot synthesis of lipophilic esters of hydroxytyrosol from agro-industrial wastes. [3] We describe here the application of the lipase/tyrosinase cascade reaction system for the synthesis of biologically active benzoxazines. The reaction pathway included the generation in-situ of electrophilic quinones from appropriate phenol esters, followed by internal nucleophilic 1,6-Michael addition and subsequent domino intramolecular lactonization and aromatization processes (Figure 1, Panel A). [4] Likewise, the preparation of bioactive flavanones was obtained from aromatic carbonyl derivatives by promiscuous aldolase activity of a tandem lipases by unprecedented intramolecular oxa-Michael addition (Figure 1, Panel B). The cascade reactions showed excellent atom economy and chemo-selectivity, and they were energetically favoured by substrate channelling effects.

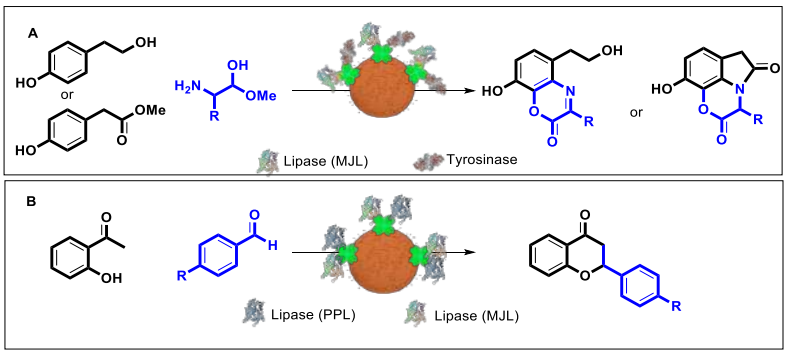

Figure 1: One-pot synthesis of benzoxazines (A) and flavanones (B).

References:

[1] E. Capecchi, D. Piccinino, R. Saladino. RSC Advances 2020, 10, 29031-29042.
[2] D. Piccinino, V. Ubertini, E. Capecchi, R. Saladino. ChemCatChem 2023, e202300533.
[3] E. Tomaino, E. Capecchi, R. Saladino. ChemCatChem 2024, 14, e202200380.
[4] E. Tomaino, E. Capecchi, R. Saladino. Journal of Organic Chemistry 2024, 89, 2343–2350.

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Stereoselective Approach to Heavily Hydroxylated Azepane and Azocane Iminosugars via Osmium-Catalyzed Tethered Aminohydroxylation

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Iminosugars, namely carbohydrates with a nitrogen atom replacing the endocyclic oxygen of sugars, are among the most challenging glycomimetics known to date. Compared to five- and six-membered iminosugars (e.g. polyhydroxylated pyrrolidines and piperidines), seven- and eight-membered ones (e.g. polyhydroxylated azepanes and azocanes) received little attention. Therefore, the development of efficient and selective strategies for their synthesis is of great interest. We present a straightforward approach to azepane iminosugars **1**[1] and our efforts in the synthesis of azocane iminosugars **2**. Of the five stereocenters in the final compounds, three of them derive from D-mannose, the carbohydrate used as starting material of our chiral pool approach. The key step of our methodology relies on a osmium-catalyzed "tethered aminohydroxylation" (TA) reaction, introduced by Donohoe in 2001,[2] which was previously exploited by some of us for the stereoselective synthesis of 2-and 3-aminosugars from glycals.[3] This reaction was combined with a former addition of vinyl or allyl metal to a D-mannose derived aldehyde which led to the key intermediates **4**, and allowed the stereoselective introduction of the two new C-N and C-O bonds. We report herein the results or our investigation.

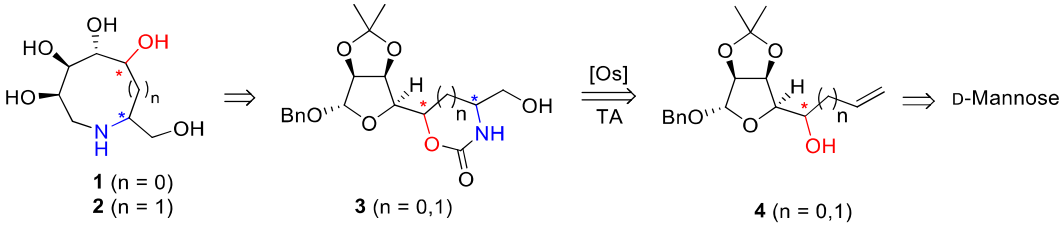

Figure 1: Our retrosynthetic approach for the preparation of azepane and azocane iminosugars.

This work was funded by Regione Toscana (Bando Salute 2018—project: Lysolate). We also thank #NEXTGENERATIONEU (NGEU) funded by the Ministry of University and Research (MUR) (Bando Prin 2022, Project code 2022N9E847—project: MULTIFUN. CUP: B53D23015580006).

References:

[1] M. Martínez-Bailén, C. Matassini, F: Clemente, C. Faggi, A. Goti, F. Cardona, Org. Lett. 2023, 25, 5833 – 5837.
[2] T. J. Donohoe, P. D. Johnson, M. Helliwell, M. Keenan, Chem. Commun. 2001, 2078 – 2079.
[3] S. Mirabella, F. Cardona, A. Goti, Org. Lett. 2015, 17, 728 – 731.

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New Hydrogen Bonding Motifs for Anion Binding Catalysis

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Supramolecular Catalysis refers to the use of supramolecular interactions to accelerate chemical reactions.[1] This field, inspired by nature, has received increasing attention over the years. Within this realm, Anion Binding Catalysis is being explored more and more.[2] This type of catalysis can be accomplished using H-bonding [3], as well as halogen bonding [4] and chalcogen bonding.[5] In each case, the binding of an anion is pivotal to promoting a chemical reaction. In our work, we study the catalytic properties of receptors based on a 1,8-diaminocarbazole scaffold, which is well known for its anion-binding properties,[6] by designing our receptors featuring multiple hydrogen bonding recognition sites. A family of structurally related diaminocarbazole receptors has been prepared using a convergent and high-yielding synthesis, and their anion-binding properties have been evaluated via NMR titrations.

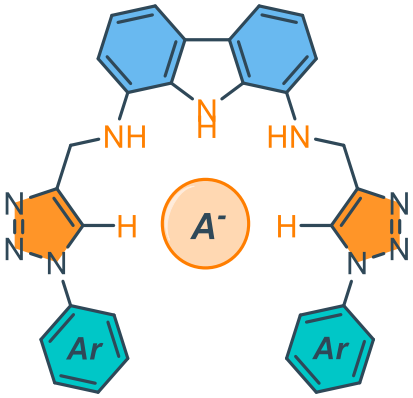

Figure 1: The core structure of the family of receptors based on a 1,8-diaminocarbazole scaffold.

References:

[1] Breslow, R.; Dong, S. D. *Chem. Rev*. **1998**, *98*, 1997-2012;
[2] Ovian, J. M., Vojáčková, P., Jacobsen, E. N., *Nature*, **2023**, *616*, 84-89;
[3] Raheem, I. T., Thiara, P. S., Peterson, E. A., Jacobsen, E. N., *J. Am. Chem. Soc*., **2007**, *129*, 13404–13405;
[4] Keuper, A. C., Fengler, K., Oster, F., Danelzik, T., Piekarski, D. G., García Mancheño, O., *Angew. Chem. Int. Ed*., **2023**, *62*, e202304781;
[5] Pang, Y., Zhao, Z., Wang, Y., *Chem. Commun*., **2023**, *59*, 12278-12281
[6] M. J. Chmielewski, M. Charon, J. Jurczak, *Org. Lett*., **2004**, *6*, 3501–3504;

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ORG-OR-008

Reductive Dehalogenation Through a New Photo-Generated Super-Reducing Excited State Di-Anion

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The reductive activation of aryl chlorides and fluorides is a recurring challenge in synthetic organic chemistry, and over the years various methods based on TM and photoredox catalysis were developed to tackle the issue. Recently was found that some coloured organic anions can be excited by visible light irradiation, making them super-reductants (E_{red} < -3.0 V vs SCE).

Herein we present a new excited state di-anion obtained by the simple and commercially available diphenylacetic acid, which shows extremely efficient reduction of highly unactivated substrates, with high selectivity and FG-tolerance, without need of additives or H-sources.

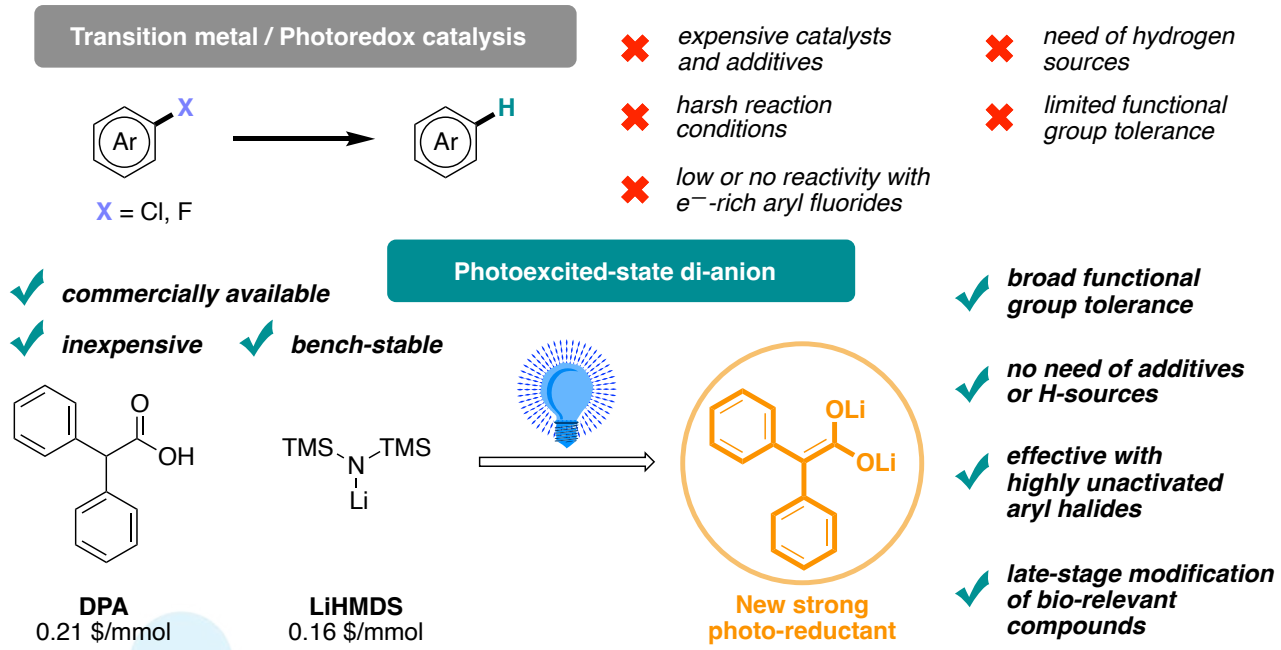

Figure 1: caption.

References:

[1] S. Wu, F. Schiel, P. Melchiorre, *Angew. Chem. Int. Ed.* 2023, *62*, e202306364 doi.org/10.1002/anie.202306364

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ORG-OR-009

Nanosized drug delivery systems of anticancer active ingredients: an NMR perspective

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Chemotherapy relies heavily on potent active ingredients, but their efficacy can be limited by poor solubility, degradation, and low selectivity. Drug Delivery Systems (DDS) offers a promising solution by encapsulating anticancer drugs, modulating their cytotoxicity, and ultimately enhancing their therapeutic potential. In this context, Nuclear magnetic resonance (NMR) spectroscopy offers a comprehensive analytical tool for the investigation of novel nanosystems,[1] especially fitting for the necessary molecular characterization required in DDS development. In this communication, the analysis on self-folding and thermoresponsive pegylated-fluorinated amphiphilic random copolymers (PEGMA-*co*-FA), employed as DDS for the potent highly hydrophobic anticancer drug Combretastatin-4 (C-4) will be described.[2] Experimental conformational and temperature-responsive properties have been observed by using ^{1}H-^{1}H, ^{1}H-^{19}F and ^{19}F-^{19}F 2D NOESY maps, above and below cloud point temperature. Size determination of DDS through DOSY and solubility enhancement of Combretastatin A-4 (C-4), has been evaluated. The small size and the stimuli responsive behaviour of these platform could represent a more effective way at delivering drugs to cells than conventional non-responsive nanocarriers.

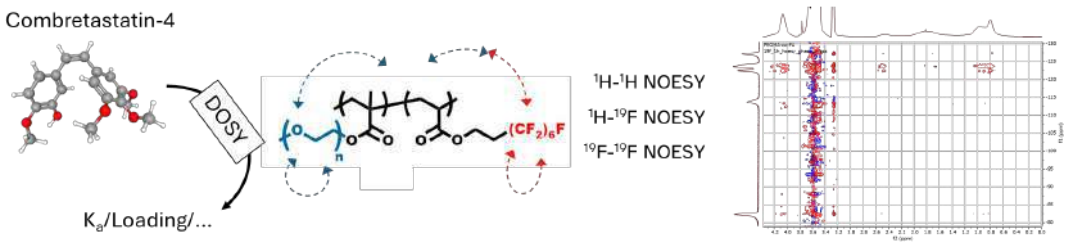

Figure 1: NMR strategies for fluorinated-pegylated DDS: determination of C-4/DDS association constant and loading with DOSY (left); ^{1}H and ^{19}F homo- and hetero-NOEs are useful for a complete conformational description of the DDS during thermoresponsive transitions.

Acknowledgement
This work was supported by the European Union's NextGenerationEU initiative under the Italian Ministery of University and Research as part of the PNRR - M4C2-I1.3 Project PE00000019 'HEAL ITALIA', CUP I53C22001440006, awarded to Prof. F. Bellina, Dr. A. Cesari.

References:

[1] S. Takeuchi, A. Cesari, S. Soma, Y. Suzuki, M. A. Casulli, K. Sato, F. Mancin, T. Hashimoto, T. Hayashita, Chem. Commun. 2023, 59, 4071-4074.
[2] M. Calosi, E. Guazzelli, S. Braccini, M. Lessi, F. Bellina, G. Galli, E. Martinelli, Polymers 2022, 14, 774.

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ORG-OR-010

Synthesis of 5-Hydroxyindoles Scaffold Using Resonance Acoustic Mixing

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The heterocyclic structure is a common feature in natural and synthetic compounds, often exhibiting important biological properties. Nitrogen-containing heterocycles are frequently found in vitamins, hormones, antibiotics, and alkaloids.[1]

One of the most attractive scaffolds among general nitrogen-containing heterocycles is the 5-hydroxy indole moiety. Discovered almost a century ago, the Nenitzescu reaction remains one of the most useful methods for obtaining 5-hydroxyindoles from simple starting materials. [2] Resonance Acoustic Mixing (RAM) represents a new era of mechanochemistry 2.0, aiming to overcome the limitations of traditional synthetic methods with the use of the latest developments in mechanochemistry.[3] RAM method induces molecule collision, promoting reactivity and overcoming problems of classical mechanochemistry: contamination, scalability, and equipment.

The objective of this research is to synthesize a 5-hydroxyindole scaffold using the Nenitzescu reaction, while avoiding traditional methods that involve long reaction times, the use of acids, and result in low yields. With the ideal conditions at our disposal, we were able to obtain various scaffolds by simply precipitating the product from the reaction mixture and recovering it with ethyl acetate.

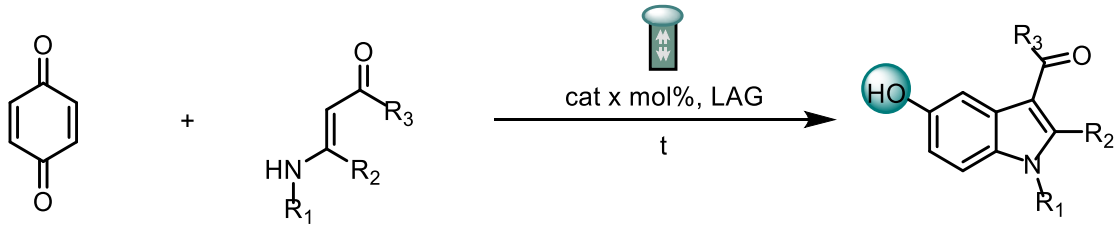

Figure 1: Synthesis of 5-hydroxy moiety by using a Lab RAM II device.

References:
[1] *J. Am. Chem. Soc.,* **1974,** 96, 17, 5495–5508
[2] *Eur. J. Org. Chem.* **2021**, 5835–5842
[3] *Nat Rev Chem*, **2023**, 7, 51–65

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Structural Characterization of Legumins and Vicilins from Chickpea Seeds by Mass Spectrometry

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Chickpea (*Cicer arietinum L.*) seed proteins show a lot of functional properties leading this legume an interesting component for the development of protein-enriched foods.[1,2] However, both in-depth proteomic investigation and structural characterization of chickpea proteins seed are still lacking. Here we show a characterization of chickpea seed protein fraction by means of SDS-PAGE, in-gel protein digestion, high-resolution mass spectrometry, and database searching. By this approach about 360 different proteins were identified and characterized, a result that up to date represents the most detailed description of seed's proteome of this legume. The most abundant components were vicilins and legumins. Legumins, as expected, were revealed at 45-65 kDa, as whole subunits with the α- and β-chains linked together by a disulphide bond, but also at lower mass ranges (α- and β-chains migrating alone).[3] Similarly, but not expected, also the vicilins were spread along the mass region between 65 and 23 kDa, with some of them identified in several bands. MS structural characterization allowed to determine that, although chickpea vicilins were always described as proteins lacking of cysteine residues, they contain this amino acid residue. Moreover, similarly to legumins, these storage proteins are firstly synthesized as pre-propolypeptides (Mr 50-80 kDa), that probably may undergo to proteolytic steps that cut not only the signal peptides but also produce different subunits having lower molecular masses.

References:

[1] J.S. Sandhu, S. Tripathi, S.K. Chaturvedi, in Sustainable Food Value Chain Development (Springer) 2023, 175-183.
[2] A.K. Jukanti, P.M. Gaur, C.L.L. Gowda, R.N. Chibbar, British Journal of Nutrition 2012, 108, S11-S26.
[3] J.A. Gatehouse, D. Bown, J. Gilroy, M. Levasseur, J. Castleton, T.H. Ellis, Biochemistry Journal 1988, 15-24.

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ORG-OR-012

Dyedauxiliary group approach for the Truce-Smile rearrangement of *N*-sulfonyl-*N*-substituted acrylamides via sulfonyl radicals.

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The Truce-Smiles rearrangement is a key-reaction for the preparation of highly functionalized amides via an *ipso*-substitution reaction. While the initial version of the reaction was based on a polar two-electron pathway, a radical variant of this reaction for organic transformations is possible.[1] Arylazo sulfones (**1**, Figure 1), are bench stable and coloured compounds able to release different radical species (e.g. aryl radicals, sulfonyl radicals) when irradiated with blue light.[2-3] Such behaviour has been exploited in the present work to convert a wide range of *N*-sulfonyl-*N*-substituted acrylamides (**2**) into the corresponding *N*-substituted-2-aryl-3-sulfonyl amides (**3**) via a Truce-Smile radical rearrangement. The optimized protocol requires a simple set-up and it is easy scalable under both flow and batch conditions. With the proposed protocol bicalutamide (**4**) analogues (primarily used to treat prostate cancer) may be easily synthesized.

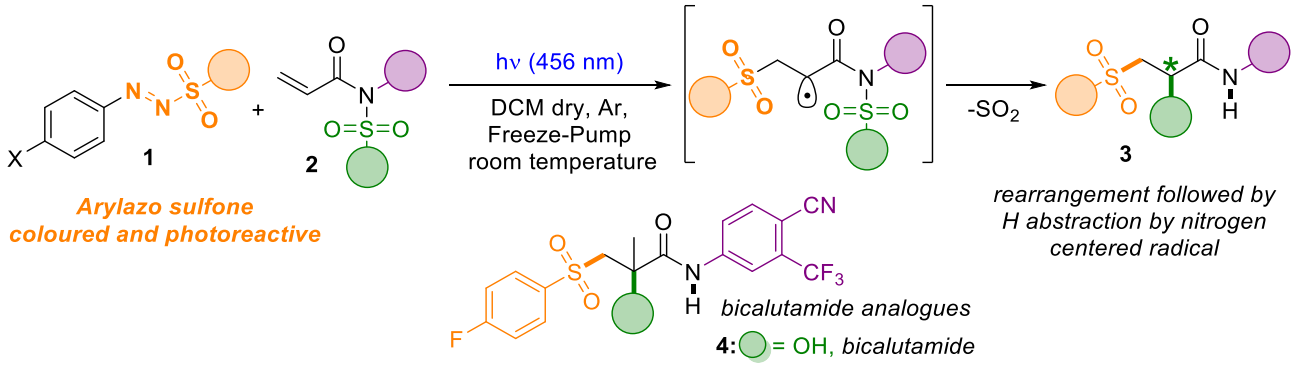

Figure 1: Truce-Smile rearrangement promoted by photogenerated sulfonyl radicals.

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References:

[1] C. M. Holden, M. F. Greaney, *Chem. Eur. J.* **2017**, 23, 8992–9008.
[2] L. Di Terlizzi, L. Nicchio, C. Callegari, S. Scaringi, L. Neuville, M. Fagnoni, S. Protti, G. Masson, *Org. Lett.* **2023**, 25, 50, 9047–9052.
[3] D. Qiu, C. Lian, J. Mao, M. Fagnoni, S. Protti, *J. Org. Chem.* **2020**, 85, 20, 12813–12822.

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Use of ionic liquids in amidation reactions for PROTACs' synthesis

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Proteolysis Targeting Chimeras (PROTACs) represents an emerging class of small molecule compounds that in the last two decades has gained even more attention as a novel and innovative therapeutic modality.[1] Structurally, PROTACs are heterobifunctional molecules consisting of two ligands joined by a linker: one ligand recruits and binds a protein of interest (POI) while the other recruits and binds an E3 ubiquitin ligase. Simultaneous binding of the POI and the E3 ligase by the PROTAC molecule induces ubiquitination of the POI and its subsequent degradation by the ubiquitin-proteasome system.[1] Despite the advances made so far, the structural chemical complexity of PROTACs poses challenges in their synthetic approaches. PROTACs are typically prepared through a convergent approach, entailing the parallel synthesis of the two fragments (POI and E3 ligase ligands) and then their successive coupling to produce the fully assembled PROTAC.[2-3]

In this context, PROTACs components are often combined via late-stage amide couplings, thus resulting in the amide bond as the most exploited linkage in PROTACs design and synthesis. Unfortunately, the overall isolated yields of such synthetic procedures are usually low due to also one or more purification steps needed to obtain the final PROTAC with acceptable purity. Furthermore, only a few conditions for the amide coupling in the synthesis of PROTACs have been reported so far in the literature.[2,4]

In the present study, we conducted an in-depth study aimed at exploring and optimizing the final amidation step for the synthesis of PROTAC derivatives. In particular, we focused our attention on the optimization of the final amidation step for the synthesis of an anti-SARS-CoV-2 PROTAC, previously reported by us,[5] by investigating different amidation coupling reagents and a range of alternative solvents, including ionic liquids (ILs). Among the ILs screened, [OMIM][ClO_4] emerged as a successful replacement of the commonly used DMF within the HATU-mediated amidation reaction, thus allowing the synthesis of the target PROTAC under mild conditions and in very high isolated yields. With the optimised conditions in hands, we explored the scalability of the synthetic approach as well as the substrate scope of the reaction by employing different E3 ligase ligands-based intermediates containing linkers of different lengths and compositions or by using different POI ligands.

References:

[1] M. Bekes, D. R. Langley, C. M. Crews, Nat Rev Drug Discov 2022, 21, 181-200.
[2] C. Cao, M. He, L. Wang, Y. He, Y. Rao, Chem Soc Rev 2022, 51, 7066-7114.
[3] A. Bricelj, C. Steinebach, R. Kuchta, M. Gutschow, I. Sosic, Front Chem 2021, 9, 707317.
[4] O. Bakulina, A. Sapegin, A. S. Bunev, M. Krasavin, Mendeleev Commun 2022, 32, 419-432.
[5] J. Desantis, B. Mercorelli, M. Celegato, F. Croci, A. Bazzacco, M. Baroni, L. Siragusa, G. Cruciani, A. Loregian, L. Goracci, Eur J Med Chem 2021, 226, 113814

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Synthetic optimization of **N,N Dialkyl-2-arylindol-3-ylglyoxylamides**

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The development of more sustainable chemistry synthesis is mandatory for reaching the target of a carbon neutral European Union in 2050, as stated by the European Green Deal. One of the most impacting parameters in synthetic chemistry is the use of large quantities of solvent. Classical solvents are mainly petroleum-derived, volatile, and show significant hazard for safety and health. To overcome the inherent problems of classical solvents, many new solvents are currently studied as a safer and greener alternative. The pharmaceutical field is an industrial sector that is very demanding in the use of solvents. In this context it is necessary to find safer and more sustainable solvents for the synthesis of active pharmaceutical ingredients (APIs), as well as to find new synthetic pathways capable of reducing energy consumption and waste production and endowed with sustainable work-up. An interesting class of APIs is represented by N,N-Dialkyl-2-arylindol-3-ylglyoxylamides (fig 1). These compounds selectively target the translocator protein (TSPO); interestingly, overexpression of this protein is linked to different diseases. The classical synthesis reported[1] for this class of compounds requires both the use of different hazardous solvents like diethyl ether and chromatographic purification. In this research, after identifying the most impactful parameters in the reported synthesis, we focused our attention on the replacement of classical solvents with less hazardous and more sustainable alternatives. Another key point of this work was the optimization of the synthesis for the reduction of waste and improved work up.

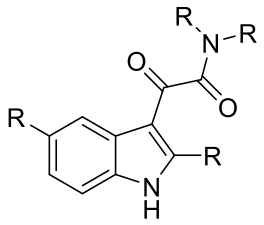

Figure 1 Structure of N,N-Dialkyl-2-arylindol-3-ylglyoxylamides

References:

[1] G. Primofiore, F. Da Settimo, S. Taliani, F. Simorini, M.P. Patrizi, E. Novellino, G. Greco, E. Abignente, B. Costa, B. Chelli, C. Martini, Journal of Medicinal Chemistry, 2004, 47, 1852-1855.

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Chemoenzymatic Catalysis for the Stereoselective Synthesis and Derivatization of Terpenes

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Terpenes represent a large class of natural products with applications in both pharma and fragrance industry. They are characterized by enourmous structural diversity and stereochemical complexity, which ensure a broad range of biological properties.[1] Therefore, stereochemical control is paramount in their synthesis and derivatization.[2] In this context, biocatalytic reduction and oxidation reactions offer an opportunity for both selectivity and sustainability.[3] Herein, we present redox approaches in the synthesis and functionalization of terpenes by chemoenzymatic catalysis. In particular, we will present (*a*) the enzymatic C=C and C=O bond reduction for the stereoselective preparation of sandalwood fragrances;[4] (*b*) a stereoselective chemoenzymatic approach to the fragrance Ambrocenide®;[5] (*c*) a chemoenzymatic approach to bioactive derivatives of Cannabidiol, itself recovered from agricultural biomass waste.[6]

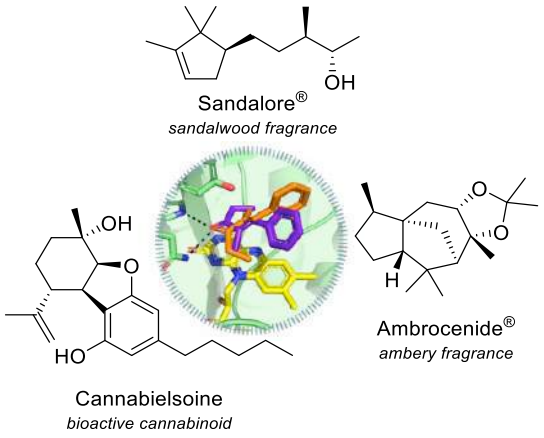

Figure 1: Chemoenzymatic catalysis for terpene synthesis and derivatization

References:

[1] E. Breitmaier, Terpenes: Flavors, Fragrances, Pharmaca, Pheromones, Wiley-VCH, Weinheim, Germany, 2006.
[2] T. J. Maimone, P. S. Baran, Nat. Chem. Biol. 2007, 3, 396−407.
[3] F. Hollmann, D. J. Opperman, C. E. Paul, Angew. Chem., Int. Ed. 2021, 60, 5644−5665.
[4] M. C. Cancellieri, D. Maggioni, L. Di Maio, D. Fiorito, M. E. Brenna, F. Parmeggiani, F. G. Gatti, *submitted.*
[5] V. De Fabritiis, S. Magni, F. G. Gatti, M. E. Brenna, D. Fiorito, *manuscript in preparation*.
[6] D. Fiorito, D. Tessaro, F. Sangalli, C. Nobbio, M. E. Brenna, F. Parmeggiani, *submitted.*

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Organocatalytic Asymmetric Reduction of δ-Nitro Dienes: a Viable Entry to Functionalized Amines and Highly Substituted Enantioenriched Cyclopentanes

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The reduction of conjugated nitroolefins is considered a powerful tool to access nitroalkanes;[1] in the last few years, the organocatalytic stereoselective reduction of nitroolefins received great interest by organic chemists. In this context, the organocatalytic stereoselective reduction of β,β-disubstituted nitroolefins with Hantzsch ester was firstly disclosed by List[2] and further explored by other groups.[3] Nevertheless, no example about the enantio-, chemo- and regioselective reduction of dienes trisubstituted at the double bond bearing the nitro group was found in the literature.

Based on these considerations, a new strategy for the synthesis of δ-nitroalkenes from nitro dienes was disclosed, with complete chemo and regioselectivity and enantioselectivity up to 97%. The enantioenriched products were successfully elaborated and employed in the stereoselective cyclization reaction that affords an almost enantiomerically pure highly functionalised cyclopentane featuring 5 contiguous stereocenters.[4]

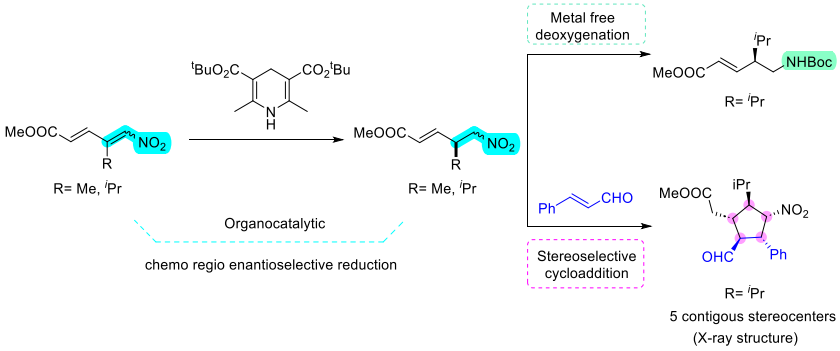

Figure 1: Organocatalytic reduction and further elaboration of the product

References:

[1] Kabalka, G. W.; Varma, R. S. *Org. Prep. Proced. Int*. **1987**, *19*, 283-328. b) Barrett, A. G. M.; Graboski, G. G.; *Chem. ReV*. **1986**, *86*, 751-762.
[2] N. J. A. Martin, L. Ozores, B. List,*J. Am. Chem. Soc.,* **2007**,*129*, 8976-8977.
[3] a) E. Martinelli, A.C. Vicini, M. Mancinelli, A. Mazzanti, P. Zani, L. Bernardi, M. Fochi, *Chem. Commun*., **2015**, *51*, 658–660; b) E. Massolo, M. Benaglia, M. Orlandi, S. Rossi, G. Celentano, *Chem. Eur J*., **2015**, *21*, 3589-3595.
[4] C. Faverio, F Franco, G. Taini, L. Raimondi, M. Benaglia, *Eur. J. Org. Chem*., **2024**, e202301043

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Gold-catalyzed allylation of derivatized tropolones

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Homogenous gold catalysis has attained an exceptional degree of maturity, robustness, and predictability concerning both chemical and stereochemical outcomes in site-selective manipulations of unsaturated hydrocarbons. Recently, we have introduced new fluorinated JohnPhos-type ligands (namely PedroPhos) as acceleration tools in benchmark reactions catalyzed by Au(I)[1]. In this context, aiming to employ these catalysts in novel synthetic procedures, we hereby present a gold-catalyzed Friedel-Crafts-like allylation of tropolone derivatives in the presence of diversely functionalized allenes. Tropolones and related derivatives constitute a fascinating class of compounds due to their peculiar geometry and remarkable biological activities, as evidenced by their presence in several natural and synthetic compounds[2]. In this scenario, the selective and mild formation of C-C bonds on precise positions of this scaffold remains largely unexplored[3]. The incorporation of an electron-donor group, elaborated onto the tropolone hydroxyl group, serves as an "umpolung tool" for the cycloheptatrienone moiety, in combination with the elegance and efficiency of homogeneous gold catalysis, allows the formation of allylated tropolone derivatives in high yields and under mild conditions.

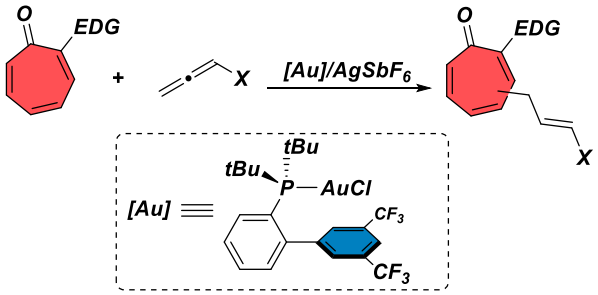

Figure 1: Alkylation reaction of tropolone derivatives exploiting gold catalysis.

References:

[1] R. Pedrazzani, S. Kiriakidi, M. Monari, I. Lazzarini, G. Bertuzzi, C. Silva López, M. Bandini, *ACS Catal.* **2024**, *in press*.

[2] K. C: Nicolau, R. Yu, Z. Lu, F. G. Alvarez, *J. Am. Chem. Soc.* **2022**, *144*, 5190.

[3] A. Brunetti, M. Garbini, N. G. Kub, M. Monari, R. Pedrazzani, C. Zanardi, G. Bertuzzi, M. Bandini *Adv. Synth. Catal.* **2024**, *e202400050*

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Synthesis of a Novel Fluorinated Climacostol Analogue *via* DAST-Promoted Reaction

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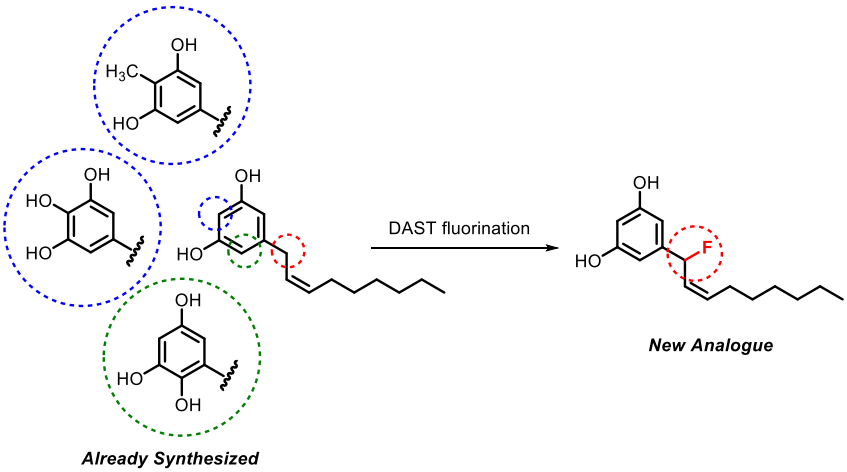
Small organic molecules have maintained a central position in drug discovery and development in the 20th century.[1] In 2018, 38 small-molecule pharmaceuticals were approved by the U.S. FDA, of which 17 were fluoro-pharmaceuticals.[2] Among other things, a wise replacement with fluorine atoms in the molecule increases their bioavailability and potency, generally also improving their half-life and metabolism stability.

Based on these considerations, and given the experience of our group in the synthesis of analogues of climacostol,[3] a resorcinolic lipid that shows antitumor activities both *in vitro* and *in vivo* through an effective and potent cytotoxic, pro-apoptotic, and anti-autophagic action on multiple tumour cell lines, we decided to develop the synthesis of a new fluorinated analogue to test its activity as an anticancer agent. After several attempts with the most recent fluorination methodologies,[4] our target fluorinated molecule was obtained using DAST, a powerful reagent utilized for the conversion of alcohols into corresponding fluorides.



References:

[1] P. Das, M. D. Delost, M. H. Qureshi, D. Y. Smith, J. T. Njardarson, J. Med. Chem. 2019, 62, 4265−4311.
[2] M. Inoue, Y. Sumii, N. Shibata, ACS Omega 2020, 5, 10633-10640.
[3] (a) F. Buonanno, E. Catalani, D. Cervia, C. Cimarelli, E. Marcantoni, C. Ortenzi, Microorganism 2020, 8, 809. (b) F. Buonanno, E. Catalani, D. Cervia, F. Proietti Serafini, S. Picchietti, A. M. Fausto, S. Giorgi, G. Lupidi, F. V. Rossi, E. Marcantoni, D. Petrelli, C. Ortenzi, Toxins 2019, 11, 42.
[4] P. Adler, C. J. Teskey, D. Kaiser, M. Holy, H. H. Sitte, N. Maulide, Nature Chem. 2019, 11, 329-334.

ORG-OR-019

Oxidative anionic homo-Fries rearrangement under bench-type aerobic conditions

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The development of new sustainable protocols which enable the use of aerobic/protic conditions in alkali-metal-mediated transformations has profoundly reshaped the conceptual chemistry of these highly polar organometallic reagents.[1] Our recent findings in this field disclosed that highly reactive alkyllithiums can efficiently promote chemoselective nucleophilic acyl substitution (S_NAc)[2] and regioselective metalation[3,4] reactions using deep eutectic solvents (DESs) or cyclopentyl methyl ether (CPME) as sustainable reaction media, working at room temperature, in the presence of moisture and air. Furthermore, we recently illustrated the beneficial active role of protic deep eutectic mixtures in the regioselective metalation/Fries rearrangement of *O*-aryl carbamates, as the commonly detrimental competitive protonolysis of the organolithium occurring in these reaction media prevents the formation of byproducts arising from multiple metalation steps.[5]
Motivated by our ongoing interest in extending the feasibility of organolithium reagents in unconventional sustainable solvents, we herein investigate the usefulness of bench-type conditions to promote the aerobic oxidation of benzylic anions generated from *O*-tolyl carbamate derivatives upon a metalation-Fries rearrangement sequence. Kinetic studies and mechanistic insights into the formation of dianionic species will be also discussed.

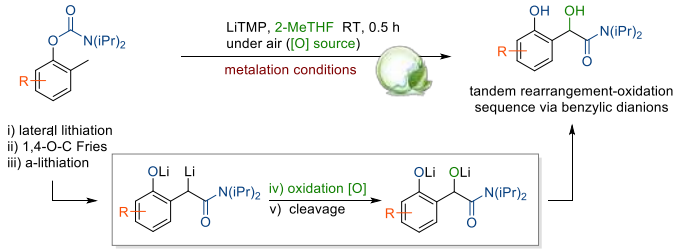

Figure 1: one-pot oxidative anionic homo-Fries rearrangement.

References:

[1] a) F. M. Perna, P. Vitale, V. Capriati, Curr. Opin. Green Sustain. Chem. 2021, 30, 100487; b) S. E. Garcia-Garrido, A. Presa Soto, E. Hevia, J. García-Álvarez, Eur. J. Inorg. Chem. 2021, 2021, 3116 – 3130; c) J. García-Álvarez, E. Hevia, V. Capriati, Chem. Eur. J. 2018, 24, 14854 – 14863.
[2] S. Ghinato, D. Territo, A. Maranzana, V. Capriati, M. Blangetti, C. Prandi, Chem. Eur. J. 2021, 27, 2868 – 2874.
[3] S. Ghinato, G. Dilauro, F. M. Perna, V. Capriati, M. Blangetti, C. Prandi, Chem. Commun. 2019, 55, 7741 – 7744.
[4] D. Arnodo, S. Ghinato, S. Nejrotti, M. Blangetti, C. Prandi, Chem. Commun. 2020, 56, 2391 – 2394.
[5] S. Ghinato, F. De Nardi, P. Bolzoni, A. Antenucci, M. Blangetti, C. Prandi, Chem. Eur. J. 2022, 28, e202201154.

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ORG-OR-020

(L)-Mono-methyl Tyrosine (Mmt): new synthetic strategy via bulky 'forced-traceless' regioselective Pd-catalyzed C(sp^2)–H activation

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The enormous influence in terms of bioactivity, affinity, and selectivity represented by the replacement of (L)-2,6-dimethyl tyrosine (Dmt) instead of phenylalanine (Phe) into Nociceptin/orphanin (N/OFQ) neuropeptide analogues, has been well documented in literature.[1] Here we report a new synthetic strategy to obtain mono-methyl tyrosine (Mmt), based on the well-known Pd-catalyzed ortho-C(sp^2)–H activation approach.
The uncontrolled double *ortho*-methylation on tyrosine has been previously reported[2], the aim of this work however, was the obtainment of the mono-alkylated product. The introduction of a dibenzyl-amine moiety in meta position allowed the Pd-catalyzed C(sp^2)–H activation, its bulkiness led to the formation of 2-methyl-tyrosine, acting like an inducer of regioselectivity, indeed, the alkylation occurred exclusively in position 2. (Fig. 1).

In this regard we are pleased to report that the introduction of the dibenzyl-amine moiety on Tyr aromatic nucleus is a convenient and traceless method to achieve such a goal, as a matter of fact, once reduced and converted in diazonium salt, it was easily removable through proto-deamination.[3]

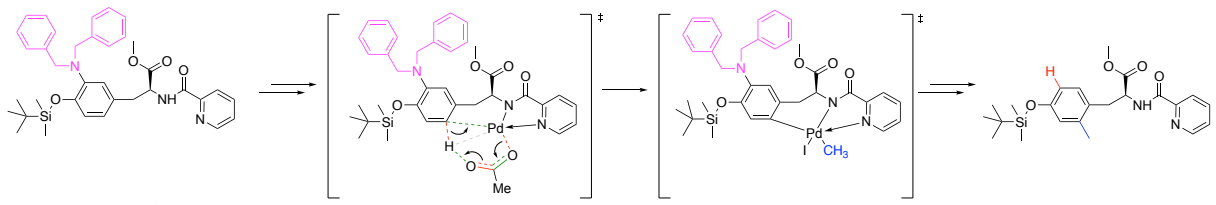

Figure 1: 2-methyl-tyrosine derivative obtained through Pd-catalyzed C(sp^2)–H activation reaction.

References:

[1] S. Pacifico, V. Albanese, D. Illuminati, et al., J. Med. Chem. 2021, 64, 10, 6656-6669
[2] X. Wang, S. Niu, L. Xu, et al., Org. Lett. 2017, 19, 1, 246-249
[3] D. Illuminati, C. Trapella, V. Zanirato, et al., Pharmaceuticals, 2023, 16, 1, 1592-1606

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ORG-OR-021

*aquo*DESs Dilutions: Cluster Formation of Water-Based Deep Eutectic Solvents in Water

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Deep Eutectic Solvents (DESs) are an innovative class of organic solvents that are increasing their importance in the research activity thanks to their environmental-friendly features as well as to their structural characteristics and catalytic properties. Formed by no-solvent mixing of two substances, namely a hydrogen bond donor and a hydrogen bond acceptor, DESs are finding fruitful applications in many different topics as alternatives to common organic compounds.[1,2] One of the most interesting and studied properties of DESs is their peculiar water dilutions structures, because the DESs retain their structural features until high water contents (until about 50% w/w), showing clusters of DESs solvated by water in equilibrium with free-solvated species. The disruption of the DESs' structures occurs over 60% w/w of water added.[3,4]

In this presentation the properties of water dilutions of *aquo*DESs (binary DESs formed with water mixed with counterparts over their maximum solubility)[5] will be shown. Clusters of water-based systems in water were observed and characterized with techniques such as ionic conductivity; rheological measures; high resolution ultrasound spectroscopy; PGSE NMR. Finally, the cytotoxicity of these water dilutions of water-based DESs was tested in an in vitro model of intestinal cell culture (Caco-2) by MTT assay.

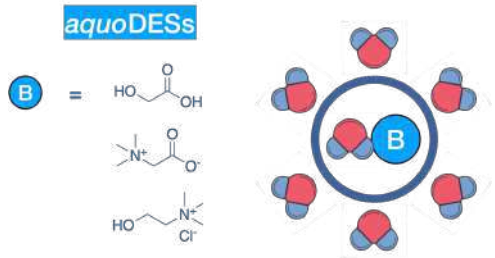

Figure 1: water-based DESs' clusters in water dilutions.

[1] D. A. Alonso, S. J. Burlingham, R. Chinchilla, G. Guillena, D.J. Ramón, M. Tiecco, EurJOC 2021, 29, 4065 - 4071.
[2] Y.Liu, J.B. Friesen, J. B. McAlpine, D. C. Lankin, S. N. Chen, G. F. Pauli, G. F., J Nat Prod 2018, 81(3), 679 - 690.
[3] C. Ma, A. Laaksonen, C. Liu, X. Lu, X. Ji, Chem Soc Rev 2018, 47(23), 8685 - 8720.
[4] F. Gabriele, M. Chiarini, R. Germani, M. Tiecco, N. Spreti, J Mol Liq 2019, 291, 111301.
[5] E. Picciolini, G. Pastore, T. Del Giacco, G. Ciancaleoni, M. Tiecco, R. Germani, J Mol Liq 2023, 383, 122057.

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ORG-OR-022

Organolithium-induced Kinetic Resolution and Anionic Fries Rearrangement of *O*-aryl Carbamates

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The development of enantioselective strategies is of utmost importance owing to the fundamental role of enantiopure molecules in biological processes. Among these methods, the kinetic resolution (KR) of racemic mixtures is one of the most utilized in organic synthesis.[1] *N*-Acyl 2-phenylpiperidines are optimal substrates for this process giving chiral amines, important scaffolds for the synthesis of bioactive compounds.[2] In particular, we herein investigate the kinetic resolution of the racemic *O*-phenyl 2-phenylpiperidine carbamate **1** (Figure 1) in the presence of (+)-sparteine as chirality inducer; electrophilic quench affords a mixture of enantioenriched starting material **1*** and the α-functionalized product **2** with an adequate enantiomeric ratio. Optimization of the reaction conditions (base, ligand, solvent, temperature) is presented. Furthermore, carbamate **1** represents a versatile reactive scaffold which can be also employed as substrate in an anionic Fries rearrangement process.[3] Several metalation conditions are investigated to promote the anionic migration either of the amide group or the ester moiety on the aromatic rings. Optimization of the reaction, with particular interest on sustainable bench-type conditions, and studies on the regioselectivity of the migration (1,3-*O*-*C* vs 1,4-*N*-*C*) are presented.

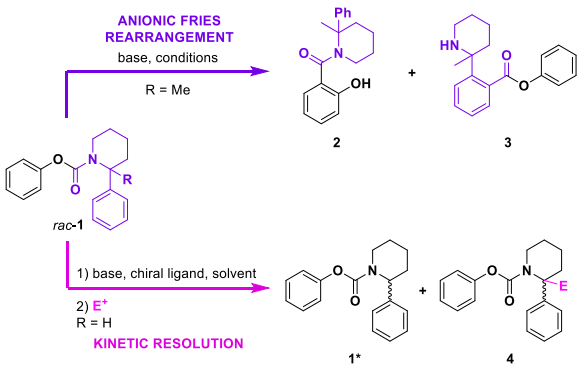

Figure 1: Kinetic Resolution and anionic carbo-Fries rearrangement of racemic carbamate **1**.

References:

[1] R. S. Ward, *Tetrahedron: Asymmetry*, **1995**, *6*, 1475-1490.
[2] (a) E. J. Cochrane, D. Leonori, L. A. Hassallb, I. Coldham, *Chem. Commun.*, **2014**, *50*, 9910-9913; (b) A. Choi, A. J. H. M. Meijer, I. Proietti Silvestri, I. Coldham, *J. Org. Chem.*, **2022**, *87*, 8819−8823.

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ORG-OR-023

Electrochemical Organocatalytic Asymmetric Radical Functionalization of Aldehydes

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In the realm of asymmetric organic synthesis, aminocatalysis stands out as a well-established tool that enables the production of enantioenriched compounds under mild conditions.[1] Beyond its classic utilization, aminocatalysis serves as an exceedingly versatile tool of molecular activation, as testified by its seamless integration with various synthetic approaches.[2] While the combination of aminocatalysis with metal catalysis,[3] and photochemistry[4] has been extensively explored, its synergy with electrochemical activation remains largely unexplored. Herein, we present the successful merger of electrochemistry and aminocatalysis to perform SOMO-type transformations, expanding the toolkit for asymmetric electrochemical synthesis.[5] The methodology harnesses electricity to drive the oxidation of catalytically generated enamines, which ultimately partake in enantioselective radical processes, leading to α-alkylated aldehydes. Crucially, mechanistic studies highlight how this electrochemical strategy is enabled by the use of a redox shuttle, 4,4'-dimethoxybiphenyl, to prevent catalyst degradation and furnishing the coveted compounds in good yield and high enantioselectivity.

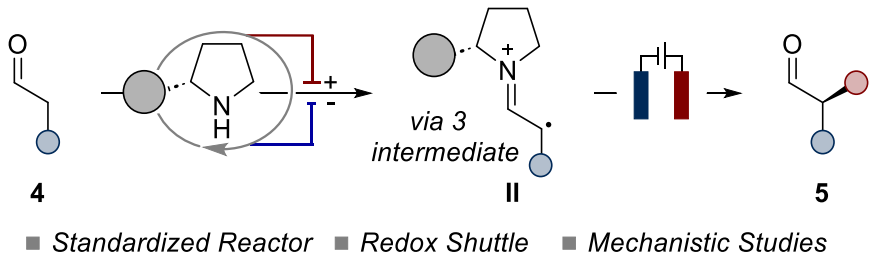

Figure 1: Electrochemical organocatalytic asymmetric radical functionalization of aldehydes.

References:

[1] P. Melchiorre, M. Marigo, A. Carlone, G. Bartoli, *Angew. Chem. Int. Ed.* **2008**, *47*, 6138 – 6171.
[2] A. Del Vecchio, A. Sinibaldi, V. Nori, G. Giorgianni, G. Di Carmine, F. Pesciaioli, *Chem. Eur. J.* **2022**, *28*, e202200818.
[3] S. Afewerki, A. Córdova, *Chem. Rev.* **2016**, *116*, 13512 – 13570.
[4] M. Silvi, P. Melchiorre, *Nature* **2018**, *554*, 41–49.
[5] D. Mazzarella, C. Qi, M. Vanzella, A. Sartorel, G. Pelosi, L. Dell'Amico, *manuscript under review*.

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Electrochemical Stereoselective Pinacol coupling: an Easy Access to Chiral Diamines

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Chiral molecules have already become the key target for synthetic chemists.1,2 Thus, it is necessary to create new synthetic routes continuously. Chiral diamines represent an intriguing class of molecules. Indeed, they are useful scaffolds that can be finely functionalised and then used as organocatalysts3 and ligands for transition metals.4 Our work is focused on the use of organic electrochemistry to realise an efficient pinacol coupling, avoiding the use of stoichiometric amounts of metal (Mn, Zn, Sm, among others). Starting from an enantiopure 1,2-diamine scaffold, the stereoselective electrochemical pinacol reaction of several bis-imines was successfully realised.

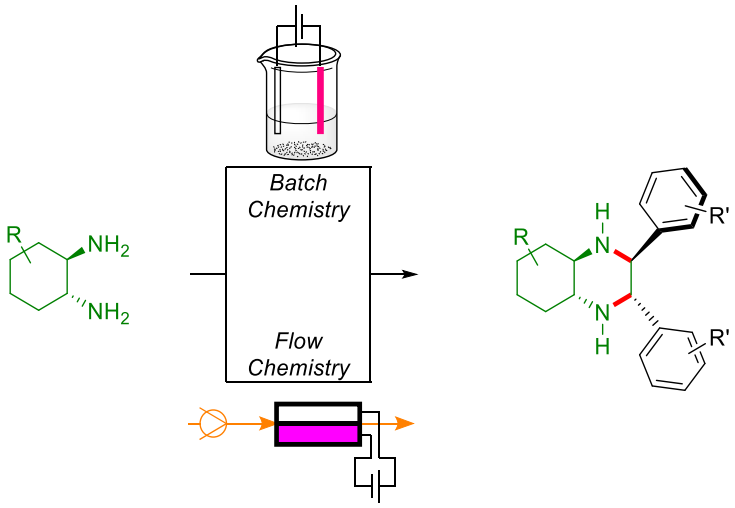

Figure 1 Scope of the work

Here, we will present the batch and flow electrosynthesis of a library of chiral diamines, which were isolated as enantiomerically pure compounds.

References:

[1] J. Ceramella, D. Iacopetta, A. Franchini, M. De Luca, C. Saturnino, I. Andreu, M. S. Sinicropi, A. Catalano, *Appl. Sci.* **2022**, *12*, 10909.
[2] I. P. Silvestri, P. J. J. Colbon, *ACS Med. Chem. Lett.* **2021**, *12*, 1220–1229.
[3] V. Kozma, F. Fülöp, G. Szőllősi, *Adv. Synth. Catal.* **2020**, *362*, 2444–2458.
[4] O. V. Khromova, M. A. Emelyanov, A. F. Smol'yakov, I. V. Fedyanin, V. I. Maleev, V. A. Larionov, *Inorg. Chem.* **2022**, *61*, 5512–5523.

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Unusual Reactivity of *N*-alkoxyamides in the Presence of Silylating Reagents.

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Since their introduction in 1981 Weinreb amides,[1] a class of standard acylating agents, were used as acylating platforms almost restricted to carbon-centered and hydride nucleophiles to access carbonyl and alkene motifs.[2] Except for the hydrolysis, acylation operations with heteroatom-based nucleophilic elements remain largely unexplored.

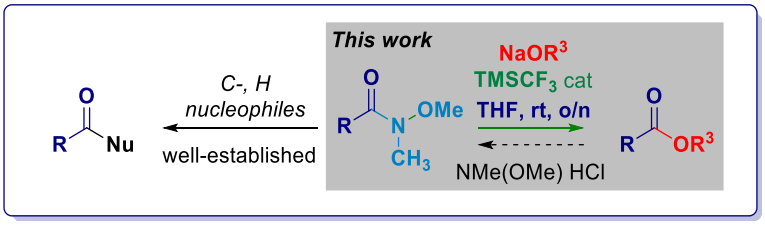

Figure 1: Esterification of amides.

We reasoned that the reaction of an alkoxide with Weinreb amides would represent an attractive synthetic tool for preparing esters through a conceptually intuitive protocol *via* the employment of the Ruppert-Prakash reagent[3] acting as a versatile catalyst enhancing their nucleophilicity.
Wide substrate scope, flexibility, genuine chemocontrol and the complete transfer of the stereochemical information demonstrate the protocol to be an attractive transformation also due to the reach portfolio of operations attainable with this class of products.[4]

References:

[1] S. Nahm, S. M. Weinreb, *Tetrahedron Lett.* **1981**, *22*, 3815-3818.
[2] V. Pace, W. Holzer, B. Olofsson, *Adv. Synth. Catal.* **2014**, *356*, 3697-3736.
[3] X. Liu, C. Xu, M. Wang, Q. Liu, *Chem. Rev.* **2015**, *115*, 683-730.
[4] (a) M. Miele, L. Castoldi, E. Beccalli, V. Pace, *Adv. Synth. Catal*. **2024**, doi.org/10.1002/adsc.202400008; (b) M. Malik, R. Senatore, T. Langer, W. Holzer, V. Pace, *Chem. Sci.* **2023**, *14*, 10140-10146.

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OXETANES AS NUCLEOPHILES FOR THE SYNTHESIS OF PHARMACEUTICALLY RELEVANT KEY BUILDING BLOCKS

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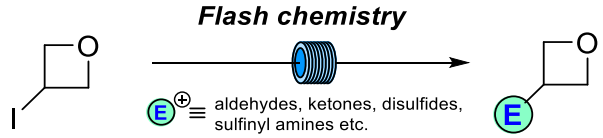
Over the last 50 years, small-molecule drug candidates have significantly increased in molecular complexity. One reason is the increased three-dimensionality introduced by a higher ratio of sp3-hybridised carbons to manage pharmacokinetic profiles. One motif to introduce three-dimensionality into drug candidates is the oxetane ring, which has found application in several approved drugs and drug candidates currently undergoing clinical trials.[1] Oxetanes exclusively substituted at the 3-position are of particular interest as the introduction of an additional stereogenic center is thus avoided.[2]

The generation of 3-substituted oxetanes has however been most frequently achieved by transition-metal-catalysed cross-couplings or nucleophilic substitutions of 3-halooxetanes, which raises not only concerns of environmental friendliness and cost, but severely limits the accessible chemical space.[3] A method for the 3-functionalisation of oxetanes with pharmaceutically relevant electrophiles are lacking and the development of such methodology is thus imperative to broaden the options space for medicinal chemists. Leveraging our expertise in flash-chemistry,[4,5] we have developed an operationally simple, sustainable and functional-group-tolerant methodology for the introduction of the oxetane moiety to a wide range of electrophiles using flow technology (Figure 1).



☐ Sustainable ☐ Reaction within seconds ☐ Broad substrate scope

Figure 1. Flash chemistry for the 3-functionalisation of oxetanes

References:

[1] J. A. Bull, R. A. Croft, O. A. Davis, R. Doran, K. F. Morgan, *Chem. Rev.*, **2016**, 19, 12150 – 12233
[2] J. A. Burkhard, G. Wuitschik, M. Roger-Evans, K. Muller, E. M. Carreira, *Angew. Chem. Int. Ed.*, **2010**, 49, 9052 – 9067
[3] J. J. Rojas, J. A. Bull, *J. Med. Chem.*, **2023**, 66, 12697 – 12709
[4] P. Natho, R. Luisi, *Tetrahedron Green Chem.*, **2023**, 10015
[5] M. Spennacchio, P. Natho, M. Andresini, M. Colella, *J. Flow Chem.*, **2023**, *ASAP*

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A Lewis Acid-Catalyzed Unconventional Behavior of Oxazolines with Aldehydes

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2-Oxazolines are privileged scaffolds due to their widespread presence in numerous biologically significant molecules, but their relevance lies additionally in their versatility as intermediates in organic synthesis or ligands in coordination chemistry. The oxazoline moiety is typically subjected to nucleophilic attack at the C5 position with subsequent ring opening to give β-substituted carboxamide.[1] Although the chemistry of oxazolines has been extensively investigated, the reactivity of bisoxazolines is relatively unexplored. Recently, we have observed that the treatment of various bisoxazolines in the presence of nickel(II) chloride and an aryl or heteroaryl aldehyde could arise in the formation of β-iminoesters. Moreover, the same behavior by starting from oxazolines can be accomplished by using trimethylsilyl triflate since nickel proved to be ineffective. To the best of our knowledge, just one example reports the ring opening of oxazolines in the presence of aldehydes to access a tetrahydroisoquinoline scaffold.[2]

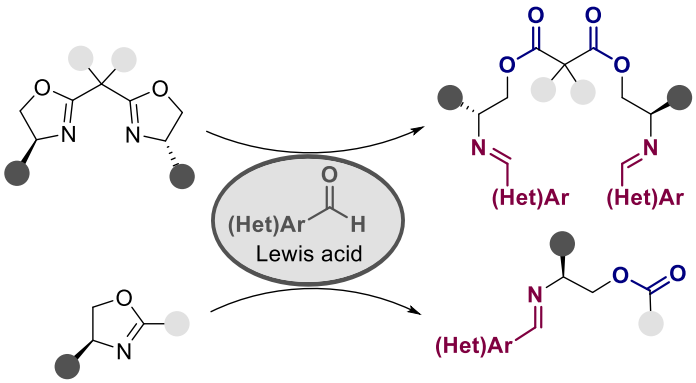

Figure 1: Lewis acid-catalyzed conversion of oxazoline into β-iminoesters.

Although bisoxazolines are useful themselves as chiral ligands, the generation of new β-iminoesters would greatly enhance their synthetic potential. Such a conversion would valorize the chemistry of oxazoline with the possibility of obtaining new molecules with two reactive sites that can undergo further transformation.

References:

[1] D. S. Laitar, J. W. Kramer, B. T. Whiting, E. B. Lobkovsky, G. W. Coates, Chem. Commun. 2009, 38, 5704 – 5706.
[2] J. M. Lerestif, S. Feuillet, J. P. Bazureau, J. Hamelin, J. Chem. Res. (S) 1999, 1, 32 – 33.

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ORG-OR-028

Deep Eutectic Solvents for Eco-Sustainable Synthesis of APIs: A Promising Approach

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In recent years, increasing environmental awareness has prompted chemists to prioritize the sustainability of chemical processes as a "key driver for innovation" within the pharmaceutical industry. The 12 Principles of Green Chemistry have emerged as the guiding framework for developing greener and more efficient methods to produce active pharmaceutical ingredients (APIs), with the aim of establishing environmentally responsible manufacturing processes.[1]

The selection of solvents during pharmaceutical process development is crucial for ensuring the sustainability of future production lines.[2] Traditionally, toxic and harmful volatile organic compounds (VOCs) have been widely used as solvents by organic and industrial chemists, but their use has been greatly restricted and even blacklisted. Consequently, the entire issue of solvent selection requires re-evaluation and has become a primary focus, particularly in pharmaceutical manufacturing, as solvents contribute to over 80% of the organic waste produced. This "solvent problem" not only pertains to their initial use but also involves considerations regarding containment, recovery, and reuse. Therefore, increasing attention has been paid to the efficient removal of VOCs from manufactured drugs.

Among the non-conventional and environmentally friendly solvents proposed as replacements for VOCs, deep eutectic solvents (DESs) have increasingly been employed for the synthesis of pharmaceutical molecules of interest. The adoption of these non-conventional solvents not only reduces the environmental footprint of synthesis processes, as demonstrated by green metrics calculation, but also enhances reaction efficiency.[3]

Building on our interest in the use of environmentally responsible solvents in API synthesis,[4] in this communication, we report on the sustainable preparation of nitrogen-containing heterocyclic compounds. Specifically, the synthesis of bis(indole) alkaloids, commonly referred to as indigo alkaloids, will be tackled as these compounds have long been recognized for their significant pharmacological properties.

References:

[1] P. T. Anastas, J. C. Warner, *Green Chemistry: Theory and Practice*; Oxford University Press: Oxford, UK, 2000; pp. 1–148.
[2] B. H. Lipshutz, F. Gallou, S. Handa, *ACS Sustain. Chem. Eng.* **2016**, *4*, 5838–5849.
[3] L. Cicco, G. Dilauro, F. M. Perna, P. Vitale, V. Capriati, *Org. Biom. Chem.* **2021**, *19*, 2558–2577.
[4] A. F. Quivelli, F. V. Rossi, P. Vitale, J. García-Álvarez, F. M. Perna, V. Capriati, *ACS Sustain. Chem. Eng.* **2022**, *10*, 4065–4072.
[5] L. Cicco, F. M. Perna, V. Capriati, P. Vitale, *Molecules*, **2024**, *29*, 1399.

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Triangulenium ions: Versatile Organic Photocatalysts for Metallaphotoredox protocols

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During the last decade, the merger of transition metal and photoredox catalysis, termed metallaphotoredox catalysis, has attracted considerable interest due to the mild operational conditions and the possibilities of stereoselective variants.[1] Among all the classes of photocatalysts reported in the literature, Harrit and Lacour introduced stable helical carbenium ions capable of harvesting light in the low-energy portion of the visible spectrum (orange and red light)[2] and Giannetti exploited their peculiar photophysical and redox properties as photocatalysts for organic transformations.[3] More recently, our group reported the use of the carbenium ion dimethoxyquinacridinium ($DMQA^+$) in highly diastereoselective and enantioselective pinacol couplings of aromatic aldehydes promoted by both titanium[4] and vanadium[5] in low oxidation state. In our presentation, we will illustrate the potential and differences between these two approaches, and the problems still unresolved.

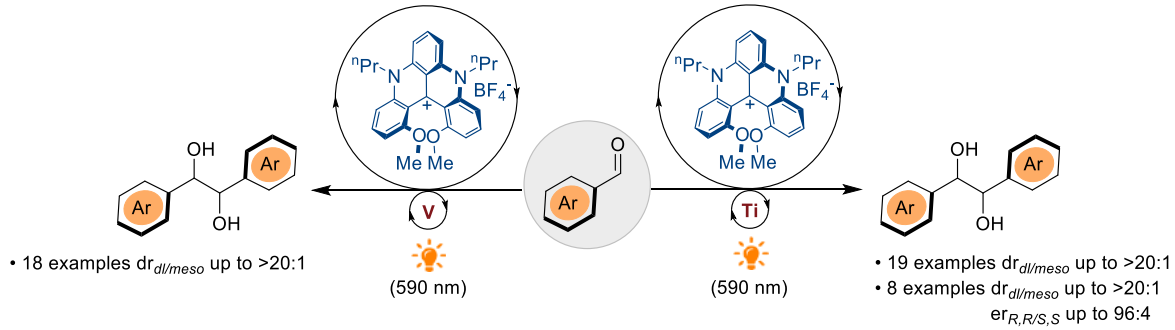

Figure 1: diastereoselective and enantioselective metallaphotoredox pinacol coupling of aromatic aldehydes promoted by titanium and vanadium in low oxidation state.

References:

[1] J. Twilton, C. Le, P. Zhang, M. H. Shaw, R. W. Evans, D. W. C. MacMillan, Nat. Rev. Chem. 2017, 1, 0052
[2] B. W. Laursen, F. C. Krebs, M. F. Nielsen, K. Bechgaard, J. B. Christensen, N. Harrit, J. Am. Chem. Soc. 1998, 120, 12255-12263; R. Vanel, F.-A. Miannay, E. Vauthey, J. Lacour, Chem. Commun. 2014, 50, 12169-12172.
[3] L. Mei, J. M. Veleta, T. L. Gianetti, J. Am. Chem. Soc. 2020, 142, 28, 12056-12061.
[4] F. Calogero, G. Magagnano, S. Potenti, F. Pasca, A. Fermi, A. Gualandi, P. Ceroni, G. Bergamini, P. G. Cozzi, Chem. Sci. 2022, 13, 5973-5981.
[5] E. Pinosa, Y. Gelato, F. Calogero, M. M. Moscogiuri, A. Gualandi, A. Fermi, P. Ceroni, P. G. Cozzi, Adv. Synth. Catal. 2024, 366, 798-805.

ORG-OR-030

A microfluidic photo-induced platform to tune the synthesis of functionalized gold nanoparticles

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Nanomedicine and the applications of nanomaterials in the life and health sciences have not yet expressed their full potential and kept the promises of their beginnings. In fact, despite the highly interesting and promising properties of nanoparticles (NPs), the full implementation of NPs in the current practice of medicine is still far from being fulfilled. One of the main obstacles is represented by the lack of reliable, reproducible, and scale-up protocols for the preparation of these materials.[1] Flow chemistry is a privileged pathway to synthesize NPs employing reproducible, and scaling-up protocols. Once optimized, the continuous synthesis is more reliable, productive, and less expensive if compared to wet synthesis.[2]

In this context, we have developed an innovative and versatile microfluidic approach to synthesizing functionalized gold nanoparticles (AuNPs).[3] The flow protocol is coupled with a photo-induced reduction promoted by a UV lamp, that avoids the use of any further chemical reductant, templating agent or co-solvent. The use of a 125W lamp allows the one-pot synthesis of functionalized ultra-small AuNPs, a class of luminescent AuNPs with a diameter less than 5 nm. Exploiting this protocol, it was possible to obtain a small library of glyco-AuNPs, checking thoroughly the displacement of the multiple copies of glycans on AuNP surface. The protocol resulted effective for the synthesis of other plasmonic NPs, i.e. silver and platinum NPs. Moreover, preliminary data showed that control over the size of AuNPs is possible by using a 6W UV lamp and tuning the ratio of gold precursor/ligands.

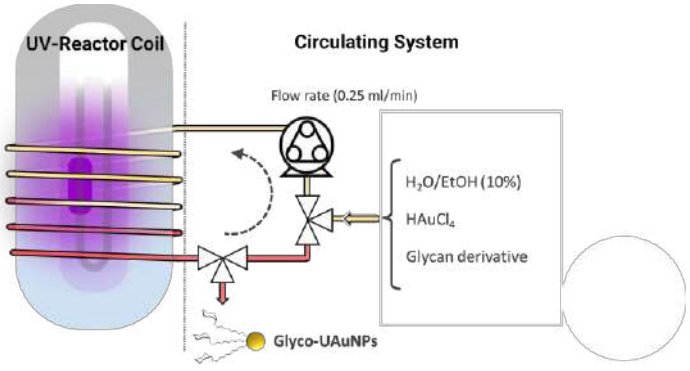

Figure 1: synthesis of ultra-small AuNPs

References:

[1] J. Nette, P. D. Howes, A, J. DeMello Adv. Mater. Technol. 2020, 2000060
[2] L. Polito et al. ACS Appl. Mater. Interfaces 2020, 12, 38522–38529
[3] L. Polito et al. Angew. Chem. Int. Ed., 2023, 62, e20221014

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Exploring the fascinating properties of *Bombyx mori* Silk fibroin in catalysis

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Social and environmental challenges require the continuous development of new materials. Consequently, exploring biomaterials presents a suitable alternative to achieve sustainable use of resources. In particular, the use of biopolymers as catalysts has increased considerably due to their natural availability, remarkable chemical efficiency, and interesting properties such as biodegradability, biocompatibility, and non-toxicity.[1] Within this context, Silk fibroin (SF), an attractive natural fibrous protein extracted from *Bombyx mori* silkworm cocoons, has gained increasing attention because of its natural accessibility, physical-chemical properties, biocompatibility, and adaptability.[2] Besides the traditional use in textile industry, SF is recognized as a versatile material that has been investigated as a promising resource in biomedicine, optoelectronics and many other technological applications. It is known that SF is an efficient support for Palladium, Platinum and Rhodium in hydrogenation reactions.[3]

This study reports the preparation of new heterogenous metal supported on SF catalysts.[4,5] Thus, SF-Palladium catalyst for Suzuki-Miyaura cross-coupling was prepared and optimized, often giving the desired pure biaryl as the only product in mild conditions, avoiding tedious purification steps and chromatography techniques. It is worth noting that Pd/SF showed high recyclability (up to 19 cycles) and it has been demonstrated that the catalyst exhibits a purely heterogeneous catalytic mechanism with no leaching during the reactions.

References:

[1] 1. R. Höfer, J. Bigorra, Green Chem. 2007, 9, 203.
[2] C. Z. Zhou, F. Confalonieri, Proteins: Struct. Funct. 2001, 44, 119-122.
[3] A. Akamatsu, Y. Izumi, Nature 1961, 34, 1067.
[4] G. Rizzo, G. Albano, Eur. J. Org. Chem. 2020, 45, 6992-6996.
[5] G. Rizzo, G. Albano, T. Sibillano, C. Giannini, R. Musio, F. G. Omenetto, G. M. Farinola, Eur. J. Org. Chem. 2022, e202101567.

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Regioselective Nitration of Polyaromatic Systems at Room Temperature

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Nitration of aromatic compounds is one of the most widely studied reactions and an immensely important industrial process due to the pivotal role of nitroarenes as precursors of industrial products and functional materials. Several reagents are available; the most common ones are mixtures of nitric and sulfuric acid, nitronium tetrafluoroborate, and acetyl nitrate. However, nitration reactions are notoriously unselective, leading mixture of isomers. Moreover, they require harsh conditions, by means of an excess of highly corrosive mineral acids at high temperatures. Crivello introduced the use of mixtures of ammonium nitrate and trifluoroacetic anhydride (TFAA) to nitrate a variety of aromatic compounds at room temperature in good yield.[1] However, this procedure has never been applied to polyaromatic compounds and the mechanism of the reaction is not explained to date in the case of nitrate salt.

9,9'-Spirobifluorene is a three-dimensional polyaromatic hydrocarbon compound receiving recently growing scientific and industrial interest due to the application of its derivatives in many technological fields.[2,3]

The nitration of 9,9'-spirobifluorene gives the 2,2′-dinitro-9,9′-spirobifluorene in fair yield (around 65%) under harsh conditions, which allows a very limited control of regioselectivity. Indeed, even working under carefully controlled reaction conditions, the mono-substituted 2-nitro-9,9′-spirobifluorene is recovered in very poor yield (11%).[4] Noteworthily, the formation of side products and the harsh conditions affect dramatically the reproducibility, as underlined by the different yields reported in the literature, ranging from 39 to 65%.

In this contribution we report the regioselective nitration of 9,9'spirobifluorene under mild conditions, that is, by using Menke and Crivello conditions, with very high yield. The presence of two independent fluorene units in one single compound allowed us a novel understanding of the mechanism originally described by Crivello.[5]

References:

[1] J. V. Crivello, J. Org. Chem. 1981, 46, 3056– 3060.
[2] L. Vaghi, F. Rizzo, Solar RRL 2023, 7, 22011081.
[3] F. Schlüter, K. Riehemann, N. S. Kehr, S. Quici, C. G. Daniliuc, F. Rizzo, Chem. Commun. 2018, 54, 642 – 645.
[4] J. H. Weisburger, E. K. Weisburger, F. E. Ray, J. Am. Chem. Soc. 1950, 72, 4253– 4255.
[5] D. Yousif, L. Vaghi, C. G. Daniliuc, R. Po, A. Papagni, F. Rizzo, J. Org. Chem. 2023, 88, 5285 – 5290.

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Catalyst-free Visible-Light Promoted Thiol-ene Reaction of Alkenes

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The thioether class is renowned among sulfur-containing scaffolds for its chemical versatility and vast applications in the pharmaceutical field as bioactive moieties.[1]

In this context, the thiol-ene reaction is considered to be a core methodology in modern chemistry to access *anti*-Markovnikov thioethers due to its robustness.[2] Traditionally, the straightforward coupling of an unsaturated C=C bond and a thiol requires highly energetic UV light (< 300 nm) to generate the reactive thiyl radicals, arising major challenges related to sustainability and chemoselectivity.[3] Recently, despite the considerable efforts that have been made to accomplish hydrothiolation reactions promoted by visible light,[4] there is still a need for costly photocatalysts and radical initiators to harvest its energy.[5]

In this framework, we unveiled a new activation mode based on the formation of a key photo-active complex between the thiol and its conjugated base, thus developing an innovative catalyst-free approach for the synthesis of *anti*-Markovnikov thioethers employing visible light (390 nm). Depending on the alkene structure, water can be employed either as an additive or as the alternative solvent to dichloromethane, thus increasing the sustainability of this methodology.

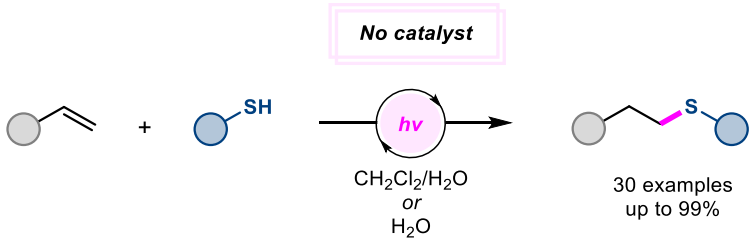

Figure 1: Catalyst-free hydrothiolation reaction of alkenes mediated by purple light for the synthesis of *anti*-Markovnikov thioethers.

References:
[1] K. A. Scott, J. T. Njardarson, *Top Curr. Chem.* **2018**, *376:5*.
[2] C. E. Hoyle, C. N. Bowman, *Angew. Chem. Int. Ed.* **2010**, *49*, 1540-1573.
[3] A. K. Sinha, D. Equbal, *Asian J. Org. Chem.* **2019**, *8*, 32-47.
[4] E. L. Tyson, Z. L. Niemeyer, T. P. Yoon, *J. Org. Chem.* **2014**, *19*, 1424-1436.
[5] A. Das, K. R. Thomas, *Eur. J. Org. Chem.* **2020**, 7214-7218.

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Characterization of disulfide bonds in the rat VDAC3 protein by high resolution mass spectrometry

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Voltage-Dependent Anion Channels (VDAC1, VDAC2, VDAC3) are mitochondrial outer membrane proteins whose primary function is to allow the communication and exchange of molecules between cytosol and mitochondrion. Despite the high sequence homology and the high structural similarity, the three VDAC isoforms show a different tissue dependent expression pattern, a variable abundance, a difference in cysteine content and are characterized by distinct, specific interactome partner.[1]

The present work is part of a research line concerning the structural characterization of VDAC proteins. We have reported the oxidation pattern of cysteines in rat and human VDACs using "in solution" proteolysis and nanoUHPLC/High Resolution nanoESI-MS/MS, a procedure originally developed by us.[2,3,4] Recently, the position of intramolecular disulfide bonds in the rat VDAC2, using a modification of this procedure to minimize disulfide reshuffling, was investigated.[5]

In the present work, we extended the analysis to the rat VDAC3 protein that contains 6 cysteines. Cys^{2} and Cys^{8} are present in the N-terminal region, which contains the channel voltage sensor; Cys^{165} is the only cysteine exposed to the cytosol, while the other cysteines (Cys^{36}, Cys^{65}, Cys^{122}, Cys^{229}) are located in the loops exposed to the intermembrane space (IMS).

Our results indicate the presence of disulfide bonds both in the N-terminal fragment of the protein and between the cysteines located in the loops exposed toward the IMS.

Here, we also present preliminary results about the possibility that intermolecular disulfide bridges can form between the three VDAC isoforms.

References:

[1] M.G.G. Pittalà, S. Conti Nibali, S. Reina, V. Cunsolo, A. Di Francesco, V. De Pinto, A. Messina, S. Foti, R. Saletti, Int. J. Mol. Sci. 2021, 22, 12833.

[2] R. Saletti, S. Reina, M.G.G. Pittalà, R. Belfiore, V. Cunsolo, A. Messina, V. De Pinto, S. Foti, Biochim. Biophys. Acta–Biomembr. 2016, 1859, 301-311.

[3] R. Saletti, S. Reina, M.G.G. Pittalà, A. Magrì, V. Cunsolo, S. Foti, V. De Pinto, Biochim. Biophys. Acta–Bioenerg. 2018, 1859, 806-816.

[4] M.G.G. Pittalà, R. Saletti, S. Reina, V. Cunsolo, V. De Pinto, S. Foti, Int. J. Mol. Sci. 2020, 21, 1468.

[5] M.G.G. Pittalà, S. Reina, A. Cucina, V. Cunsolo, F. Guarino, A. Di Francesco, S. Foti, V. De Pinto, R. Saletti, J. Am. Soc. Mass Spectrom., under review.

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Chirality sensing by chiroptical dithienyl probes

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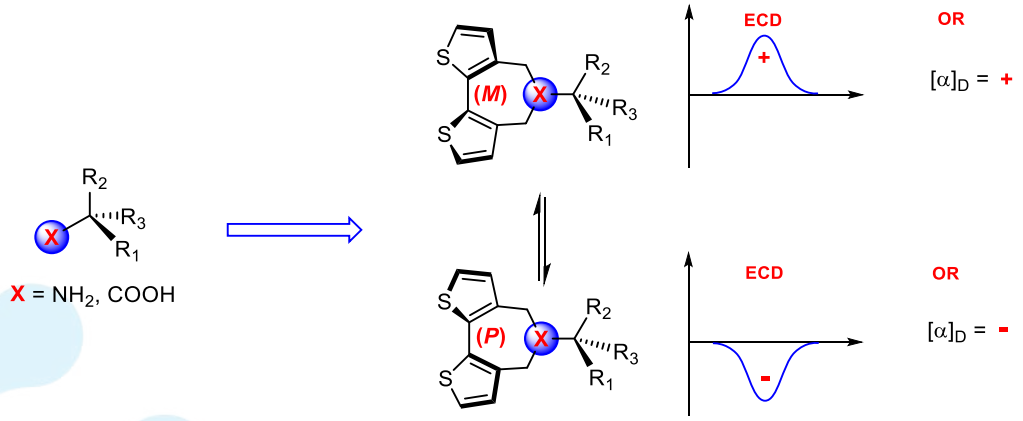
Chiral sensing and recognition are among the most relevant topics in many fields of chemistry, such as medicinal chemistry, natural product chemistry, material science, and environmental chemistry. In fact, the knowledge of the absolute configuration (AC) and enantiomeric composition of chiral molecules are prerequisites for the study of their properties and behavior both in the environment and in living organisms. One of the most promising approaches for chiral sensing is the use of stereodynamic chiroptical probes *i.e.* either achiral or racemic compounds which, when linked to the chiral analyte assumes a preferred chiral conformation giving rise to electronic circular dichroism (ECD) signal(s) from which the AC and/or the enantiomeric excess of the analyte can be determined. This approach allows the AC assignment in short time, in solution, and requires sub-milligram samples, thus being suitable to treat even not-crystalline natural products. Moreover, such methods constitute a practical alternative to computational chiroptical analyses, when dealing with conformationally flexible and/or UV-transparent (cryptochiral) molecules. In the past, our group described the use of flexible biphenyls probes for the assignment of AC of chiral diols,[1] carboxylic acids,[2] amines,[3] and complex natural products. Herein we report a novel *dithienyl probe* to determine the AC of chiral amines, acids and aminoacids. By transforming amines in the corresponding dithienyl azepines or acids in dithienyl amides, a preferred *M* or *P* twist is induced by the chiral substrate in the *bis*-heteroaromatic moiety, depending on its AC. The preferred twist can be detected by the sign of a diagnostic band in the ECD spectrum or by the Optical Rotation (OR) sign, thus arriving at the AC of the derivatized chiral compound.



References:

[1] S. Superchi, D. Casarini, A. Laurita, A. Bavoso, C. Rosini, *Angew. Chem. Int. Ed.* **2001**, *40*, 451.
[2] S. Superchi, R. Bisaccia, D. Casarini, A. Laurita, C. Rosini, *J. Am. Chem. Soc.*, **2006**, *128*, 6893.
[3] S. Vergura, L. Pisani, P. Scafato, D. Casarini, S. Superchi, *Org. Biomol. Chem.*, **2018**, *16*, 555.

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ORG-OR-036

Dimethyl carbonate mediated synthesis of 2,5-furandicarboxylic acid esters from galactaric acid

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2,5-Furandicarboxylic acid (FDCA) has been extensively studied as monomer for the production of polyesters[1] such as polyethylene furanoate (PEF), considered as one of the most valuable bio-based substitute of the petroleum-derived polyethylene terephthalate (PET).[2] Most of the synthetic processes to FDCA employ glucose and fructose as substrates via the formation of 5-hydroxymethyl furfural (HMF) as key intermediate (Figure 1, top reaction).[1] The main disadvantage of this process regards the intrinsic instability of HMF, together with its high market price and its difficult separation and purification, which ultimately lead to the production of humins, drastically lowering the overall reaction yield.[3] Few studies focused instead on the production of FDCA from alternative substrates. In fact, FDCA can be synthetized starting from aldaric acids, which can be obtained either via oxidation of sugars or directly extracted from citruses peel (Figure 1, bottom reaction).[4] From these premises, the present study reports an alternative synthetic procedure for the production of 2,5-furandicarboxylic acid dimethyl ester (FDME) starting from galactaric acid via dimethyl carbonate (DMC) chemistry. Both sulfonic resins and an iron-based Lewis acid showed to promote the one-pot formation of FDME. The pure product was retrieved as a white crystalline solid with an isolated yield of up to 70 %. Finally, on the basis of the different intermediates identified, a possible reaction mechanism was proposed, which highlights the essential contribute of DMC in the product formation.

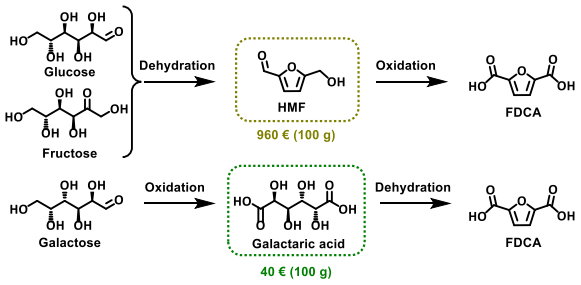

Figure 1: FDCA synthesis via HMF and galactaric acid routes.

References:

[1] G. R. Dick, A.D. Frankhouser, A. Banerjee, M.W. Kanan, Green Chem. 2017, 19, 2966.
[2] A.J.J.E Eerhart, A.P.C Faaij, M.K. Patel, Energy Environ. Sci. 2012, 5, 6407–6422.
[3] C. Thoma, J. Konnerth, W. Sailer-Kronlachner, P. Solt, T. Rosenau T., H.W.G. van Herwijnen, ChemSusChem 2020, 13, 3544.

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ORG-OR-037

P53 MODULATING SMALL MOLECULE DRUG CONJUGATES FOR TARGETED IMMUNO-ONCOLOGICAL THERAPY

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The significance and unique nature of protein interactions in cellular functions and the development of numerous pathological conditions have sparked interest in targeting protein-protein interactions for therapeutic purposes. In cancer, various cell surface protein receptors, including $\alpha_v\beta_3$, $\alpha_v\beta_5$ and $\alpha_5\beta_1$ integrins, are recognized as specific markers of tumor angiogenesis, advancement, and metastasis. We have recently reported the synthesis and the biological evaluation of small molecule drug conjugates (SMDCs) based on the selective $\alpha_v\beta_3$ integrin ligands: *cyclo*(DKP-RGD) and *cyclo*(DKP-*iso*DGR). The conjugates containing *iso*DGR ligands and several cytotoxic agents (e.g. paclitaxel, auristatins and α-amanitin) generally displayed high selectivity towards cells overexpressing integrins, maintaining nanomolar activity.[1] Tumor protein p53, known as "the guardian of the genome", is a critical regulatory protein in vertebrates, crucial for preventing cancer formation by regulating processes like cell cycle progression, apoptosis, and genomic stability. Its levels are typically kept low by the E3 Ubiquitin ligase MDM2, which, along with MDM4, facilitates its proteasomal degradation. However, in certain cancers, MDM2 overexpression leads to p53 inactivation. Recent research has unveiled a negative crosstalk between the transmembrane integrin receptor $\alpha_5\beta_1$ and p53, contributing to chemoresistance in glioblastoma (GBM).[2] Thus, in GBM, the overexpression of both $\alpha_5\beta_1$ and MDM2 leads to the degradation and downregulation of the p53 protein. These findings lay a strong foundation for developing conjugates that can simultaneously target $\alpha_5\beta_1$ integrin and MDM2 protein. In this study, we present the design, synthesis, and *in vitro* evaluation of novel immunomodulating SMDCs incorporating the MDM2 protein inhibitor, SAR405838,[3] and the $\alpha_5\beta_1$ integrin homing peptide, *cyclo*(phg-*iso*DGR-k),[4] for targeted delivery to GBM cancer cells (Figure 1).

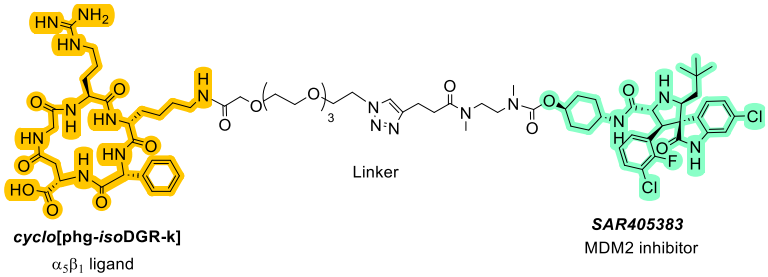

Figure 1: Schematic representation of the synthesized SMDC.

References:

[1] a. Bodero L., et al.,*Eur. J. Org. Chem*. 2021, 2383– 2387 b. Zambra M., et al., *Frontiers in Pharmacology* 2023, 14 c. Bodero L, et al. Beilstein *J Org Chem. 2018*, 14, 407-415
[2] Sani, S., et al., *Cancers* 2022, 14, 369
[3] Wang, S., et al., *Cancer Res.* 2014, *74*, 5855–5865
[4] Bochen, A., et al.; *J. Med. Chem.* 2013, *56*, 1509–1519

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ORG-OR-038

Synthesis, characterization and 3D bioprinting of hydrogels for the production of glioblastoma multiforme in vitro models

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Glioblastoma multiforme (GBM) remains one of the most aggressive and challenging brain tumors to treat with poor prognoses. Understanding the intricate molecular mechanisms driving GBM pathogenesis is crucial for the development of effective treatments. Three-dimensional (3D) in vitro models, reproducing the complexity of the tumor human microenvironment, are promising tools to identify personalized therapies. Addressing the limitations inherent in vivo animal models, which lack human cells and fail to faithfully recapitulate human physiology, underscores the significance of 3D in vitro models. This study aims to produce 3D in vitro models not only to faithfully mimic the extracellular matrix (ECM) but also to precisely replicate cell-ECM interactions crucial for cancer progression[1-3]. For that, we selected gelatin and hyaluronic acid as starting materials to formulate hydrogels upon proper crosslinking. Characterization of functionalized biomaterials was performed via Fourier-Transform Infrared Spectroscopy (FTIR) and Nuclear Magnetic Resonance (NMR) analysis. The physico-mechanical properties of the formulated hydrogels were assessed through swelling tests and rheometry, while the porosity was investigated with Scanning Electron Microscopy (SEM) analysis. Hydrogels were then bioprinted with GBM cell lines and spheroids. Biological experiments were conducted under both static and dynamic conditions, aiming to simulate the tumor microenvironment more accurately and study how the physical and biomolecular stimuli induce the cell behaviour. This comprehensive approach aims to advance our understanding of GBM pathobiology and facilitate the development of models for the validation of novel therapeutic strategies.

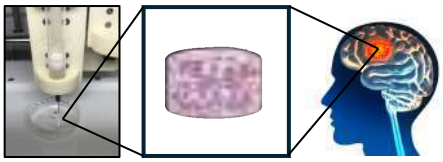

Figure 1: 3D Bioprinted model of Glioblastoma multiforme representation

References:

[1] F. Cadamuro, et al. J. Controlled Release 2023, 354, 726-745.
[2] F. Barbugian, et al. Carbohydr. Chem. 2021, 45, 572–608.
[3] F. Cadamuro, et al. Carbohydrate Polymers 2023, 302, 120395.

Acknowledgment: Iniziativa "PNC0000003 - "ANTHEM: AdvaNced Technologies for Human-centrEd Medicine". CUP BICOCCA B53C2200667000; Ministero della Salute, RF-2021-12371959 Tackling immunomodulatory properties of stromal cells to improve therapeutic strategies in lung cancer. MUR PRIN 2022, 2022MY7AZT Dynamic multifunctional hydrogels for glioblastoma therapy (DINGO).

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Melanin-based glycopolymer as a tool for bioinspired dynamic Galectin Binding

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Melanins are a group of insoluble dark pigments that are widespread in nature[1]. In mammals, brown-black eumelanins and yellow-red pheomelanins are major determinants of skin, hair and eye pigmentation and play a significant role in photoprotection and many biological functions. Due to their broad spectrum of light absorption, electrical conductivity, paramagnetic behaviour, and biocompatibility, eumelanins represent ideal candidates for biomedical applications. The biogenesis of eumelanins arises from the oxidative polymerization of the key intermediates 5,6-dihydroxyindole (DHI) and related derivatives. In a previous study, a thiogalactoside DHI (S-GAL-DHI) was synthesized that provides a powerful tool to access soluble eumelanins and thus to study eumelanin more thoroughly[2]. The main feature of S-GAL-DHI is its aptitude to undergo spontaneous oxidative polymerization under appropriate conditions, which leads to a biocompatible scaffold for exposing multivalent glycans and makes it a golden candidate for developing advanced protein antagonists/modulators. In this work, soluble eumelanin polymers were synthesized for the purpose of interacting with galectins. The galectins are a family of soluble β-D-galactoside-binding proteins characterized by a highly conserved carbohydrate recognition domain (CRD),[3] involved in several cellular processes, their altered expression or localization is associated with various pathologic conditions. Thus, discovering inhibitors is a critical issue. Within this framework, the synthesis of water-soluble eumelanins was carried out with the aim of studying their interaction with galectins, in order to design eumelanin-based activable galectin inhibition. A combined UV-Vis spectrophotometric/Dynamic Light Scattering approach was adopted to follow oxidation and polymerization over time. Then, the interaction of Galectin-3 CRD with melanins and precursors thereof was assessed by isothermal titration calorimetry.

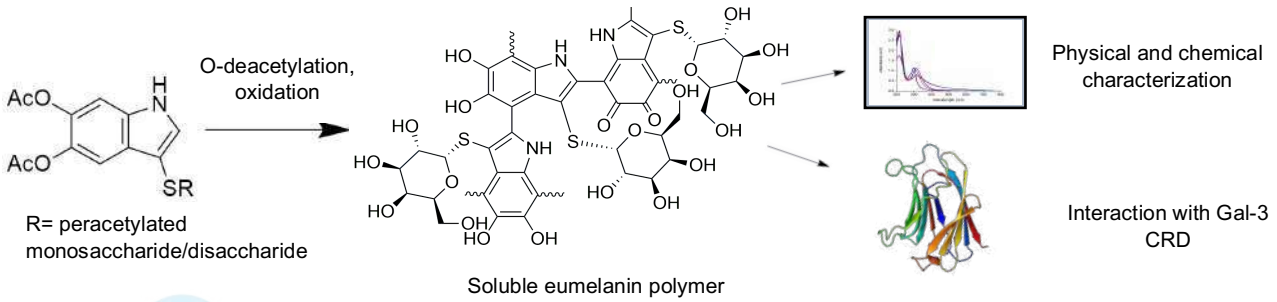

Figure 1: Synthesis and characterisation of water-soluble melanin and its interaction with Galectin-3 CRD.

References:

[1] M. D'Ischia, K. Wakamatsu, A. Napolitano, S. Briganti, J. C. Garcia-Borron, D. Kovacs, P. Meredith, A. Pezzella, M. Picardo, T. Sarna, J. D. Simon, S. Ito, S. Pigment Cell and Melanoma Research 2013, 26 (2), 616-633.
[2] A. Pezzella, A. Iadonisi, S. Valerio, L. Panzella, A. Napolitano, M. Adinolfi, M. d'Ischia, J. Am. Chem. Soc. 2009, 131 (42), 15270–15275.
[3] D. Laaf, P. Bojarová, L. Elling, V. Křen, Trends Biotechnol. 2019, 37 (4), 402–415.

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ORG-OR-040

Exploring the chemical space of antidiabetic marine sesquiterpene avarone by synthesis of 1,4-benzoquinones for targeting PTP1B and aldose reductase

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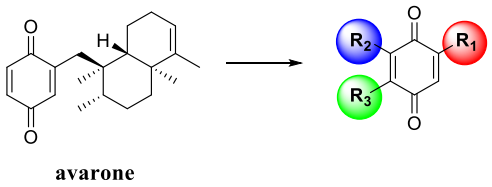
Type 2 diabetes mellitus (T2DM) is a complex disease characterized by a persistently elevated blood glucose and serious long-term complications. T2DM is an ongoing, risky, and costly health problem which often requires the concurrent administration of several hypoglycemic drugs increasing the risk of side effects[1]. Therefore, the use of multitarget drugs is an emerging strategy to treat this multifactorial disease. Marine Natural Products (MNPs) are a great resource for this purpose since they occupy much of the chemical space with pharmacological value due to their high chemical diversity. Additionally, MNPs may serve as biologically validated starting points for the design of focused libraries for novel ligands with enhanced properties. In this view, we demonstrated that the marine sesquiterpene quinone avarone (Figure 1), isolated from the sponge *Dysidea avara*, is a potent inhibitor of both PTP1B and aldose reductase (AKR1B1), emerging targets involved in the onset and progression of T2DM. The thorough pharmacological characterization revealed that avarone has both insulin-sensitizing and mimetic activity on muscle C2C12 cells[2]. Thus, avarone was selected as a natural hit compound for designing multitarget agents for diabetes. To explore its antidiabetic potential, a focused chemical library of 1,4-benzoquinone-derived compounds was synthesized by a versatile and regioselective protocol (Figure 1). All the simplified and modified synthetic derivatives were screened against both enzymes, and preliminary SARs have been performed. The obtained results highlighted that modification on the alkyl side chains and/or the quinone ring may strongly affect the interaction with enzymatic counterpart underlying different antidiabetic mechanism of action for the synthetic analogues.



avarone

Figure 1: Structures of the sesquiterpene avarone and its designed analogues.

References:

[1] A. Artasensi, et al., Molecules 2020, 25, 1987.
[2] M. Casertano, et al., Pharmaceutics 2023, 15, 528.

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ORG-OR-041

Targeting L-SIGN: a potential tool against SARS-CoV-2.

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The C-type lectin receptors (CLRs) DC-SIGN and L-SIGN are known to interact with surface glycoproteins of many pathogens, thus inducing activation of the initial stages of the adaptive immune response. Nevertheless, several deadly viruses - such as HIV, Ebola, hepatitis C viruses - have developed strategies to subvert the natural role of CLRs and use them to promote virus internalization and dissemination.[1] The recent discovery that also SARS-CoV-2 can exploit DC and L-SIGN to adhere to the host and enhance its infection, has stimulated the development of antagonists for these receptors [2,3] and in particular against L-SIGN, which is co-expressed with the viral entry receptor ACE2 in the lungs and in endothelia. However, designing selective L-SIGN ligands is extremely challenging, due to the very high similarity of the two lectins (ca. 80% homology).

We have recently reported the first class of highly selective L-SIGN ligands, whose structure relies on a mannose scaffold modified at position 2 with a methylene guanidine triazole. The first member of this class, **Man84,** displays 50-fold selectivity for L-SIGN against DC-SIGN.[4] Inspired by this molecule, we here present a new set of glycomimetics, able to keep and, in some cases, improve the aforementioned selectivity. All the designed antagonists are based on a mono-mannose scaffold, modified at position 2 with a triazole moiety, decorated with a guanidinium isosteric group. Their synthesis and biological activity will be described and the structure-activity relationship (SAR) of the isosters' set will be discussed.

Acknowledgments: the project is supported by EU funding within the NextGeneration EU-MUR PNRR Extended Partnership initiative on Emerging Infectious Diseases (Project no. PE00000007, INF-ACT). We are grateful to Dipharma Francis s.r.l. for their support in the scale up of crucial intermediates for this project.

References:

[1] P.P. Avdonin, E.Y. Rybakova, S.K. Trufanov, P.V. Avdonin, *Biochem.(Mosc.) Suppl.Ser.A Membr.Cell Biol*., 2023, 17, 1-11 and refs. therein.

[2] M. Thépaut, J. Luczkowiak, C. Vivès, N. Labiod, I. Bally, F. Lasala, Y. Grimoire, D. Fenel, S. Sattin, N. Thielens, G. Schoehn, A. Bernardi, R. Delgado, F. Fieschi, *PLoS Pathogens,* 2021, 17: e1009576.

[3] S. Pollastri, C. Delaunay, M. Thépaut, F. Fieschi, A. Bernardi, *Chem. Commun.,* 2022, *58*, 5136–5139.

[4] C. Delaunay, S. Pollastri, M. Thepaut, G. Cavazzoli, L. Belvisi, C. Bouchikri, N. Labiod, A. Gimeno, A. Franconetti, J. Jiménez-Barbero, A. Arda, R. Delgado, A. Bernardi, F. Fieschi, *ChemRxiv*, DOI: 10.26434/chemrxiv-2023-tf1fg, Dec. 2023

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ORG-OR-042

Targeting ferroptosis in *Pyricularia oryzae*

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Rice *(Oryza sativa L.)* is the major staple food for more than 50% of world's population. The rice-blast fungus *Pyricularia oryzae* is the most destructive rice pathogen worldwide, causing globally between 20% and 40% yield losses. The management of the rice blast disease requires a massive application of fungicides, which accounts for more than 8% of total fungicide market.[1]

Diverse classes of fungicides, during the years, have been used against *P.* oryzae,[2,3] including strobilurins and demethylation inhibitors (DMI).[4] Both classes of antifungal compounds have a single-site mode of action and the fungal pathogen populations developed resistance to them. For this reason, the identification of new targets and the discovery of new scaffolds to combat the pathogen is urgently needed.

The modulation of ferroptosis, a form of iron-dependent cell death, has recently emerged as a potential new strategy to control fungal pathogenesis. Ferroptosis, in *P. oryzae*, starts from the terminal conidial cell, and then progresses to the other two cells during the appressorium formation and maturation, and this ferroptotic cell death is required for the infection. Herein, we present the synthesis and biological evaluation of natural (Figure 1) and nature-inspired iron chelators (siderophores), containing the catecholamide moiety, as potential inhibitors of ferroptosis in *P. oryzae.*

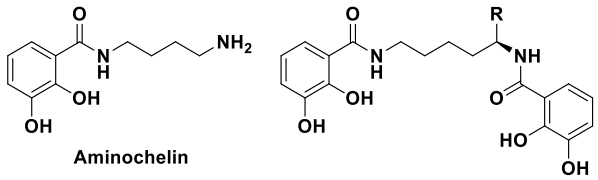

Figure 1. Natural siderophores.

References:

[1] J.C. Collins, *Pesticide Chemistry, Crop Protection, Public Health, Environmental Safety*, Wiley VCH Verlag, Weinheim, Germany, **2007**, pp. 3 – 12.

[2] H. Ishii, *Fungicide Resistance in Plant Pathogens*, Springer, Tokyo, Japan, **2015**, pp. 341 – 354.

[3] A. Kunova, P. Cortesi, *Fungicides: Classification, Role in Disease Management and Toxicity Effects*, Nova Science Publishers, New York, NY, USA, **2013**, pp. 39 – 66.

[4] Fitogest®Image Line Fitogest®. Available online: https://fitogest.imagelinenetwork.com/it/

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Design and synthesis of polyamines as tools to develop highly performing ferritin-conjugates for RNA therapeutics.

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Cancer is one of the most health and socioeconomic disease worldwide. Despite significant progresses have been registered, and several drugs are available to treat cancer, the onset of resistance is a major drawback that often causes the failure of the treatment.[1] Recently, new therapies based on small interfering RNA (siRNA), micro-RNA mimics (miR mimics), and antisense micro-RNA (antagomiR) have been largely exploited to cure cancer, neurodegenerative diseases, and some rare diseases.[2] In the last decade, to circumvent the obstacles imposed by delivery vehicles such as nanoparticles which are composed of potentially toxic exogenous materials, the development of protein-based systems (HumAfFt) as well as chemical modifications of canonical oligoribonucleotides have been considered as promising strategies to improve RNA delivery, stability and efficacy.[3] RNA encapsulation in HumAtFt can be achieved by means of poly-cationic molecules (PCs), which can both specifically bind to the protein and stabilize the oligonucleotide through electrostatic interactions. In order to evaluate a structure-encapsulation relationship between PCs and oligonucleotide, a library of polyamine molecules (PA) (Figure 1) was rationally designed and synthesized featuring a pentafluorobenzene sulfonamine moiety to ensure the anchorage of the polyamines to the cysteine residues of HumAfFt. The first series features cyclic amines which were synthesized by performing subsequent reductive amidation reactions starting from *N*-methyl-4-piperidone and final introduction of the pentafluorobenzene moiety. On the other hand, linear PAs were synthesized by performing subsequent Steglich couplings to join glycine, β-alanine, and methylamine as major building blocks of this series with further introduction of the selective moiety for thiols. Results obtained with cyclic PAs highlighted an efficient siRNA delivery and a good silencing action on glyceraldehyde-3-phosphate dehydrogenase (GAPDH) gene expression in three cancer cell lines.

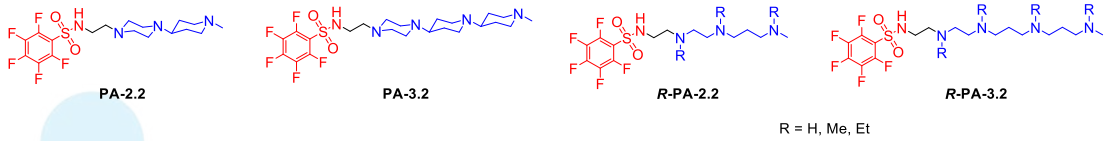

Figure 1: Chemical structures of polyamine molecules **PA-2.2**, **PA-3.2**, ***R*-PA-2.2**, and ***R*-PA-3.2**.

References:

[1] Y. Li, Z. Wang, J. A. Ajani, S. Song, Cell Communication and Signaling 2021, 19, 1-11.
[2] Z. Tian, G. Liang, K. Cui, Y. Liang, Q. Wang, S. Lv, X. Cheng, L. Zhang, Frontiers in Pharmacology 2021, 12, 308.

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ORG-OR-044

Structural and Immunological characterization of lipopolysaccharide from gut microbe *Prevotella copri*

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Prevotella copri is an abundant member of the human gastrointestinal microbiota.[1] Owing to its vast distribution and variable abundance, studies are contradictory about whether it is beneficial or detrimental to human health. As a Gram-negative bacterium, it expresses lipopolysaccharide (LPS) on the external leaflet of its outer membrane. LPSs are amphiphilic macromolecules consisting of a hydrophilic hetero-polysaccharide (formed by the Core oligosaccharide and the O-Antigen) covalently linked to a lipophilic domain termed Lipid A.[2] Besides this general architecture, structural variations potently influence their biological activity. Indeed, LPSs are largely known as potent immunostimulatory molecules able to interact with key receptors of the human innate immune system, leading to potent inflammatory reactions aimed at eradicating the bacterial infection.[2] Nevertheless, LPS immunological properties are strongly dependent on their chemical structures and therefore even the most subtle chemical alteration can dramatically affect the resulting immune response, exhibiting different trends in the induction of an inflammatory reaction.[2]

This acknowledged concept faces the reality of the human gut. Indeed, the intestinal tract is home for more than one thousand billion bacteria, most of which are equipped with LPS, but remain harmless and, in some cases, even beneficial for human health.[3] How LPS is tolerated in the gut is a major unresolved question representing a frontier in our understanding of innate immunity. The answer to this question resides in the peculiar chemistry of LPS from harmless gut microbes that must differ from their pathogenic counterparts. Overall, the elucidation of the structure and the immunological activity of LPS from microbiota will bear new advances in the medicinal chemistry and in the field of search of new molecules able to prevent uncontrolled host immune response against our own microbiota.

In this communication, I will describe the structural and immunological determination of the LPS from *P. copri* which entailed the combined use of chemical analyses and degradations, NMR and mass spectrometry studies, as well as cell culture experiments. A novel LPS structure was disclosed which was reflected in a moderate activator of TLR4-mediated immune response.

References:

[1] N.A. Abdelsalam, S.M. Hegazy, R.K. Aziz, Gut Microbes 2023, 15(2), 2249152.
[2] F. Di Lorenzo, K.A. Duda, R. Lanzetta, A. Silipo, C. De Castro, A. Molinaro. Chemical Reviews 2022, 122(20),15767-15821.
[3] F. Di Lorenzo, C. De Castro, A. Silipo, A. Molinaro. FEMS Microbiol Rev. 2019, 43(3), 257-272.

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ORG-OR-045

Novel Olanzapine-based PROTACs Targeting Human D-Aspartate Oxidase (DASPO)

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D-Aspartate oxidase (DASPO) plays a crucial role in the catabolism of D-amino acids, particularly D-aspartate (D-Asp), an activator of *N*-methyl-D-aspartate (NMDA) receptors. Dysregulation of NMDA receptor function is implicated in various mental disorders such as schizophrenia. Thus, inhibiting DASPO could potentially elevate D-Asp levels in the brain, thereby improving NMDA receptors activity and offering therapeutic benefits.[1] Olanzapine, a well-known antipsychotic drug, has been identified as a potent inhibitor of DASPO, increasing extracellular D-Asp levels in the prefrontal cortex.[2]

Building upon this finding, we have employed Proteolysis Targeting Chimeras (PROTAC) technology to target DASPO using bifunctional compounds based on the structure of Olanzapine. The primary aim of PROTACs is to induce the degradation of proteins within cells *via* the proteasomal pathway, leading to an enhancement of intracellular D-Asp levels.[3] This innovative approach holds promise for addressing conditions associated with D-Asp deficiency.

We designed a panel of new bifunctional molecules starting from Olanzapine and incorporating aliphatic, amide-based, or PEGylated linkers (Figure 1). Chosen E3 ligase binders were lenalidomide and VHL ligand. Synthesis of the compounds was achieved through efficient "click" chemistry approaches. Preliminary biological evaluation revealed that MGA26 displayed significant DASPO inhibition (IC_{50} = 4.13 μM) and impacted cellular levels of DASPO.

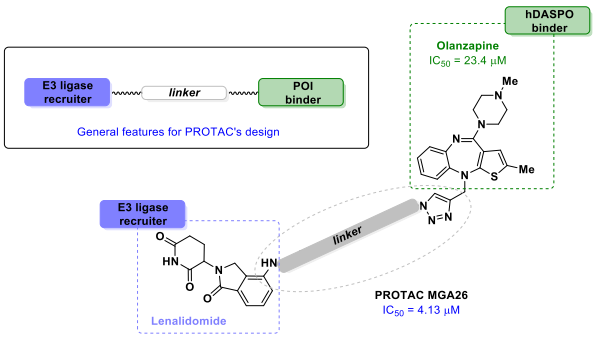

Figure 1: design of novel Olanzapine-based PROTACs targeting DASPO.

References:

[1] L. Pollegioni, G. Molla, S. Sacchi, G. Murtas, *Frontiers in Molecular Biosciences* **2021**, *8*, 689719.
[2] S. Sacchi, V. De Novellis, G. Paolone *et al.*, *Scientific reports*, **2017**, *7* (1), 46288.
[3] C. Wang, C. Zheng, H. Wang, L. Zhang, Z. Liu, P. Xu, *European Journal of Medicinal Chemistry*, **2022**, *235*, 114290.

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ORG-OR-046

Rational design of multi-target modulators interfering with the three main pathways of the arachidonic acid cascade

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Developing compounds targeting multiple pathways is a promising strategy in medicinal chemistry, offering synergistic effects and potential dose reduction. Here, the design, synthesis and biological behaviour of new compounds able to inhibit different targets within the arachidonic acid (AA) cascade are reported.[1] Starting from 1,3,4-thiadiazole based compounds (Figure 1), previously discovered by us as microsomal prostaglandin E_2 synthase-1 (mPGES-1) inhibitors,[2] we decided to modulate the inhibitory activity also against soluble epoxide hydrolase (sEH) and 5-lipoxygenase (5-LO). Therefore, we generated new combinatorial virtual libraries of molecules modifying the phenyl moiety at position 5, while keeping the substituents unchanged in position 2. After *in silico* investigations based on molecular docking calculations, the best-selected compounds were synthesized starting from substituted 2-(4-bromobenzylidene)hydrazinecarbothioamides, obtained by reaction between substituted 4-bromo-benzaldehydes and thiosemicarbazide followed by cyclization reactions with I_2 to give 2-amine-1,3,4-thiadiazoles. The final compounds were obtained using Pd-catalyzed Suzuki-Miyaura cross-coupling and acylation. The effects of synthesized molecules against the three targets of interest were investigated by different biochemical and enzymatic assays, disclosing **2**, **5**, and **7**, as active compounds able to inhibit all the three targets at low micromolar concentrations, while other six compounds showed dual inhibitor activity. Last, MTT assays were performed to evaluate the J774 murine macrophage cell viability, disclosing compound **2** as the most promising one for the *in vivo* and *ex-vivo* experiments of acute peritonitis model.

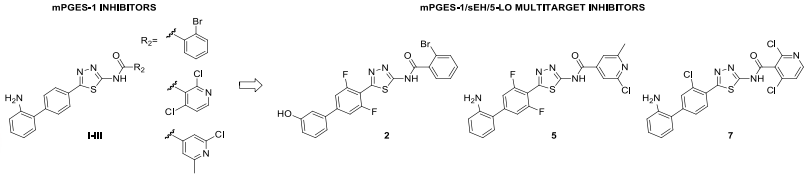

Figure 1: Structure of the initial hit compounds (**I-III**) and the active multitarget inhibitors (**2**,**5**,**7**).

References:

[1]AIRC IG 2023-ID 28846 (PI: Prof. Giuseppe Bifulco) project funded by the Italian Association for Cancer Research.
[2]M. Potenza, A. Giordano, M. G. Chini, A. Saviano, C. Kretzer, F. Raucci, M. Russo, G. Lauro, S. Terracciano, I. Bruno, M. Iorizzi, S. Pace, F. Maione, O. Werz, G. Bifulco ACS Medicinal Chemistry Letters 2022, 14, 26-34.

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Semisynthetic glycoconjugates based on capsular polysaccharide fragments of *Haemophilus influenzae* type a as potential vaccine candidates

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Glycoconjugate vaccines, which combine pathogen-associated carbohydrates with immunogenic carrier proteins, are a highly cost-effective strategy for preventing bacterial, viral, and fungal infections. While most licensed glycoconjugate vaccines currently derive their saccharide antigens from bacterial sources, synthetic oligosaccharide antigens offer a promising alternative[1]. These well-defined structures provide homogeneous constructs. *Haemophilus influenzae* (Hi), a significant cause of severe diseases like meningitis, sepsis, and otitis in young children, has recently seen an increased rate of invasive infections caused by Hi serotype a[2,3]. Unfortunately, no vaccine specifically targeting Hia is currently available. The capsular polysaccharide (CPS) of Hia consists of phosphodiester-linked repeating units of 4-β-D-Glucose-(1→4)-D-ribitol-5-(PO_4→) and serves as the antigen for protein-conjugated polysaccharide vaccines[4]. To explore the potential of Hia CPS as an antigen, we synthesized well-defined oligosaccharides with varying chain lengths, containing up to five repeating units (Figure 1). After optimizing the required monosaccharide building blocks synthetically, we assembled them through fine-tuned glycosylation reactions and combined them using the phosphoramidite approach. The resulting CPS-based Hia oligomers were then conjugated to the CRM_{197} carrier protein and evaluated for their immunogenic potential in a rat animal model. The results demonstrated that all prepared glycoconjugates induced antibodies that bound to Hia oligosaccharides; hence, the well-defined synthetic oligosaccharides can potentially mimic Hia CPS and the obtained glycoconjugates could be employed for the development of anti-Hia glycoconjugate vaccines.

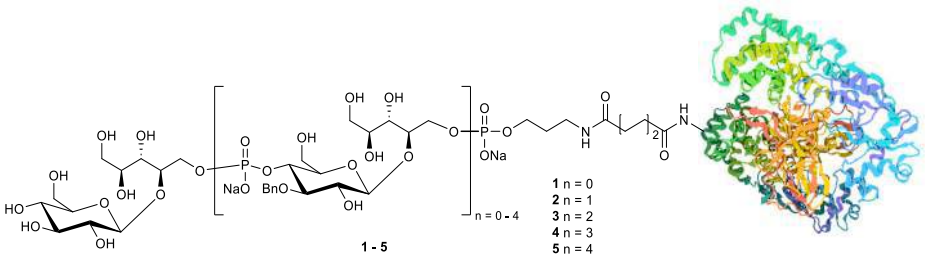

Figure 1: Structure of the synthesized Hia oligomers-CRM_{197} conjugates.

References:

[1] M. E. Zasłona et al., Biochem Soc Trans, 2021, vol. 49, no. 5, pp. 2411-2429
[2] M. Ulanova and R. S. W. Tsang, Lancet Infect Dis, 2014, vol. 14, no. 1, pp. 70-82.
[3] M. Bertran et al., Lancet Infect Dis, 2023, vol. 23, no. 10, pp. 1197-1206.

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Affinity Enhancement of Protein Ligands by Reversible-Covalent Engagement of Lysine Residues

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The design of synthetic small drugs capable of forming a covalent bond with the target protein of interest typically aims at stabilizing the drug-protein complex and to improve the pharmacological effects.

The amino acid Lysine (Lys) is highly abundant in the proteome and one of the most frequent residues on the outer structural layers of proteins. Due to thi s high frequency, the derivatization of synthetic ligands with aldehyde tags capable of imine bond formation with Lys ε-amino groups may represent a general strategy for the discovery of potent small-molecule inhibitors.

Ortho-hydroxy aldehydes such as pyridoxal or salicylaldehyde (SA) derivatives have been used to form imines in aqueous media, stabilized by an intramolecular H-bond between the imine N atom and the ortho-phenolic proton. By virtue of this reactivity, SA derivatives are being installed into various classes of protein ligands, aimed at the reversible-covalent engagement of protein Lys residues.[1,2,3]

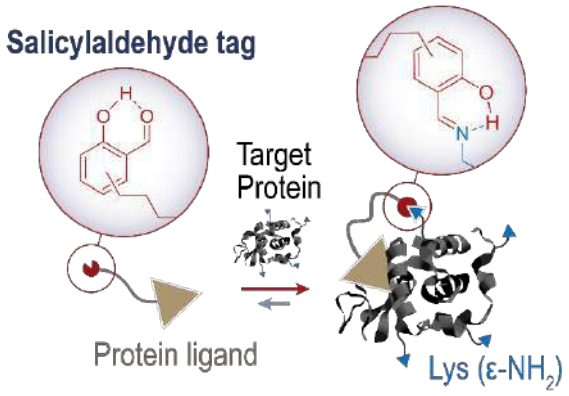

Figure 1: "Dock and Lock" mechanism of small protein ligands bearing the salicylaldehyde tag.

References:

[1] A. Dal Corso, M. Catalano, A. Schmid, J. Scheuermann, D. Neri, *Angew. Chem. Int. Ed.* **2018**, *57*, 17178-17182.

[2] G. Sacco, D. Arosio, M. Paolillo, A. Gloger, J. Scheuermann, L. Pignataro, L. Belvisi, A. Dal Corso, C. Gennari, *Chem. Eur. J.* **2023**, e202203768.

[3] M. Mason, L. Belvisi, L. Pignataro, A. Dal Corso, *ChemBioChem* **2023**, e202300743.

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Chemical synthesis and computational chemistry: a powerful combination for the identification of a new alternative approach to antitumoral therapy

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Leukemia inhibitory factor (LIF) is the most pleiotropic member of the IL-6 family of cytokines which plays a prominent role in inflammation, autoimmunity, and cancer. Its receptor is leukemia inhibitory factor receptor (LIFR, also known as CD118) and is expressed in liver, bone, uterus, and the central nervous system. After binding the cytokine, the transphosphorylation of Tyr1034 induces a conformation change which causes JAK1 activation. Thus, JAK1 initiates a cascade of tyrosine phosphorylation that stimulates three distinct signaling cell-type specific pathways. The JAK/STAT, MAP-kinase and PI(3)kinase pathways contribute to cell differentiation, survival and self-renewal; the balance of all these determines the cell fate. Several studies reported the role of LIF/LIFR axis in the cancer progression, even if the mechanism is poorly defined. Thus, the inhibition of LIFR signalling could have beneficial effects on cell growth and tumour progression in several cancers. In 2019, a novel study identified a first-in-class inhibitor of LIFR, EC359, which directly interacts with LIFR to block LIF/LIFR axis[1]. This compound can reduce invasiveness and stemness and promote apoptosis. Furthermore, first results obtained through in silico strategy have shown that mifepristone could act as LIFR antagonist[2]. Computational studies have also revealed that it partially overlapped the LIFR binding site. In view of the antagonistic activity of Mifepristone and EC359 on the LIF-LIFR axis, we focused our attention on the simplification and optimization of the synthetic process[3].

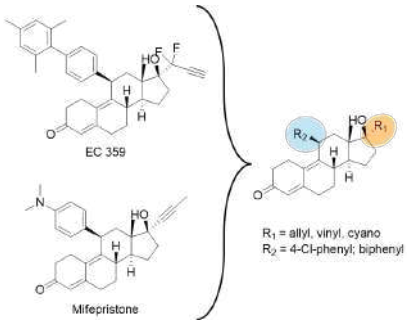

Figure 1: LIF/LIFR inhibitors' structure

References:

[1] Viswanadhapalli, S. *et al*. Mol Cancer Ther 2019, 18, 1341–1354.
[2] Di Giorgio, C. *et al*. Cells 2022, 11, 3482.
[3] Di Giorgio, C., Bellini, R., Lupia, A. *et al*. Cell Oncol. 2023.

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Discovering Cyclic Peptoids: Structures and Bioactivities of a Proteiform Scaffold

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The field of peptoids (*N*-substituted glycines oligomers) is one of the most promising in the peptidomimetic arena. However, although hundreds of structures have been reported in recent times,[1] few reports deal with:

1) the interplay between the configurational and conformational ordering;[2]

2) the chelating attitudes of the oligoamide backbone and the biological activities of the metal complexes;[3]

3) their chemical transformation in further chemical entities (such as the azamacrocycles).[4]

In this communication we report studies correlating sequence, structures, and functions of α-cyclic peptoids and describe how crucial intramolecular interactions, cationic hosts, and strategically positioned stereogenic centers forge their morphologic attributes.

The advances in the field of cyclic peptoids represent the first steps for the foundations of a rational design of protein mimetics and a possible model on which to base drug design and supramolecular/biomimetic chemistry. Moreover, the expansion of large-scale monomer assembly and the shift towards water-soluble cyclic oligomers, will certainly enable cyclic peptoids to be used as high-information content structures with unexpected properties.

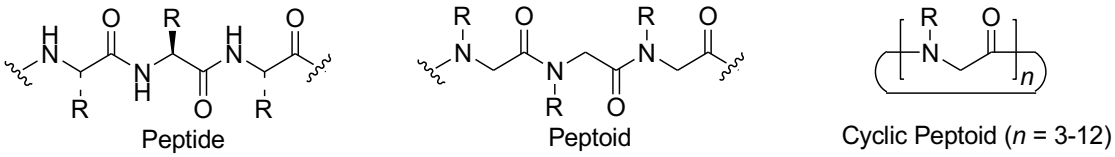

Figure 1: Structural comparison between a peptide, a peptoid and a cyclic peptoid.

References:

[1] (a) R. Schettini, C. Costabile, G. Della Sala, V. Iuliano, C. Tedesco, I. Izzo, F. De Riccardis, *J. Org. Chem.* **2018**, *83*, 12648. (b) R. Schettini, M. Sicignano, F. De Riccardis, I. Izzo, G. Della Sala, *Synthesis*, **2018**, *50*, 4777. (c) A. D'Amato, R. Volpe, M. C. Vaccaro, S. Terracciano, I. Bruno, M. Tosolini, C. Tedesco, G. Pierri, P. Tecilla, C. Costabile, G. Della Sala, I. Izzo, F. De Riccardis, *J. Org. Chem.* **2017**, *82*, 8848. (d) A. Meli, E. Macedi, F. De Riccardis, V. J. Smith, L. J. Barbour, I. Izzo, C. Tedesco *Angew. Chem.*, *Int. Ed.,* **2016**, *55*, 4679.

[2] (a) A. D'Amato, P. Ghosh, C. Costabile, G. Della Sala, I. Izzo, G. Maayan, F. De Riccardis, *Dalton Trans*., **2020**, *49*, 6020. F. De Riccardis, *Eur. J. Org. Chem.* **2020**, 2981. (b) A. D'Amato, R. Schettini, G. Della Sala, C. Costabile, C. Tedesco, I. Izzo, F. De Riccardis, *Org. Biomol. Chem.* **2017**, *15*, 9932.

[3] (a) A. D'Amato, G. Pierri, C. Tedesco, G. Della Sala, I. Izzo, C. Costabile, F. De Riccardis, *J. Org. Chem.* **2023**, *88*, 6588. (b) C. De Cola, G. Fiorillo, A. Meli, S. Aime, E. Gianolio, I. Izzo, F. De Riccardis, *Org. Biomol. Chem.* **2014**, *12*, 424.

[4] (a) R. Schettini, A. D'Amato, A. M. Araszczuk, G. Della Sala, C. Costabile, A. M. D'Ursi, M. Grimaldi, I. Izzo, F. De Riccardis, *Org. Biomol. Chem*., **2021**, *19*, 7420. (b) R. Schettini, A. D'Amato, G. Pierri, C. Tedesco, G. Della Sala, O. Motta, I. Izzo, F. De Riccardis, *Org. Lett.,* **2019**, *21*, 7365.

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Design and antimicrobial activity of short antimicrobial peptides (SAMPs) as promising agents against resilient infections

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Concomitantly to the explosion in the development of potent antibiotics, a concerning rise in resistance to targeted drugs has emerged, largely attributable to the dual forces of antibiotic use selective pressure and spontaneous genetic mutations. Recognized as a threat to humanity, antibiotic resistance looms large. Thus, short antimicrobial peptides (SAMPs) emerge as a promising therapeutic alternative to traditional antibiotics.[1] SAMPs, characterized by their widespread occurrence and nonspecific modes of action, exhibit notable efficacy against a broad spectrum of bacteria, while displaying a reduced propensity for resistance development. Their inherent susceptibility to enzymatic degradation necessitates modifications for optimal performance, achieved through the incorporation of modified or unnatural amino acids into the peptide sequence or via C- and N-terminal functionalization, which also confer them hydrophobic and cationic nature, important for selective microbial binding and lysis. Our research was focused on the investigation of novel short peptides and peptidomimetics, starting from the smallest antimicrobial peptide sequence in Phase II clinical trials, LTX-109. Structural refinements to the original peptide sequence led to the discovery of new potent antimicrobial peptides with modulated lipophilicity, steric hindrance and charge, evaluated against both standard bacterial strains and clinical isolates from patients with chronic, non-healing infected wounds. Computational studies elucidated the mechanisms of action, establishing structural correlations with observed antimicrobial efficacy. In a targeted approach towards addressing chronic non-healing wounds, a selected SAMP was integrated into a multi-layered, non-adhesive biomaterial, offering a potential solution for enhanced wound treatment.

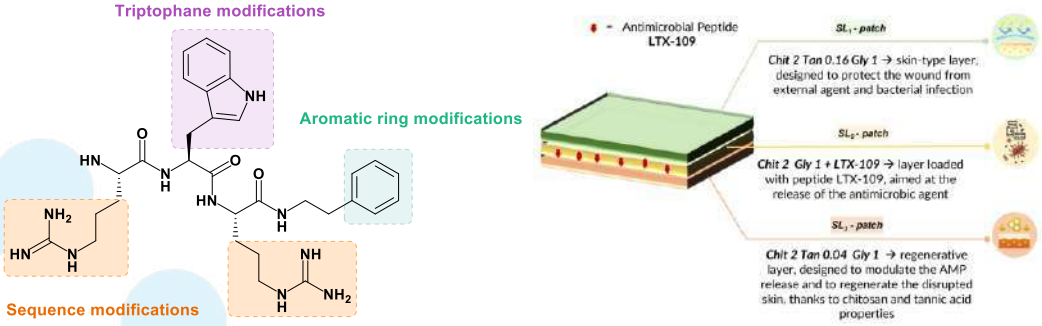

Figure 1. Structural modifications introduced in new SAMPs.

References:

[1] L. Sharma, G.S. Bisht, Curr Pharm Des. 2023, 29(38), 3005-3017.

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From design to in vitro evaluation, through synthesis: a new way of being an organic chemist.

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Over time, organic synthesis has often been accompanied by paper-based planning and characterized by obtaining, sometimes unpredictably, reaction intermediates that were more interesting than the expected compounds. For a decade, especially in the field of the synthesis of new drugs, the design phase has become important; molecular modeling as well as docking have become tools to support, facilitate and streamline the organic chemist's synthesis work. In this presentation we will take a journey through drug-receptor interaction studies, which will support the synthesis of new heterocyclic compounds and/or the extraction of compounds from Bronte pistachio (FRASTUCA PRIN 2022 project; CUP: E53D2301006 0006) with potential antibacterial[1], anti-inflammatory[2] and anti-tumor activity[3]. In silico studies of the ADME properties and the predictions of in vitro activity which will be confirmed by the relevant in vitro and in vivo assays accompanied by mechanism of action prediction studies.

References:

[1] C. Bonomo, P.G. Bonacci, D. Bivona, A. Mirabile, D. Bongiorno, E. Nicitra, C. Bonaccorso, C. G. Fortuna, S. Stefani, Antibiotics, 2023, 12, 1308 – 1312.
[2] C. G. Fortuna, M. G.Perrone, A. Scillimati et al. 2023, Eur. J. Med. Chem, 266, 116135 – 116140.
[3] C. G. Fortuna, M. G.Perrone, A. Scillimati et al. 2023, Pharmaceuticals, 17, 135 –140

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Analyzing the interaction between RNA and RBPs (RNA-binding proteins) by NMR spectroscopy: the introduction of small molecules as third wheel

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Hu (or ELAV-L) proteins belong to the class of RNA- Binding Proteins (RBPs) whose main role is to form complexes with mRNAs thus modulating the production of specific proteins.[1] HuR is a member of this family, and its target mRNAs encode proteins involved in cell growth, tumorigenesis, angiogenesis, tumor inflammation, invasion and metastasis. HuR overexpression is correlated with high-grade malignancy and poor prognosis in many tumor types.[2]

Previous studies[3] led to the identification of small, drug-like molecules able to interfere with HuR - RNA complexes by applying different approaches (*in silico* studies combined with STD NMR, virtual screening, and fragment-based drug discovery).

We present here the interaction studies between members of the new series of designed and synthetized ligands with HuR obtained by Saturation Transfer Difference (STD) NMR. Moreover, we report on NMR competition studies in presence of RNA fragment, to confirm that the ligands can bind HuR in the RNA binding site.

To overcome the limitations due to RNA handling, that can affect the NMR results, we exploited the use of Peptide Nucleic Acid (PNA) fragments as RNA mimics, using the RNA sequence of TNFα transcript (PDB code: 4ED5). Results clearly show that in STD experiments PNA can be used instead of RNA.

The method herein proposed is a worth alternative for identifying molecules that can effectively modulate HuR-RNA complexes, as potential pharmacological agents.

Furthermore, this approach will support research on more RNA-binding proteins.

References:

[1] S. Hong, 2017, *J. Cancer Prev. 22 (4),* 203–210.
[2] C. Barreau, L. Paillard and H.B. Osborne, 2005, *Nucleic Acids Research*, 33, 7138–7150.
[3] S. Della Volpe, R. Listro, M. Parafioriti, M. Di Giacomo, D. Rossi, F. A. Ambrosio, G. Costa, S. Alcaro, F. Ortuso, A. K. H. Hirsch, F. Vasile, and S. Collina, 2020, *ACS Med. Chem. Lett*., 11, 883−888
[3] S. Della Volpe, P. Linciano, R. Listro, E. Tumminelli, M. Amadio, I. Bonomo, W.A.M. Elgaher, S. Adam, A.K.H. Hirsch, F.M. Boeckler, F. Vasile, D. Rossi, and S. Collina, 2021, *Bioorganic Chemistry* 116, 105305
[3] S. Della Volpe, R. Listro, F.A. Ambrosio, M. Garbagnoli, P. Linciano, D. Rossi, G. Costa, S. Alcaro, F. Vasile, A.K. H. Hirsch, and S. Collina, 2023, *ACS Med. Chem. Lett*., 14, 1509−1516

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Synthesis of stereoisomeric cannabidiols

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(-) trans-Cannabidiol (CBD) is a not narcotic natural phytocannabinoid first isolated from hemp (*Cannabis sativa* L.) in 1940 by Adams. CBD is the active constituent of Epidiolex, a drug used to treat some rare forms of epilepsy otherwise refractory to pharmacological treatment, like the Lennox-Gastaut syndrome. CBD has a broad pharmacological profile, which include anxiolytic and anti-dyskinesic activity.[1] Remarkably, while (-)-CBD has modest affinity for CB1 and CB2 receptors, its unnatural enantiomer [(+)-CBD] is a high-potency ligand for both receptors,[2,3] suggesting that stereochemistry is critical for biological activity. Since both *cis*-enantiomers of Δ^9-THC occur in *C. sativa*, we wondered if the *cis*-isomers of CBD also occurred in the plant, and what their biological profile would be. Inspired by chemistry reported in the proprietary literature, we have developed a total synthesis of both enantiomers of *cis*-CBD starting from phloroglucinol (**2**). The key reaction is the initial Friedel-Craft reaction, which gave the *trans* isomer as the major compound along with ca. 5 % of its *cis*-isomer **3** (NMR quantification). The crude reaction mixture was purified to afford **3**, which then underwent, after phenol activation at the *para*-position and protection at the two *ortho* positions, Negishi cross coupling and reductive deprotection, affording **7** in configuration depending on the chirality of the limonene-derived terpene **1**. The conformation and biological profile of the final products will be discussed.

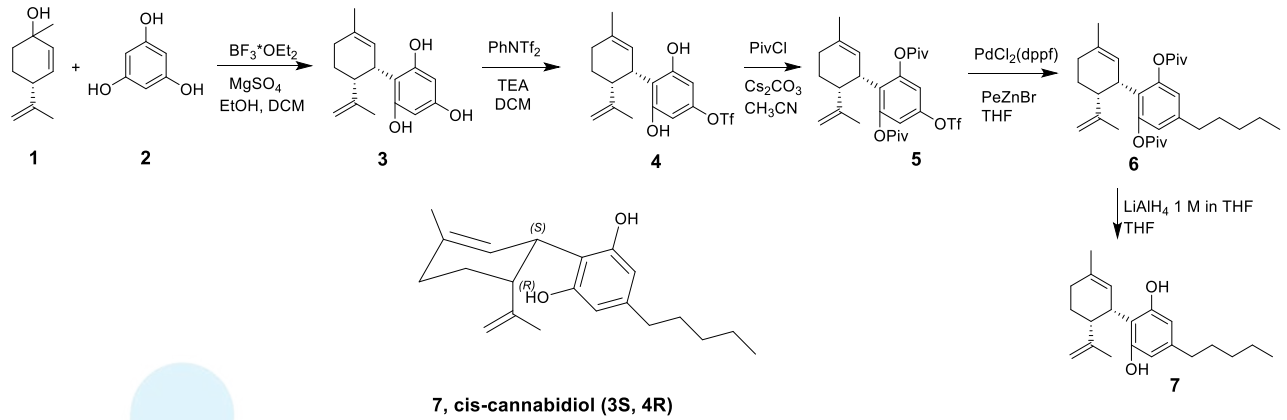

Figure 1: synthetic route to *cis*-cannabidiol **7**.

References:
[1] P.H. Reggio, et al. 1995, 56, 2025-2032.
[2] S. Burstein, 2015, 23(7), 1377-1385.
[3] T. Bosquez-Berger, et al., 2022, 102, 259-268

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Old methods, new applications: light-promoted triterpenoids skeleton interconversion in the synthesis of complex natural products

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Natural product chemistry is constantly challenged by newly discovered complex molecules with unprecedented frameworks frequently characterized by interesting biological activity. Unfortunately, they are usually produced in small amounts and, for their total synthesis, a limit of what is considered sensible in terms of steps and yield is frequently reached. As an alternative, semisynthetic approach could be a solution to provide answers to the pressing demand for sustainable, facile and concise routes even to the most complex targets.[1]

Remodelling the carbon skeleton of natural compounds represents a powerful tool in organic chemistry to rapidly generate new natural-like libraries to study different biological processes. Bond breaking, and structure rearrangements are dominant features in the photoreactivity of 4,4-dialkyl-2-cyclohexenones that irradiated undergo to the lumiketone rearrangement giving bicyclo [3.1.0] hexenones as well demonstrated in testosterone like compounds.[2]

In this field, we explored the photoreactivity of Δ^1-3-keto-pentacyclic triterpenic acids and of Δ^1-3-keto-dihydrocholesterol obtaining new *lumi*-derivatives through a stereoselective rearrangement of the A/B rings.

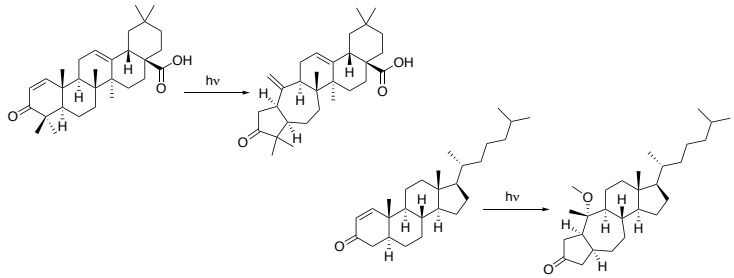

Figure 1: *lumi*-rearrangement of Δ^1-3-keto-triterpenoids

The mechanism of the rearrangement along with the possible applications to the synthesis of complex natural compounds will be discussed.

References:

[1] M. Alekseychuk, P. Heretsch, Chem. Comm. 2023, 56, 6811 – 6826.
[2] W. W. Kwie, B. A. Shoulders, P. D. Gardner, J.A.C.S., 1962, 84, 2268-2269.

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ORG-OR-056

Synthesis of a novel 4th generation of TKI targeting L858R/T790M EGFR: exploring the reversible drug binding dynamics by plasmonic nanoantenna-based SEIRA structures and atomistic simulations

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Targeted therapy with tyrosine kinase inhibitors (TKIs) is the standard of care for patients with non-small cell lung cancer (NSCLC) harbouring mutations of the epidermal growth factor receptor (EGFR) gene. First-line therapy of mutated EGFR forms, such as L858R/T790M, is often osimertinib, a 3rd generation irreversible TKI, but of about 30% of patients develop the C797S mutation, which prevents the formation of the covalent bond with 797 residue[1]. Here, we report the *in silico* design, synthesis, and biological evaluation of a novel chemical entity as a reversible wild-type sparing EGFR inhibitor. Starting from our previous work, the 6-(4-nitrophenoxy)-2-(3-phenoxyphenyl)-4H-chromen-4-one (**FL-4**)[2] was modified to increase the potency and efficacy toward EGFR L858R/T790M mutant. From the results obtained a novel TKI (**FL-28**) was identified with an IC50 120-times lower with respect to **FL-4** for the EGFR L858R/T790M form. Finally, to provide insights on the conformational variations of EGFR induced by **FL-28**, a previous optimized plasmonic nanoantenna-based SEIRA (Surface-Enhanced Infrared Absorption) structures was used. Results suggested variations of helix hydration, ascribable to the ability of compounds to induce the transition of mutant EGFR from the constitutive active to the inactive EGFR conformation. Structurally similar analogues have been synthesized and the following inhibition assays underlined the importance of the presence of acrylamide group and methyl group linked to the A ring of flavone scaffold.

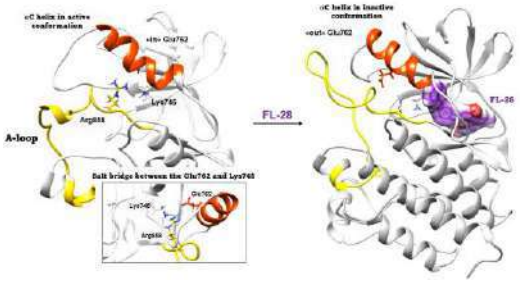

Figure 1: Conformational changes induced by FL-28 to the EGFR L858R/T790M.

References:
[1] E. Laudadio, L. Mangano, C. Minnelli, ACS Chemical Biology 2024, accepted.
[2] C. Minnelli, E. Laudadio, L. Sorci, G. Sabbatini, R. Galeazzi, A. Amici, M.S. Semrau, M. Marcaccio, G. Mobbili. Bioorganic Chemistry 2022, 129, 106219.

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A functional proteomics-based multidisciplinary strategy for the Drug-Target Deconvolution of a novel cytotoxic thiadiazolopyrimidone

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In recent years, thiadiazol-pyrimidine derivatives have been acknowledged for their attractive poly-pharmacological profile, thus representing excellent candidates for Drug-Target Deconvolution strategies, aiming at the identification of their full spectrum of protein targets. In this scenario, we disclosed the interactome of the lead compound of a small set of cytotoxic thiadiazolo-pyrimidinones, namely compound **1** (i.e., 2-(5'-bromo-2'-ethoxy-[1,1'-biphenyl]-4-yl)-7-methyl-5H-[1,3,4] thiadiazolo [3,2-a] pyrimidin-5-one), through *label-free* functional proteomics strategies based on limited proteolysis. Such approaches are indeed straightforward methods enabling an *in-solution* study of protein/molecule binding through the evaluation of the compound-induced protein conformational changes, either at a protein level (i.e., protein-centred approaches) or at a peptide level (i.e., peptide-centred approaches)[1,2].

Thus, our strategy comprised both protein-centred and peptide-centred approaches, respectively Drug Affinity Responsive Target Stability (DARTS)[3] to identify, in complex mixtures, proteins whose proteolytic response was altered by the interaction with compound **1**, and targeted-Limited Proteolysis coupled to Multiple Reaction Monitoring Mass Spectrometry (t-LiP-MRM)[4] to observe the conformational fluctuation induced at a peptide level, pinpointing compound **1** interacting protein region(s) putatively involved in the binding, either locally or distally.

Thus, DARTS allowed us to disclose Annexin A6 (i.e., ANXA6) as compound **1** main cellular target in HeLa cell lysates, and such interaction was then validated by both Western Blotting, Thermal Shift Assays and Surface Plasmon Resonance. Subsequently, t-LiP-MRM was performed to evaluate compound **1**-ANXA6 interaction features, via the comparison of ANXA6 tryptic profile in samples treated or not with the molecule and submitted to limited proteolysis with subtilisin and then to an extensive trypsinization. ANXA6 conformational changes due to compound **1** interaction were thus identified in the protein C-terminus. To then estimate the consequences of such an interaction, biological assays were performed, proving the ability of compound **1** to inhibit Ca^{2+} transition, as well as HeLa cells migration and invasion[5].

References:

[1] E. Morretta, et al. Bioorg Chem 2021, 115:105168.
[2] E. Morretta et al. Int J Mol Sci 2023, 24:9200.
[3] B. Lomenick, et al. ACS Chem Biol 2011, 6, 34–46.
[4] Y. Feng, et al. Nat Biotecnol 2014, 32, 1036-1044.
[5] E. Morretta, et al. Bioorg Chem 2023, 138:106620.

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ORG-OR-058

Biomimetic synthesis of oligomeric compounds derived from natural neolignans as metabolic enzyme inhibitors

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Biocatalysis, using defined enzymes for organic transformations, has emerged as a tool in organic synthesis, finding widespread application in various industrial sectors. Laccase (EC 1.10.3.2), is a copper-containing protein within its active site. Renowned for its mild and environmentally friendly oxidation, laccase utilizes atmospheric oxygen as a reactant, yielding water as a by-product. The versatile nature of laccase-mediated reactions generates a diverse array of products through radical coupling mechanisms, further augmented by the use of mediators to expand substrate compatibility.

Magnolia species' bark and leaves contain oligomeric compounds derived from two neolignans, magnolol and honokiol, which are renowned for their diverse biological activities.[1,2] However, limited extraction yields and the necessity for extensive purification steps have impeded comprehensive investigations into their biological effects. Overcoming these challenges requires the development of synthetic strategies to facilitate a broader exploration of their biological potential. This work focuses on synthesizing two honokiol oligomeric compounds, Houpulin A and B, utilizing laccase as a catalyst. This approach boasts significant advantages, employing buffer solution and eliminating the requirement for organic solvents and mediators. Employing optimized reaction conditions, we successfully synthesized two additional oligomers: the magnolol dimer and a honokiol-magnolol dimer. These compounds were subjected to in vitro spectroscopic analyses and molecular docking investigation, revealing their potential as novel α-amylase, α-glucosidase, and lipase inhibitors, thus presenting promising candidates for addressing conditions such as type 2 diabetes and obesity.

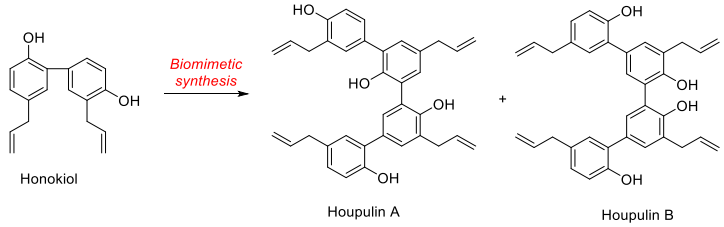

Figure 1. Biomimetic synthesis of Houpulin A and B.

Acknowledgments: This work was financed by MUR ITALY PRIN 2022 PNRR (Project No. P2022MWY3P).

References:

[1] L. Pulvirenti, V. Muccilli, N. Cardullo, C. Spatafora, C. Tringali, Journal of Natural Products 2017, 80, 1648 – 1657.
[2] C. Sciacca, N. Cardullo, L. Pulvirenti, A. Di Francesco, V. Muccilli, Bioorganic Chemistry 2023, 134,106455.

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ORG-OR-059

An improved mRNA delivery system for injury repair and regeneration therapy

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The inherent fragility of mRNA poses a significant challenge due to its susceptibility to degradation. Although lipid nanoparticle technology has been validated as an effective route for mRNA delivery, the interaction of certain chemical functionalities, such as oxidation, can destroy the integrity of mRNA structures and lead to translation errors.[1] Enhancing the stability of mRNA becomes paramount to ensure effective translation and therapeutic outcomes of mRNA therapeutics. Our group has been dedicated to address the challenges facing mRNA therapeutics by developing novel delivery systems and RNA modification techniques for enhanced nucleic acids delivery.[2-4] Here, we report an improved lipid nanoparticle (LNP) system to enhance mRNA stability and demonstrate its superiority in mRNA delivery for injured hepatocytes restoration. Briefly, a library of antioxidant lipids (AO-lipid) was obtained successfully through one-step esterification reaction by introducing antioxidant groups including sulfhydryl, phenol, and its derivatives into ionizable lipid (Figure 1). Combinational screening and systemic investigations of these AO-LNPs reveal the importance of structure design in enhancing antioxidation effects. In both acute liver injury and chronic liver fibrosis animal models, hepatocyte-growth-factor (HGF) mRNA delivered by lead AO-LNP could effectively attenuate inflammation and fibrosis via modulation of liver macrophages and hepatic stellate cells as demonstrated by liver damage biomarker detection, single cell sequencing and histologic examination. Overall, our study provides insights into antioxidation LNP for more effective mRNA therapeutics application.

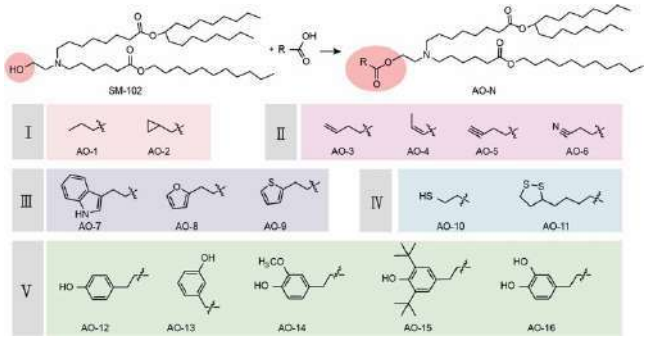

Figure 1: Ionizable antioxidant lipids (AO-lipids) developed for mRNA delivery.

References:

[1] Packer M, Gyawali D, Yerabolu R, Schariter J, White P. Nat. Commun. 2021, 12(1): 6777.
[2] Li B, Zhao M, …**Ni Q***. Angew. Chem. Int. Ed. 2023, 62(25): e202302676.
[3] Wang K, Zhang X, …**Ni Q***, et al. Nat. Commun. 2023, 14(1): 6748.
[4] Yang L, Lang Y, .. **Ni Q***, et al. ACS Nano. 2023, 17(6): 5340-5353.

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ORG-OR-060

State-of-the-art molecular docking and computer aided methods in the study of natural products, from single molecules to complex matrices

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Since ancient times, plant derived natural products have been used as remedies for the treatment of a variety of diseases and phycological disorders. Today, based on modern characterization tools, single molecules isolated from vegetable matrices and natural extracts from plants can be considered as a nearly unlimited source of potential new drugs with less side effects for the treatments of a plethora of affections with high percent of morbility characterized by the appearance of prolonged oxidative stresses, like chronic diseases of metabolic syndromes.

In this context, the exhaustive characterization of vegetable extracts in terms of secondary (specialized) metabolites allows investigating their potential as antioxidants and their compatibility with biological targets imputable to the occurrence of degenerative diseases as single compounds or as complex matrices components through the use of computer based methods.

Exploiting our knowledge both in terms of characterization of complex plant matrices[1], and molecular docking of natural products[2,3], our activity aims to:

1) analyse from a biochemical point of view the metabolic profile of complex plant matrices considered an excellent source of biologically active compounds by means of MS-based tools

2) use computer based investigations on selected biological targets as preliminary biological evaluation tool in the study of potential drugs.

References:

[1] V. Russo, A. Continella, C. Drago, A. Gentile, S. La Malfa, C. G. Leotta, L. Pulvirenti, G. Ruberto, G. M. Pitari, L. Siracusa, Plos One 2021, 16 (8), e0255831.
[2] V N. Cardullo, V. Muccilli, L. Pulvirenti, C. Tringali, Journal of Natural Products 2021, 84 (3), 654-665.
[3] C. Sciacca, N. Cardullo, L. Pulvirenti, A. Di Francesco, V. Muccilli, Bioorganic Chemistry 2023, 134, 106455.

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ORG-OR-061

Structure optimization of Cycloastragenol (CAG) derivatives as novel anticancer agents

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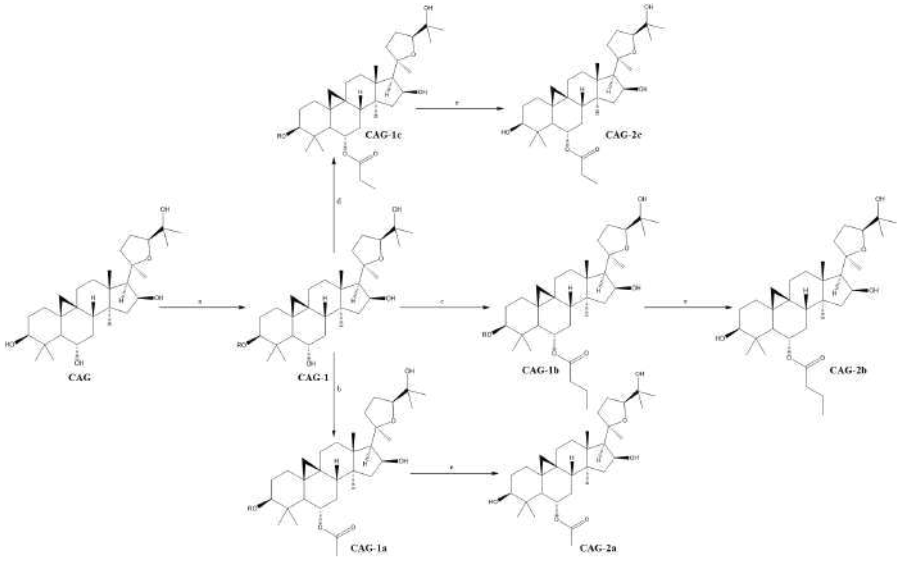
Cycloastragenol (CAG) with steroid-skeletal characteristics is a cycloartan saponin of Astragaloside IV (AG-IV) which is one of the main active components of *Astragalus membranaceus*. It is considered as valuable clinical choice for those specific diseases caused by inflammation, oxidative stress, cell senescence, or autophagy. In addition, Cycloastragenol is the only telomerase activator reported in natural products, which is closely related to MAPK and PI3K/Akt signaling pathways[1]. Our group has long been engaged in drug discovery projects using natural compounds as guide structures and considering the above highlighted, the aim of this study was to synthesize a new library of small synthetic modifications to produce semi-synthetic derivatives for enhancing the binding towards the target (**Scheme 1**).



Scheme 1: **a)** Im (6 eq.), TBSCl (4 eq.), DMF, rt, 3h30', 63%; **b)** Ac_2O (18 eq.), Pyridine, 5°C, 24h, 47%; **c)** Butyryl chloride (9 eq.), Pyridine, 5°C, 7h45', 45%; **d)** Propionic anhydride (18 eq.), Pyridine, 5°C, 24h, 98%; **e)** CSA (4 eq.), MeOH, rt.

In *vitro* studies of all synthetic derivatives on HCT 116 and NF-κB reporter (Luc)-HCT-116 cell lines, have been designed to monitor Nuclear Factor Kappa B (NF-κB) signal transduction pathways and evaluate the crosstalk between tumor development and inflammatory processes.

References:

[1] M. Dong, J. Li, D. Yang, M. Li, J. Wei, Molecules 2023, 28, 5018.

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ORG-OR-062

How D-amino acids embedded in the protein sequence modify digestibility: behaviour of digestive enzymes on a D-amino acids-containing model peptide used as target

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Food industry uses processes involving acid or basic treatments, combined with heat, to extracts proteins both from plant and animal sources. Among the most employed treatments, basic pH and high temperature for long-duration treatments were proven to induce strong amino acids racemization. The presence of D-amino acids inside proteins can obviously change their digestibility and consequently the absorption of essential and non-essential amino acids. Likewise, changes of digestibility may also affect the release of bioactive peptides and the functionality of foods beyond their nutritional aspects. Indeed, during gastrointestinal digestion, proteins are normally cleaved into peptides and amino acids, which can be absorbed by our body. The hydrolysis of food proteins in our gastrointestinal tract is catalysed by specific proteases. However, the molecular details of how much the digestive process is affected by the racemization are still largely unknown. In this work the behaviour of the main stomach and gut digestive enzymes in the presence of D-amino acids in the protein chain was monitored over time using a model peptide where L-amino acids were systematically substituted by D-amino acids. To perform this study, a peptide belonging to β-lactoglobulin was chosen as a model for a protein chain containing diverse amino acids. The model peptide contained cleavage sites for pepsin, trypsin, and chymotrypsin. Several peptides having identical sequence were then also synthesized by systematically introducing a D-amino acid in each different chain position. Then, the hydrolysis of the model peptide, and of all its D-amino acid containing homologues, both by pepsin and by trypsin/chymotrypsin, was monitored by LC-MS, allowing to evaluate the behaviour of the digestive enzymes in the presence of D-amino acids, not only at the cleavage sites, but on all the peptide sequence. The results showed several changes in the behaviour of digestive enzymes, not only when the D-amino acids are inserted at the specific cleavage sites, but in some cases also when in distant positions. Interestingly, the effect seemed more pronounced in the case of pepsin rather than the gut enzymes. The results demonstrated that protein racemization impairs nutritional value by slowing down digestibility and has different effects according to the enzyme/amino acids involved.

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ORG-OR-063

A dimeric receptor for the recognition of adenine derivatives via triplex-like interactions.

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The pattern of interaction holding natural T-AT and C^+-GC nucleobase triplets can be artificially reproduced by using tailored nucleobases that recognize both the Watson-Crick and Hoogsteen domains of purine targets.[1] To develop a novel model of this kind of nucleobases, we designed the dimeric receptor **1** (**Figure 1a**), in which two uracil units are arranged on a naphthalene scaffold to bind adenine derivatives by triplex-like base pairing. This compound was tested in the complexation of 9-ethyl adenine (**9-Et-A**) by a series of ^{1}H NMR titrations ($CDCl_3$, 50°C), estimating an association constant (*Ka*) of $4 \cdot 10^5$ M^{-1}. The monomeric control compound **2** (**Figure 1b**), instead, recognized the same substrate with *Ka* = 58 M^{-1}, suggesting a high cooperation between the uracil units of **1**. The chemical shift perturbations observed during the titrations, in combination with NOESY experiments, evidenced a structural rearrangement of **1** in the presence of its target and suggested the formation of triplex-like interactions (**Figure 1a**). Also, a $CDCl_3$ solution of this receptor sequestered 40% of adenosine from D_2O, forming of an insoluble 1/1 complex at the interphase. When a mixture of all the four ribonucleosides was present in the D_2O layer the same 1/1 complex was isolated from the interphase, demonstrating the selectivity of **1** for adenosine. Instead, the monomeric control compound **2** did not cause any precipitation.

Currently, we are evaluating the conversion of **1** into an artificial nucleobase for peptide nucleic acids (PNAs), with the aim of using the resulting oligomers as probes for the direct detection of point mutations on relevant oncogenes (i. e. liquid biopsy).[2]

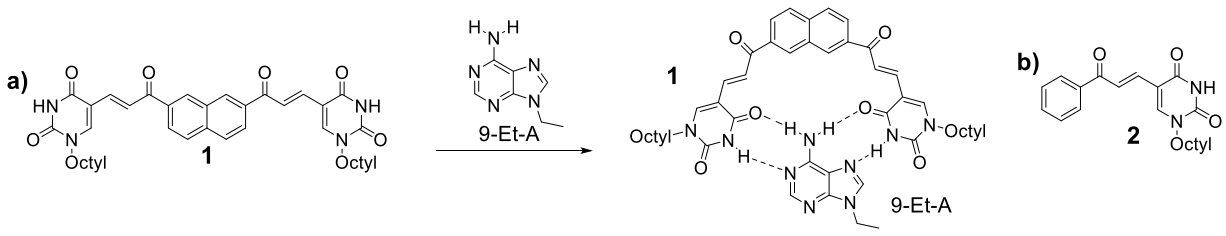

Figure 1: **a)** Complex formation between receptor **1** and **9-Et-A**. **b)** Monomeric control receptor **2**.

References:

[1] K. R. Fox, T. Brown, D. A. Rusling, DNA-targeting Molecules as Therapeutic Agents; The Royal Society of Chemistry, 2018, 1–32.

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Type-II Kinase Inhibitors- synthetic access and strategies to overcame drug resistance

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Protein Kinase Inhibitors (PKIs) have emerged as a major class of anti-cancer agents, with over 70 approved drugs in 2021. A crucial limit of this therapeutic approach is the frequent development of drug resistance in treated patients, which can occur through several mechanisms such as pathway reactivation and mutation of the kinase domain.[1] Strategies to overcome drug resistance include the development of new tailored inhibitors with alternative binding modes, the identification of drugs with increased affinity towards the target protein and the use dual/multi targeting compounds, able to block simultaneously different signalling pathways.[1,2]

We will present some case studies showcasing each of these approaches, including the rational development of broad-targeting compounds showing efficacy in clinical trials.[3] We will illustrate the use of *in-silico* tools for the design of new compound and the structural elucidation of the mechanisms of resistance (**Figure 1A**),[5,6] and the optimization of *ad-hoc* synthetic routes and methodologies designed to access more efficiently the chemical space of the target inhibitors.[5] These routes were designed to comprise a limited number of high yielding steps with little purification issues and to introduce the main diversity points of the scaffold late in the synthetic line, in order to limit the number of exclusive reactions needed for each analogue (**Figure 1B**).[5]

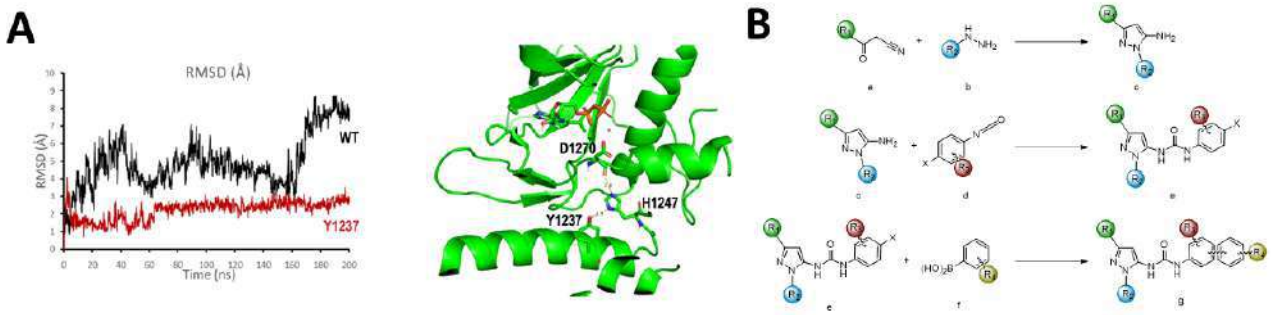

Figure 1 A *in-silico* tools guide design of new compound and structural elucidation of mechanisms of resistance **B** synthetic route to target compounds are designed to access efficiently their chemical space

References:

[1] Cohen, P.,; Cross, D.; Jänne, P.A. Nat Rev Drug Discov 20, 551–569 (2021).
[2]Mologni, L.; Marzaro, G.; Redaelli, S.; Zambon, A. Cancers, 2021, 21, 119
[3] Girotti, M.R *et al.* J. Cancer Cell, 2015, 1, 85-96
[4] Saturno, G.; *et al.* J. Annals of Oncology 2021, 32, 269–278
[5] Zambon, A., *et al.* J. Med. Chem.; 2010; 53, 5639-5655

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Metal ions trigger the gelation of peptide-appended coordination cages

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The encounter between metal-organic cages (MOCs) and gels gives rise to formation of novel nanomaterials. These new materials are characterised by the presence of dual porosities, derived from the cage's cavity and the gel meshes.[1] Advances in this field may contribute to the development of next-generation materials for molecular separation or purification of environmental pollutants.[1] Among the possible gelators, low-molecular weight peptides are very intriguing and are yet applied for different applications as templation of nanoparticle[2] or catalysis[3]. This work reported the formation by sub-component self-assembly (**Figure 1**) of three $Fe^{II}_4L_4$ MOCs containing enantiopure peptides functionalities on the sidechain with sulfur atoms. The use of enantiopure peptides guaranteed the preferential formation of one of the two possible diastereomers, suggesting the chirality transfer exerted by the peptide to the metal vertices. The MOCs gelation has been triggered by coordination between thiol groups of peripherical peptides and the second metal ions, Ag^+, Zn^{2+}, Hg^{2+} (**Figure 1**). The gels displayed the formation of spherical nuclei that interconnect forming the 3D network instead of peptide alone that generally gave rise to formation of fibrils. This gelation in the presence of heavy metals holds promise for the removal of toxic metal ions from the environment.

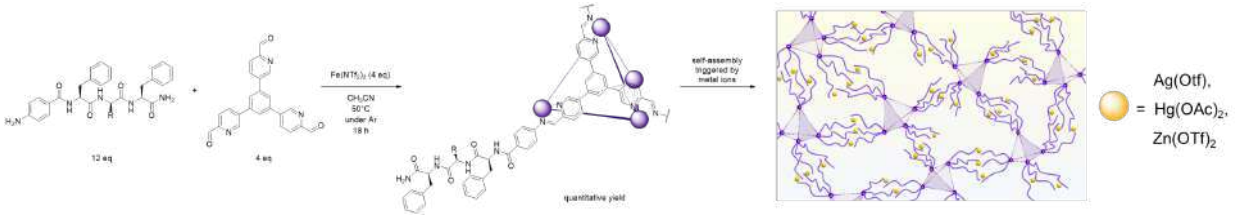

Figure 1: General MOCs synthetical protocol and gelation trigger by metal ions coordination.

References:

[1] Jahović, I.; Zou, Y.-Q.; Adorinni, S.; Nitschke, J. R.; Marchesan, S., *Matter* **2021**, 4 (7), 2123-2140.
[2] Adorinni, S.; Gentile, S.; Bellotto, O.; Kralj, S.; Parisi, E.; Cringoli, M. C.; Deganutti, C.; Malloci, G.; Piccirilli, F.; Pengo, P.; Vaccari, L.; Geremia, S.; Vargiu, A. V.; De Zorzi, R.; Marchesan, S., *ACS Nano* **2024**, 18 (4), 3011-3022.
[3] Adorinni, S.; Goti, G.; Rizzo, L.; Grassi, F.; Kralj, S.; Matroodi, F.; Natali, M.; De Zorzi, R.; Marchesan, S.; Dell'Amico, L., *Chem. Commun.* **2023**, 59 (49), 7619-7622.

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ORG-OR-066

A Detailed Investigation of the Sensing Mechanism of an Azocalix[4]arene Chromoionophore

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Calix[4]arenes functionalized with azo groups at the upper rim and cation binding sites at the lower rim are widely used as chromogenic sensors due to their facile synthesis and significant absorption band shifts upon complexation.[1] Despite their popularity, however, a detailed investigation of their sensing mechanism, arising from an azo-phenol – quinone-hydrazone tautomerism, remains unreported.

In this study, we present the synthesis of a novel azocalixarene ligand and investigate its complexation behavior with Ca^{2+} both in neutral and basic conditions. The complete characterization of the metal complexes in solution (by ^1H NMR and UV-vis spectroscopies) and at the solid-state (by X-ray diffractometry), allowed us to elucidate that cation complexation prompts a shift in the tautomeric equilibrium toward the quinone-hydrazone form (Figure 1), while deprotonation of the complex leads to the reversion to the azo-phenol tautomer. At the same time, the hydrazone NH groups provide an anion binding site for the counteranions.[2] Finally, complexation of different chloride salts and of different calcium salts gives rise to different colour changes, allowing naked-eye detection of both metal ions and of anions.

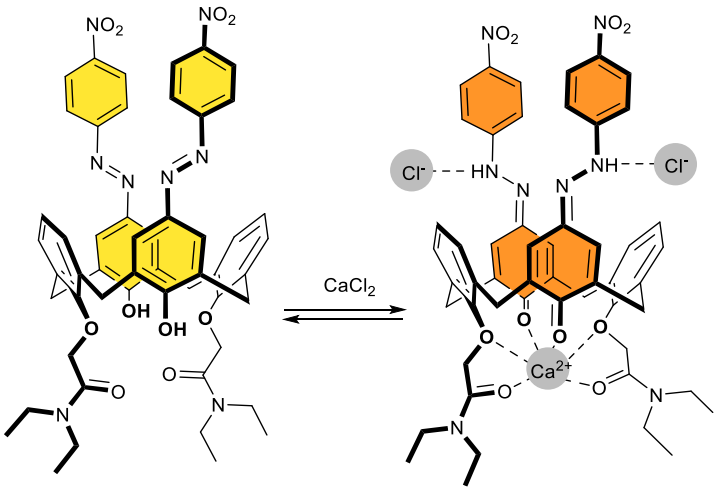

Figure 1

References:

[1] D. Diamond, M.A. McKervey, *Chem. Soc. Rev*. **1996**, *25*, 15–24.
[2] L. Baldini, D. Balestri, L. Marchiò, A. Casnati, *Molecules*, **2023**, *28*, 4704.

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Synthesis and characterization of Near Infrared dyes for colorless dye sensitized solar cells

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Transparent photovoltaics (TPV) is an emerging and disruptive technology in which the solar cells selectively transmit the visible light to human eyes harvesting UV and/or NIR photons.[1] TPV is attractive as it widens the deployment of PV into new sectors, like building integrated photovoltaics (BIPV), greenhouses, car windows and sunglasses, thus providing an immense potential to generate solar electricity beyond the conventional rooftops and solar power plants. One possible approach to TPV is based on wavelength-selective absorbers where the dye requires an absorption far from the photopic response of the human eye.

Limited classes of dyes possess energetic levels that can ensure an efficient injection while having a bandgap sufficiently narrow to selectively absorb the NIR region.[2] Among these classes, cyanine dyes are promising for their high molar extinction coefficient and easily tunable properties through modification of central core or lateral units and have already been investigated for dye sensitized solar cell (DSSC) devices with promising results in terms of transparency and performance. Fully transparent and colorless DSSC were built reaching 80% transmittance in complete devices.[3,4] The aim of the present work was the development of a library of NIR dyes in order to increase the device's efficiency and stability without losing transparency.

The synthesis of new series of NIR cyanines dyes have been performed in a one or two-step reaction. A simple crystallization of the crude products yielded very low cost and industrially scalable products.

These new sensitizers have been deeply characterized in terms of their optical, photophysical and electrochemical properties, showing interesting structure/property relationships. Finally, photovoltaic performances have been evaluated in lab-scale DSSCs and optimized by different anode modifications and electrolyte formulations.

References:

[1] C.J. Traverse, R. Pandey, M.C. Barr, Lunt R.R., Nat Energy 2017, 2, 849–860.
[2] F. Grifoni, M. Bonomo, W. Naim, N. Barbero et al., Adv. Energy Mat. 2021, 11, 2101598.
[3] W. Naim, V. Novelli, I. Nikolinakos, N. Barbero, C. Barolo, F. Sauvage, JACS Au 2021, 1, 409-426.
[4] W. Naim, F. Grifoni, V. Challuri, N. Barbero, S. Pilard, C. Barolo, F. Sauvage, Cell Rep. Phys. Sci. 2023, 4, 101455.

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Tailored Metal-Porphyrin Based Molecular Electrocatalysts for Enhanced Artificial Nitrogen Fixation to Green Ammonia

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Electrochemical nitrogen reduction reactions (E-NRR) are one of the most promising approaches to obtain NH_3 sustainably. However, scarce ammonia yield and low Faradaic efficiencies still limit their use on a large scale. For these reasons, efforts focus on studying different E-NRR catalyst structures and formulations. Among all E-NRR catalysts, molecular materials such as metal-porphyrins emerged as an encouraging option due to their planar structures which favour the interaction with the *d* orbitals of the metal, responsible for the adsorption and activation of nitrogen. Nevertheless, the high hydrophobicity of porphyrins limits the aqueous electrolyte-catalyst interaction limiting the NH_3 yield. Following our previous general approach for organic design for solar generation of green hydrogen,[1] in this communication we present our work on the investigation of a series of metal-porphyrins, which have been properly functionalized in order to enhance nitrogen fixation performance. In particular, we have developed two series of hydrophilic triethylene glycol chains (TEG) and hydrophobic ethylhexyl chains (EH) derivatives, able to show different interactions at the interface with the aqueous electrolytic environment of the electrochemical cell, thus affecting the device interface phenomena and, eventually, the final response. [2]

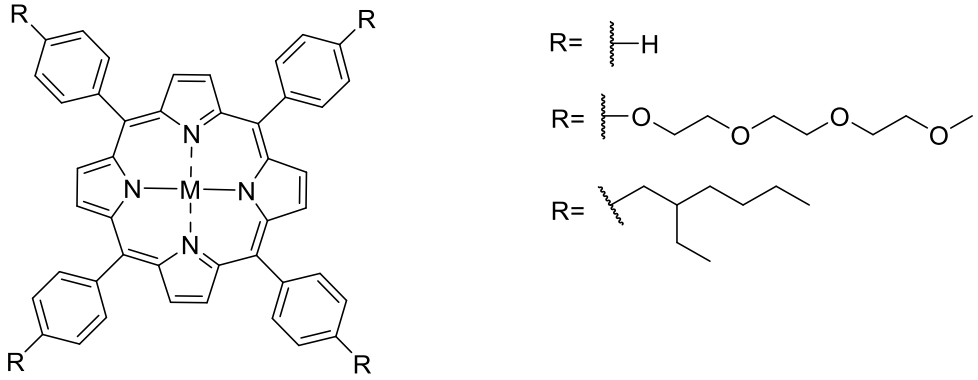

Figure 1: Metallo-porphyrin based electrocatalysts synthesized in this work

References:

[1] Boldrini, C. L.; Quivelli, A.F.; Manfredi, N.; Capriati, V.; Abbotto, A., *Molecules* **2022**, *27*, 709; Boldrini, C. L.; Manfredi, N.; Perna, F. M.; Capriati, V.; Abbotto, A. *ChemElectroChem* **2020**, *7*, 1707.

[2] Salerno, G.; Bettucci, O.; Manfredi, N.; Stendardo, L.; Veronese, E.; Metrangolo, P.; Abbotto, A. *Global Challenges*, **2024**, DOI: 10.1002/gch2.202300345.

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Sustainable Horizons: Unleashing the Power of Earth-Abundant Metal Complexes in Photo-driven CO_2 Reduction

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The contemporary scenario of climate change and the rapid depletion of Earth's resources necessitates a shift towards sustainable practices. This imperative accentuates the critical need to harness renewable resources in tandem with renewable energies. Transition metal complexes emerge as promising candidates for enhancing the photocatalytic activity and efficiency in solar energy conversion.[1]

Our research is motivated by the understanding that for these catalysts to be practically viable, they must be readily available and cost-effective, emphasizing the use of earth-abundant materials. Drawing inspiration from nature, we focus on the conversion of carbon dioxide into reactive molecules.

In this context, we introduced novel mononuclear and binuclear Cu(I) complexes, characterized by their favorable photophysical and electrochemical properties as photosensitizers. Their tunable properties, achieved through the modification of their diimine ligands, render them suitable for integration into photocatalytic systems aimed at reducing CO_2 using blue light.[2] Expanding our explorations, we have dedicated efforts to designing new CO_2 reduction catalysts centered on Fe(II) and Co(II).[3,4] The catalytic system, facilitated by a Cu(II)-photosensitizer, has demonstrated remarkable performance, achieving a TON of 576 and a quantum yield of up to 7%. Additionally, we have investigated the formation of syngas through competitive H_2 production.[3] Selective control over CO versus molecular H_2 has been a focal point of our research, leading to the development of a new cobalt complex. Optimization of a complete, earth-abundant photocatalytic system using a copper-based photosensitizer has resulted in an impressive selectivity of up to 99% towards carbon monoxide.[4] This presentation will delve into the latest results,[5] offering insights into ongoing research challenges and the strategies employed to address them.

References:

[1] (a) C. Bizzarri *Eur. J. Org.* **2022**, e202200185; (b) M. Heberle, *et al. Chem Eur. J.* **2017**, *23*, 312–319; (c) N. Armaroli; V. Balzani; *Chem. Eur. J*., **2016**, *22*, 32.

[2] (a) C. Bizzarri, A. P. Arndt, S. Kohaut, K. Fink, M. Nieger *J. Organometallic Chemistry* **2018**, *871*, 140-149; (b) L.-L. Gracia, L. Luci, C. Bruschi, L. Sambri, P. Weis, O. Fuhr, C.Bizzarri *Chem. Eur. J.* **2020**, *26*, 9929-9937.

[3] L.-L. Gracia, E. Barani, J. Braun, A. B. Carter, O. Fuhr, A. K. Powell, K. Fink, C. Bizzarri *ChemCatChem* **2022**, e202201163.

[4] L.-L. Gracia, , P. Henkel, O. Fuhr, C. Bizzarri *Beilstein J. Org. Chem*. **2023**, *19*, 1766.

[5] C. Bruschi, C. Bizzarri *et al.* in revision.

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Chiral-chiral interactions as determining factors in gelation processes

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The design of chiral materials represents an interesting field in chemistry and nanotechnology due to the multiple applications that they could access.[1] In this context, chiral gels represent a feasible material concept and could be obtained by proper chiral precursors, giving the advantage to obtain chiral scaffolds readily employable as chiral media, sensors, catalysts and chiro-optics tools.[2] In the wide panorama of chiral gels, studies are generally focused on hydro- or organogels where organic chiral gelators activate the gelation process in aqueous or organic liquid media.[3] Apart from the widely employed organic molecules as gelators, organic salts resulted in high valuable supramolecular building blocks in the field.[4] Consequently, the use of chiral organic salts could represent an interesting alternative, and advantageous strategy, to access chiral gel materials. With respect to organic medium, we focused on the less investigated Deep Eutectic Solvents (DES) that represent a greener alternative with interesting physico-chemical properties.[5] In the context of chiral gels, this contribution would give first insights into the study of chiral eutectogels through the employment of chiral organic salts, composed of diimidazolium based cations and *L*- or *D*-tartrate anions. Moreover, chiral small molecules have been employed during the gelation process to study the effect on the supramolecular gel structure formation, the related properties, and the feasibility of obtaining multicomponent gels. Our results demonstrate how chiral-chiral interaction could be a useful tool to tune gel properties.

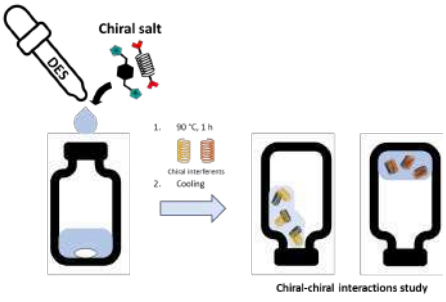

Figure 1: Schematic representation of the chiral eutectogel synthesis study case.

References:

[1] H. Kuang, C. Xu, Z. Tang, Advanced Materials 2020, 32, 2005110.
[2] D. K. Smith, Soft Matter 2024, 20, 10–70.
[3] D. Gambhir , S. Kumar, R. R. Koner, Soft Matter 2022, 18, 3624–3637.
[4] C. Rizzo, F. D'Anna, R. Noto, RSC Advances 2016, 6, 58477–58484.
[5] J. Wang, S. Zhang, Z. Ma, L. Yan, Green Chemical Engineering 2021, 2, 359–367.

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Novel chiral azole-based chromophores for optoelectronic applications

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Chiral π-conjugated molecules are attractive starting materials for the preparation of optoelectronic devices such as Circularly Polarized Organic Light-Emitting Diodes (CP-OLEDs) and CP-lasers. Elements of asymmetry in the starting material result in the formation of chiral supramolecular architectures and ultimately affect the electronic properties of the substrate in thin films.[1] Within the framework of our research program on the functionalization of azole nuclei,[2-5] we synthesized four distinct novel chiral chromophores by decorating the imidazole-based π-conjugated systems with enantiopure (*S*)-β-citronellol as the chiral aliphatic moiety (Figure 1). Three general strategies were approached for the preparation of the π-conjugated systems: 1) dehydrogenative alkynylation, 2) direct C–H arylation, 3) one-pot bromination/Sonogashira coupling. (*S*)-β-citronellol was introduced in the last step of the syntheses *via* Knoevenagel condensation. The resulting compounds exhibited CP absorption and emission properties in homogeneous thin films, with consistent chirality on both faces. Interestingly, small structural variations led to significant changes in the origin and magnitude of solid-state chiroptical properties. The introduction of a single acetylene moiety in the π-linker afforded remarkably high dissymmetry g-factors (10^{-1}) in spin-coated film, thus holding significant potential as fundamental component in optoelectronic devices. Finally, tackling the need of a cost-effective and compact device for detecting chiroptical properties, a novel and easy-to use instrument setup was developed.[6]

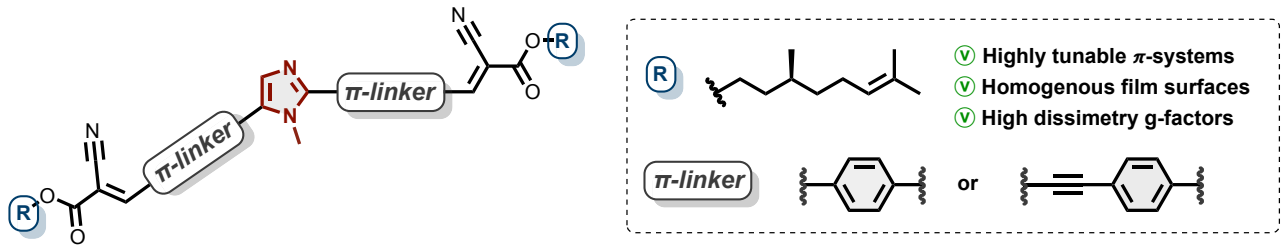

Figure 1: Targeted chiral azole-based chromophores

References:
[1] Albano, G., Pescitelli, G., Di Bari, L., Chem. Rev., 2020, 120, 10145-10243.
[2] Bellina, F., Biagetti, M., Guariento, S., Lessi, M., Ronchi, P., Rosadoni, E., RSC Adv, 2021, 11, 25504–25509.
[3] Bellina, F., Lessi, M., Marianetti G., Panattoni, A., Tetrahedron Lett, 2015, 56, 3855-3857.
[4] Bellina, F., Cauteruccio S., Di Fiore, A., Rossi R., European J. Org. Chem., 2008, 5436–5445.
[5] Bellina, F., Calandri C., Cauteruccio S., Rossi R., Tetrahedron, 2007, 63, 1970–1980.
[6] Campinoti, C., Taddeucci, A., Sardelli, F., Pescitelli,G., Di Bari, L., Lessi, M., Zinna, F., Manuscript submitted.

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Synthesis and preliminary tests of new graphene-based functionalized solid sorbents for selective CO_2 Capture

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Anthropogenic gas emissions and global warming are huge challenges that today's society must face and address by exploiting renewable resources and methods to capture and remove CO_2 from the atmosphere [1]. Carbon capture and storage technologies (CCS) have been proposed to minimize CO_2 emissions during energy production, since they enable the utilization of strategic gas mixtures released during combustion processes, and of potential energy sources like biogas [2]. Currently, most of the CCS technologies adopt systems that pose high risks to the environment and human health, because of toxic chemicals (amine scrubbing), high-pressure processes (pressure swing adsorption), etc [3].

The aim of this work falls within the PRIN 2022 PNRR project CHARYBDIS (Carbon-High AdsoRption bY Bi-functionalizeD solId Sorbents, CUP D53D23016970001, funded by the European Union – Next Generation EU) led by the University "G. d'Annunzio" of Chieti – Pescara, and the University of Messina as a research unit, in which materials based on graphene derivatives will be produced and tested for a highly selective and efficient CO_2 capture in strategic gas mixtures.

In particular, nanoporous graphene oxide (nGO) suitably derivatized with modified tetraethylene pentaamine (m-TEP) containing amide, azide or urea functional groups, are being prepared to be used for CO_2 separation technologies for biogas and syngas gas mixtures.

A set of different preliminary tests on adsorption capacity at different temperatures and pressures were carried out, with particular attention to the capacity of this new compounds to adsorb and release CO_2 in mild condition, a fundamental requirement in terms of eco-sustainability and energy requirements. Cyclability of the whole processes are also tested, followed by a set of several physico-chemical characterization before and after CO_2 adsorption to evaluate the stability of these new sorbent materials. Preliminary results are presented, which are of fundamental importance to set the best absorption P/T conditions in terms of selectivity and gravimetric quantity of adsorbed CO_2, as well as the assessment of the efficiency and the possibility of recycling used sorbents in an optical of environmentally sustainable materials, promising as safe and green alternative to the current separation techniques.

References:

[1] A.H. Alami, A.A. Hawili, M. Tawalbeh, et al. Science of the Total Environment, 717, 137221.
[2] J. Buckingham, T.R. Reina, M.S. Duyar. Carbon Capture Science & Technology, 2022, 2, 100031.
[3] M. Ciulla, V. Canale, R.D. Wolicki, S. Pilato, et al. Separations 2023, 10, 505.

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Design and synthesis of new photoactive molecules for Dye-Sensitized-Solar-Cells (DSSCs) operating in low-light conditions

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Among all the photovoltaic technologies**, Dye-Sensitized Solar Cells (DSSCs)**[1] attracted the attention of researchers for their low manufacturing costs, easy availability of raw materials, and short payback times. The latest trend for DSSC applications is moving to **indoor or dim-light environments** because DSSCs have much higher efficiencies than Si-based solar cells (~ 30 %). Thus, indoor photovoltaics are emerging as an important technology suited for IoT (Internet of Things) applications, household, and various electronic applications.[2]

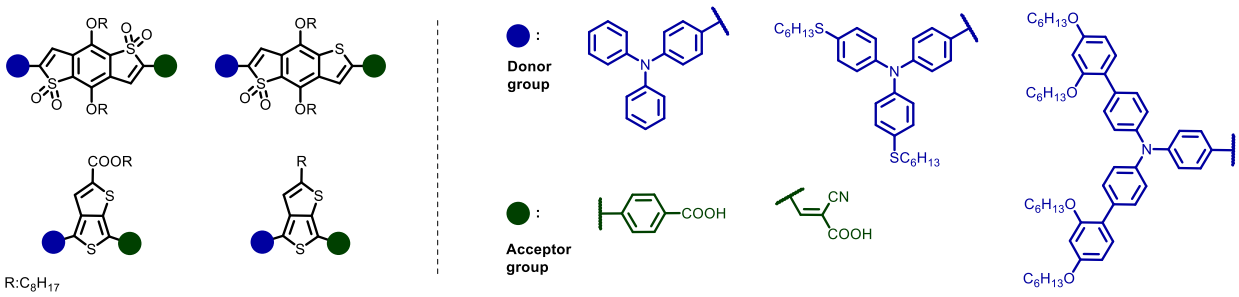

Figure 1: New photosensitizers for indoor DSSCs.

Herein, the design and synthesis of four new families of photosensitizers for indoor DSSCs are presented. The molecules showed properties suitable for this type of application, with broad light absorption in the visible region and redox potentials compatible with the most common organometallic redox couples. First preliminary DSSCs tests afforded promising efficiencies using different light sources.

References:

[1] Ren, Y.; Zhang, D.; Suo, J.; Cao, Y.; Eickemeyer, F. T.; Vlachopoulos, N.; Zakeeruddin, S. M.; Hagfeldt, A.; Grätzel, M. *Nature* **2022**, *613,* 60-68.

[2] Michaels, H.; Rinderle, M.; Freitag, R.; Benesperi, I.; Edvinsson, T.; Socher, R.; Gagliardi, A.; Freitag, M. *Chem. Sci.* **2020**, *11* (11), 2895–2906.

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Catalyzed gas-liquid biphasic aerosol (photo)reaction: a process intensification approach

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Catalyzed gas-liquid biphasic (dark or photochemical) reactions, very often are severely plagued by transport phenomena occurring at the interphase, and their full exploitation in terms of efficiency and throughput is thus far to be achieved. Their thermodynamic is regulated by Henry's law, while the corresponding kinetics are governed Fick's and Lambert-Beer's laws,[1] this latter in the case of photoreactions. Mass and photon transfer limitations affecting these reactions are then addressed by increasing the interphases surface to volume ratio,[2] and reducing the thickness of reaction mixture photo-exposure. Aerosols facilitate achieving both goals simultaneously, thus introducing microdroplets reactions as an invaluable paradigm shift. In this scenario, we focused on two model reactions: the photocatalyzed gas-liquid biphasic selective sulfoxidation,[3] of sulfides, and the catalyzes CO_2 fixation on styrene oxide.[4,5] Details of these explorations will be reported, along with our efforts in the ideation, design, implementation and characterization of new reactors and enabling technologies to perform aerosol reactions

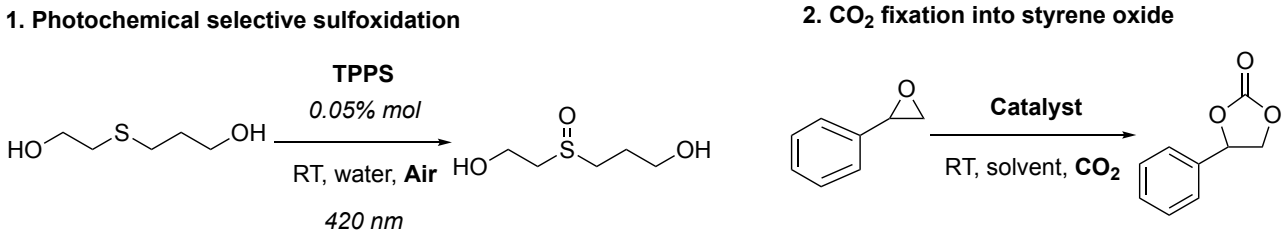

Figure 1: Selected model reactions.

References:

[1] F. Lévesque, P.H. Seeberger, *Org. Lett.* **2011**, *13*, 5008–5011.
[2] G.I. Ioannou, T. Montagnon, D. Kalaitzakis, S.A. Pergantis, G.A. Vassilikogiannakis, *ChemPhotoChem* **2017**, *1*, 173–177
[3] E. Kayahan, D. Urbani, P. Dambruoso, A. Massi, L. Braeken, T.V. Gerven, M:E: Leblebici, M.E. *Chem Eng J* **2021**, *408*, 127357.
[4] D. Urbani, C. Rovegno, A. Massi, M.E. Leblebici, E. Kayahan, E. Polo, P. Dambruoso, *J. Co2 Util.*, **2023**, *67*, 102328.
[5] L.Poletti, C. Rovegno, G. Di. Carmine, F. Vacchi, D. Ragno, A. Brandolese, A. Massi, P. Dambruoso, *Molecules* **2023**, *28* (4), 1530.

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The Hexameric Resorcinarene Capsule as Supramolecular Photoacid for the Catalysis in Confined Space

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The hexameric resorcinarene capsule **C_6** is a hydrogen-bonded self-assembled capsule obtained in wet solvents (chloroform or benzene) by six resorcinarene units and eight water molecules.[1] Several studies have highlighted the abilities of **C_6** in promoting different types of reactions within its cavity, exploiting its unique catalytic features, such as a cavity large enough to hold several substrates (internal volume of 1375 Å^3), the capability to stabilize cationic intermediates and transition states, the H-bond donating ability, and its mild Brønsted acidity (*p*ka= 5.5-6.0).[3-4] In addition to these, we here show that **C_6**, when exposed to light irradiation, can act as a photoacid exhibiting an enhancement in acidity of 8.8 log units compared to its ground state. The synergistic interplay between the nanoconfined environment of the hexameric resorcinarene capsule and its supramolecular photoacidity paves the way for further developments in unconventional reactivity and selectivity.[5]

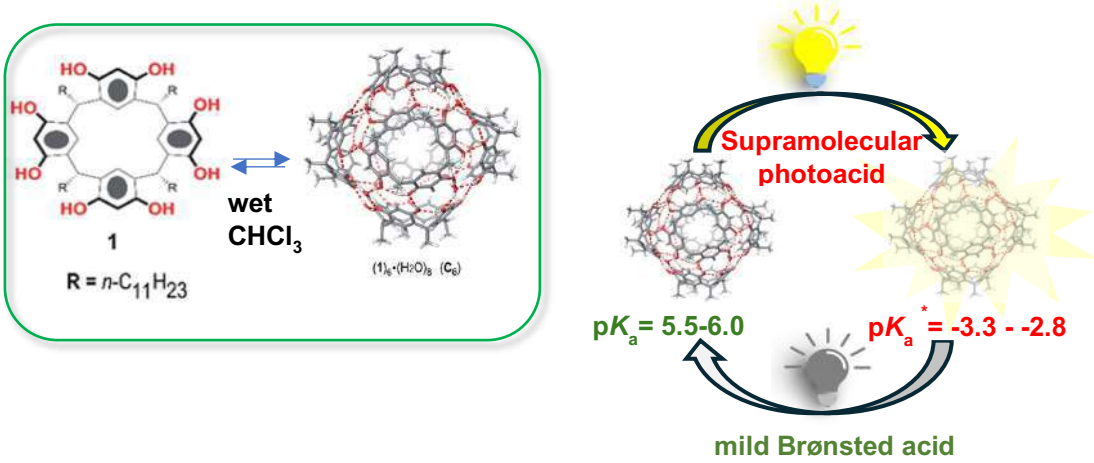

Figure 1: Light-driven pKa switch for the hexameric resorcinarene capsule.

References:

[1] A. Shivanyuk, J. Rebek, J. *Am. Chem. Soc.* **2003**, *125*, 3432-3433
[2] Q. Zhang, K. Tiefenbacher, *J. Am. Chem. Soc.* **2013**, *135*, 16213-16219.
[3] C. Gaeta, C. Talotta, M. De Rosa P. La Manna, A. Soriente, P. Neri, *Chem. Eur. J.* **2019**, *25*, 4899-4913
[4] M. De Rosa, S. Gambaro, A. Soriente, P. Della Sala, V. Iuliano, C. Talotta, C. Gaeta, A. Rescifina, P. Neri, *Chem.Sci.* **2022**, *13*, 8618-8625.
[5] G. Ferrino, M. De Rosa, P. Della Sala, C. Gaeta, C. Talotta, A. Soriente, Z. Cao, B. Maity, L. Cavallo, P. Neri, *Chem. Eur. J.* **2024**, e202303678.

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Steroid-fullerene hybrids as promising derivatives with potential application in medicinal chemistry and materials science

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In recent years, fullerenes have gained great interest because their structure enables the development of novel applications based on their chemical and physical properties.[1] With a focus on their small size and special structure, there have been considerable reports on their ability to scavenge free radicals, visualize biological processes, and neuroprotective activity. Furthermore, their ability to capture radicals makes them good antioxidants, for developing potential drugs to treat neurodegenerative diseases.[2] On the other hand, fullerene derivatives have been used as acceptor materials in solar cells for over two decades, following the demonstration of the first proof-of-concept devices at the end of the last century.[3]

This work aimed to obtain structurally novel compounds, based on generating molecular hybrids, with applications as anti amyloid-β (Aβ) peptide aggregates and as acceptor material in organic solar cells. For this purpose, fullerenes were covalently bonded to malonyl conjugates substituted with fragments such as steroids and seleno-sugars. Different strategies were designed for obtaining malonyl-steroids and seleno-sugars, as well as for their coupling reaction. The covalent attachment of the conjugates to [60]fullerene was performed by Bingel-Hirsch cyclopropanation. In addition, theoretical calculations at the DFT level of theory were used to predict the synthesized hybrids' molecular structures and to estimate their physicochemical properties. Theoretical calculations based on CNDOL Fockian together with configuration interaction of single excitations (CIS), as well as the experimental results obtained such as TEM and cyclic voltammetry demonstrated that one can be considered an appealing candidate with applications for photovoltaic devices. Molecular docking was employed to determine the potential application of these fullerene derivatives to treat neurodegenerative diseases, focusing on the interaction of these molecules with the (Aβ) peptide.

References:

[1] M. Paukov, C. Kramberger, I. Begichev, M. Kharlamova, M. Burdanova, Materials 2023, 16(3), 1276.
[2] Z. Liu, Y. Zou, Q. Zhang, P. Chen, Y. Liu, Z. Qian, Int. J. Mol. Sci. 2019, *20*, 2048.
[3] A. Mumyatov, P. Troshin, Energies 2023, 16, 1924.

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CytroCell: A *Citrus*-based micronized cellulose for advanced applications

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CytroCell is a new micronized cellulose derived from industrial waste lemon peel via hydrodynamic cavitation (HC) carried out in water only.[1] Mixed in small amount with fragile pectin-based films, this new bionanomaterial has recently shown its ability to vastly increase the mechanical and thermal properties of the resulting composite films.[2] Dissolved in green, biobased solvent cyrene and mixed a polymerizable ionic liquid (PIL) comprised of a styrene unit functionalized with a triethylphosphonium ion and BF_4^-, CytroCell turns otherwise unstable PIL into a chemically stabilized and mechanically reinforced membrane suitable for producing long-awaited anion exchange membranes for alkaline water electrolysis.[3] In this lecture, I will present the unique structural and physicochemical properties of this new *Citrus*-derived nanocellulose reproducibly produced in large quantity at ultralow cost from lemon processing waste via HC in water only.[4] I will conclude providing arguments for which the HC-based process affording the CytroCell may have solved all main hurdles that so far limited commercialization of nanocellulose on large scale.[5]

Acknowledgements
This study was funded by PNRR MICS Extended Partnership, and PNRR AdP POR H_2 "Ricerca e sviluppo sull'idrogeno" – LA 1.1.6, financed by the EU – NextGenerationEU.
We thank Enrica Fontanova and co-workers at Istituto per la Tecnologia delle Membrane, CNR, for fruitful collaboration.

References:

[1] A. Scurria, L. Albanese, M. Pagliaro, F. Zabini, F. Giordano, F. Meneguzzo, R. Ciriminna, *Molecules* **2021**, *26*, 596.
[2] A. Scurria, M. Pagliaro, G. Pantaleo, F. Meneguzzo, F. M. Giordano, R. Ciriminna, *ACS Appl. Bio Mater.* **2022**, *5*, 4942.
[3] E. Fontanova, R. Ciriminna, D. Talarico, F. Galiano, A. Figoli, G. Di Profio, R. Mancuso, B. Gabriele, G. Angellotti, G. Li Petri, F. Meneguzzo, M. Pagliaro, CytroCell@PIL: a new Citrus nanocellulose-polymeric ionic liquid composite for enhanced anion exchange membrane alkaline water electrolysis by, *ChemRxiv* **2024**.
[4] S. Al Jitan, A. Scurria, L. Albanese, M. Pagliaro, F. Meneguzzo, F. Zabini, R. Al Sakkaf, A. Yusuf, G. Palmisano, R. Ciriminna, *Int. J. Biol. Macromol.* **2022**, *204*, 587-592.
[5] R. Ciriminna, G. Angellotti, R. Luque, M. Formenti, C. Della Pina, M. Pagliaro, Fulfilling the industrial potential of nanocellulose, *ChemRxiv* **2024**, DOI:10.26434/chemrxiv-2024-wsvkz.

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Nanocellulose: a versatile platform for drug delivery

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Nanocellulose is a versatile biopolymer with excellent chemical and physical properties: high mechanical strength, low density, biodegradability, and biocompatibility. It can be extracted from waste materials such as agricultural biomass or from other sources including plants, bacteria, and algae.[1] Subsequent chemical functionalization increases the properties of nanocellulose and its applicability in medicine, including *drug delivery*. Taking advantage of the modifiable surface of the nanocellulose, carboxyl functions were introduced and used as ligands to anchor Indium Tin Oxide Nanoparticles (ITO NPs). These nanoparticles have an absorption peak in the NIR around 1700-1800 nm, which has recently been exploited to generate heat upon IR irradiation,[2] and is thus promising for photothermal therapy of tumors in the third biologically transparent window. Rose Bengal is another molecule selected for nanocellulose-mediated drug delivery. Rose Bengal has long been used in clinic, but only recently has shown to be effective in photodynamic therapy. Rose Bengal irradiated at 532 nm releases reactive oxygen species (ROS) with distinct antifungal properties.[3] Therefore, an effective synthesis was developed to bind Rose Bengal to nanocellulose and achieve effective antifungal results for the treatment of nail onychomycosis with a lower drug concentration.

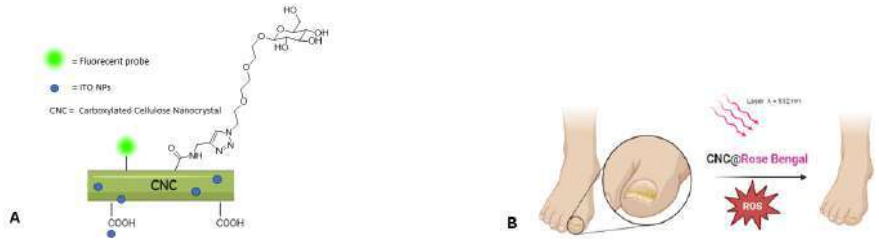

Figure 1: **A**. Drug delivery system nanocellulose based for ITO NPs selective transport. **B**. Treatment of onychomycosis with nanocellulose decorated with Rose Bengal

References:

[1] N. Lin, A. Dufresne, European Polymer Journal, 2014, 59, 302-325.
[2] A. Mazzotta, A. Gabbani, M. Carlotti, M. Ruggeri, E. Fantechi, A. Ottomaniello, F. Pineider, A. Pucci, V. Mattioli. ACS Applied Materials & Interfaces, 2022, 14, 35276–35286.
[3] J. Houang, C. Halliday, S. Chen, C.H. Ho, A. Bekmukhametova, A. Lauto. Journal of Biophotonics, 2021, 14.
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Luminescent persistent radicals for photon management applications

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Open-shell luminescent molecules are becoming increasingly studied for their unique properties, such as magnetoluminescence and the absence of heavy atom effects. They possess spin ‘‘doublet” ground states, which allows spin-allowed doublet–doublet transition, and do not suffer from quenching via the triplet state typically observable in closed-shell luminescent molecules.[1] The biggest concerns regarding their use in applications has been their stability. From the introduction of perchlorotriphenylmethyl radical (PTM) and tris(2,4,6-trichlorophenyl)methyl radical (TTM), which display room temperature luminescence but decompose under UV light, many progresses have been achieved leading to more stable derivatives, especially from the pyridyl bis(2,4,6-trichlorophenyl)methyl radical (PyBTM) family.

This contribution will describe the preparation of extended conjugation PyBTM derivatives.[2,3] The introduction of further aromatic lateral units allows to increase the materials stability up to the point that their application in luminescent solar concentrators becomes possible. Preliminary results of their use in Organic Light-Emitting Transistors will be discussed as well.

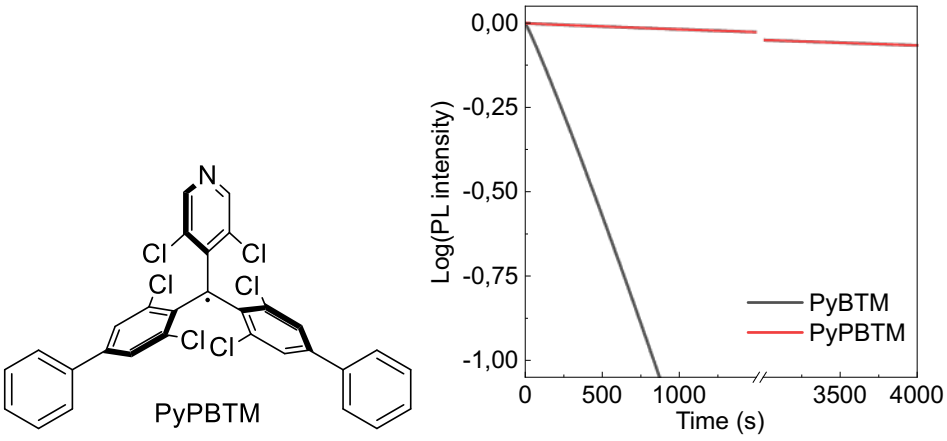

Figure 1: structure of PyPBTM, a derivative of PyBTM with extended conjugation, and its comparative stability in CH_2Cl_2 solution with respect to PyBTM under irradiation at 370 nm.

References:

[1] R. Matsuoka, A. Mizuno, T. Mibu, T. Kusamoto, Coordination Chemistry Reviews 2022, 467, 214616.
[2] S. Mattiello et al., Materials Advances 2021, 2, 7369 – 7378.
[3] S. Mattiello et al., Journal of Materials Chemistry C 2022, 10, 15028 – 15034.

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Water soluble Ir-complexes for ECL signal amplification in pathogens detection

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Electrogenerated chemiluminescence, also called electrochemiluminescence (ECL), is the generation of excited states upon recombination of oxidized/reduced species generated at the electrode and reduced/oxidized species produced by a chemical reaction.

In the past decades, ECL-active molecules have been employed in many applications such in systems for the detection of viruses/bacteria.[1] However, despite the increasing demands for accuracy in diagnostics, the sensitivity of ECL in immunoassays, already in the picomolar range, can still be improved by designing emitters with higher emission quantum yields or by thinking of multiple emitter for a single analyte.

As an example, a known strategy to increase the sensitivity of bioassays is the construction of multi-labeled systems, such as the one developed by Roche, PolyRu, consisting of 8 units connected to the same antibody. Such multiple Ru(II)-based emitters are connected to the detecting-platform which in turn binds one equivalent of analyte. This multi-labeled system allows to get considerable signal improvement since each detected analyte can be marked by the ECL-signal produced by several emitters, however the emission intensity is not as expected increased by 8 folds as should be.

Indeed, the maximum signal increase achievable is 30% due to the self-quenching of the (spatially-closed) emitters anchored on the detecting-platform surface. To overcome this problem and improve the signal increase, our strategy is to build systems in which ECL-emitters are anchored on a platform by a suitable linker allowing their release in solution under a certain stimulus . Beyond the tuning of the detecting-platform architecture, the replacement of the commercial ECL emitter $[Ru(bpy)_3]^{2+}$ with more efficient[2] and easily-color-tunable[3] emitters such as water soluble Ir(III)-complexes,[4] represents a promising tool to further improve the signal-to-noise ratio.

[1] Sobhanie, E.; Salehnia F.; Xu G.; Hamidipanah Y.; Arshian S.; Firoozbakhtian A.; Hosseini M.; Ganjali, M. R.; Hanif, S. *Trends Analyt. Chem.* **2022**, *157*, 116727.
[2] Fernandez-Hernandez, J. M.; Longhi, E.; Cysewski, R.; Polo, F.; Josel, H.-P.; De Cola, L. *Anal. Chem.* **2016**, *88*, 4174−4178.
[3] Stagni, S.; Colella, S.; Palazzi, A.; Valenti, G.; Zacchini, S.; Paolucci, F.; Marcaccio, M.; Albuquerque, R.Q.; De Cola, L. *Inorganic Chemistry* **2008**, *47* (22), 10509-10521.
[4] Bergmann, F.; Cysewski, R.; De Cola, L.; Dziadek, S.; Fernandez Hernandez, J.M.; Josel, H.-P.; Longhi, E.; Seidel, C. **2013**, PCT/EP2013/992325.

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Functionalization of carbon nanostructures with organic moieties affords composite scaffolds for tissue engineering and regenerative medicine

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Functionalizing carbon nanostructures (CNS) such as carbon nanotubes (CNT), reduced graphene oxide (RGO) and carbon nanohorns (CNHs) with suitable organic groups is an effective strategy for their inclusion as fillers in a biocompatible polymer phase, to obtain functional materials for tissue engineering applications.

We synthetized and characterized (through TGA, Raman, XPS and electron microscopies) different CNS derivatives, soluble in different organic solvents and in water, and we used them as fillers in different polymer matrices. Resulting composite materials, both in the form of films and electrospun nanofibers, were used as scaffolds for in vitro biological tests, showing that CNS derivatives promote growth and differentiation of different cell lineages, by modulating mechanical and electrical properties of the substrate.

An innovative nanocomposite surgical implant designed for nerve regeneration has been prepared by using water soluble CNT derivatives. In vivo tests show promising results in terms of biocompatibility and effectiveness in restoring.

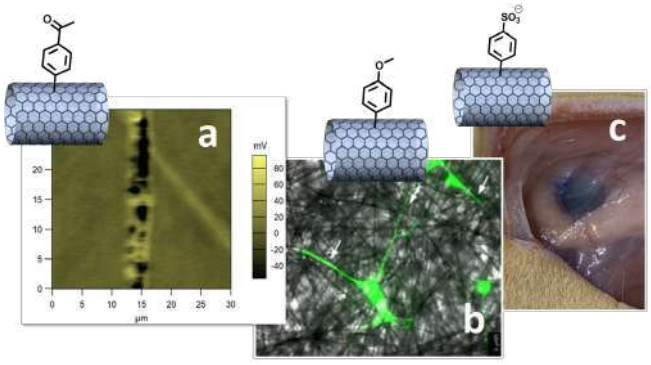

Figure 1: composite scaffolds based on different CNT derivatives: (a) scanning Kelvin probe microscopy of fibers; (b) SH-SY5Y cells extending neurites along the fibers; (c) biocompatibility assessment in vivo.

References:

[1] N. Vicentini, T. Gatti, P. Salice, G. Scapin, C. Marega, F. Filippini, E. Menna, Carbon 2015, 95, 725–730.
[2] N. Vicentini, T. Gatti, M. Salerno, Y. S. Hernandez Gomez, M. Bellon, S. Gallio, C. Marega, F. Filippini, E. Menna, Mater. Chem. Phys., 2018, 214, 265-276.
[3] G. Suarato, S. Pressi, E. Menna, et al., ACS Appl. Mater. Interfaces 2024, 16, 3093-3105

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Ionic Liquids as Efficient Media in Organic Synthesis and Geothermal Applications

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Ionic liquids (ILs) are salts with a melting point below 100°C that have been established as green solvents for two decades. They offer several advantages, including the ability to recover catalysts and reaction products easily, high thermal and air stability, and negligible vapor pressure. Over the years, we have achieved satisfactory results by performing various organic and catalytic reactions in ILs. Among the various ILs, molten tetraalkylammonium salts have proven to be superior media for many organic and organometallic reactions (see Fig. 1).

In this presentation, we will discuss how different ionic liquids affect catalyst stability, reaction rates, and regio- and stereoselectivity in carbon-carbon coupling reactions. We will focus on the superiority of quaternary ammonium halides over pyridinium- and imidazolium-derived ionic liquids, with a particular emphasis on C-H bond activation.[1,2,3]

In addition, some of us are part of the HOCLOOP[4] European consortium, aiming to explore the viability of non-traditional fluids for heat mining. Our investigation includes the use of CO2 in trans-critical or supercritical states, as well as CO2-based smart fluids (SFs) that contain ionic liquids dissolved in supercritical CO2. These SFs are a groundbreaking concept never been used before in geothermal applications.

References:

[1] A Aloia, M Casiello, A Nacci, A Monopoli, Eur. J. Org. Chem. 2024, e202400111.
[2] A Aloia, M Casiello, L D'Accolti, C Fusco, A Nacci, A. Monopoli, Chem Eur. J. 2022, 28 (65), e202202350.
[3] P Cotugno, A Monopoli, F Ciminale, A Milella, A Nacci, Angewandte Chemie International Edition, 2014, 53 (49), 13563-13567.
[4] HOCLOOP - A circular by design environmentally friendly geothermal energy solution based on a horizontal closed loop. Grant agreement ID: 101083558.

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Lipid Nanoparticles: encapsulation of Polysaccharides

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Lipid Nanoparticles (LNPs) are constructed with a lipid shell encompassing a core composed of reverse micelles encapsulating drugs, all within a diameter of about 100 nm. The lipid components typically consist of ionizable lipid, phospholipid, cholesterol, and PEGylated lipid.[1]

Recently the interest, as well as the number of approved drugs formulated with LNPs strategy, is increasing due to several advantages, such as the delivery of hydrophobic and hydrophilic drugs, the controlled release, the reduction of drugs adverse effects, the biocompatibility, and the increase of drug lifetime.[1]

Polysaccharides are heterogeneous group of natural polymers, characterized by biocompatibility, biodegradability, and nontoxicity, coupled with wide availability and usually low costs. Numerous studies have demonstrated the biological activities of polysaccharides and particularly of charged polysaccharides, such as anti-tumoral, anti-inflammatory, anti-virals, anti-coagulant, immunomodulatory and antimicrobial properties.[2]

Due to the growing interest towards polysaccharides in pharmaceutical fields, we decided to formulate LNPs containing polysaccharides. The LNPs formulations were obtained using a microfluidic system, which guarantee an excellent size control, a great homogeneity and repeatability, with the possibility to achieve volumes from µL to L and an optimal sample consumption. Furthermore, formulations would allow also to optimize the routes of administration - often a critical point for carbohydrates.

Various polysaccharides and derivatives, characterized by different molecular weight and charge, such as heparin, pentosan polysulphate and hyaluronic acid, have been selected for the encapsulation in LNPs.

Size and Zeta potential, determined by Dynamic Light Scattering, of the LNPs confirmed a size compatible with pharmaceutical applications (< 100 nm), good homogeneity and stability over time. The encapsulation efficiency is determined by Size Exclusion Chromatography. The results are encouraging in terms of efficacy and quantity of encapsulated polysaccharides. LNPs-polysaccharides formulations have been characterized by Nuclear Magnetic Resonance and Fluorescent Spectroscopy. Finally, preliminary structural studies have been carried out using electronic scanning techniques (TEM and SEM) and Small Angle X-Ray Scattering.

References:

[1] R. Tenchov, R. Bird, A. Curtze, Q. Zhou, ACS Nano 2021, 15(11):16982-17015.
[2] A.S.A. Mohammed, M. Naveed, N. Jost, J Polym Environ (2021), 29, 2359–2371.

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2-Benzylideneindan-1-one as Photoswitchable Scaffold for the Design of Light-Driven On–Off AChE Inhibitors

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Light-driven molecular switches (LDMSs) are molecules capable of interconverting between at least two different isomeric forms as a result of a light stimulus. In the last two decades different classes of LDMS (e. g. azobenzenes, stilbenes, diarylethenes, indigoids, etc.) have been explored and numerous studies have been conducted to model their photochemical properties (rotational speed, absorption wavelength, isomerization quantum yield, photostability).[1] Among the possible applications of LDMSs, photopharmacology certainly represents a continuously expanding field. Here, light-induced configurational changes are used to alter the interaction of the ligand with the binding-site and thus, modulate the pharmacological activity.[2] In this context, combining our experience in LDMS design and medicinal chemistry,[3,4] we explored the 2-benzylideneindan-1-one as a photoswitchable scaffold of potential bioactive molecules. This nucleus can easily be traced back to numerous active molecules directed towards different targets. Among these, acetylcholine esterase, an enzyme involved in numerous neurodegenerative diseases such as Alzheimer's disease, was chosen as a pharmacological target in our study. By decorating the scaffold with appropriate substituents responsible for the interaction with the enzyme we prepared a library of compounds, all obtained as *E* diastereoisomers. We demonstrated their photoswitcheable ability by inducing the formation of *Z* isomers via light irradiation at 330 nm and restoring the *E* forms using light at 400 nm. Enzyme inhibition studies have shown that, on the basis of the substitutes, *E* isomers have an AChE inhibitory activity (IC_{50}) ranging from sub-micro to sub-nanomolar range. On the other hand, photostationary states constituted of an excesses (75%) of *Z* isomer showed a reduction of the inhibition potency over one order of magnitude, confirming the possibility of modulating their biological activity via light radiation. [5,6]

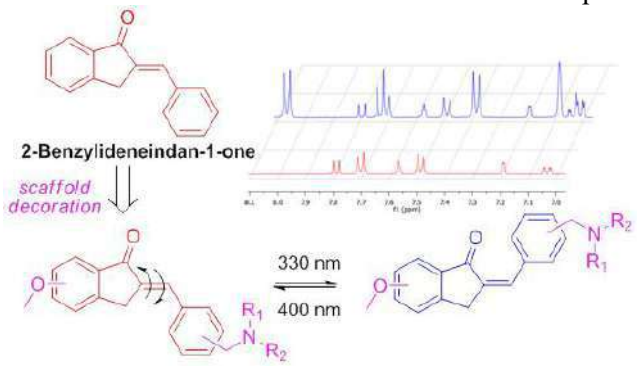

Figure 1: Decoration and photoisomerization of 2-benzylideneindan-1-one scaffold implied in the design of light-driven on-off AChE inhibitors.

References:

[1] B. L. Feringa, Angew. Chem. Int. Ed. 2017, 56, 11060–11078.
[2] M. J. Fuchter, J. Med. Chem. 2020, 63, 20, 11436–11447
[3] M. Paolino, M. Gueye, E. Pieri, M. Manathunga, S. Fusi, A. Cappelli, et al. JACS, 2016, 138, 9807–9825.
[4] M. Filatov(Gulak), M. Paolino, R. Pierron, A. Cappelli, G. Giorgi, et al. Nature Communications, 2022, 13, 6433.
[5] M. Paolino, M. Rullo, S. Maramai, M. de Candia, L. Pisani, et al. RSC Medicinal Chemistry 2022, 13, 873–883.
[6] M. Paolino, M. de Candia, R. Purgatorio, M. Catto, M. Saletti, A. R. Tondo, et al. Molecules 2023, 28(15), 5857.

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A new supramolecular calix[5]arenes-based systems for the binding of primary ammoniums in organic an aqueous environment

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The development of systems for the recognition of primary ammonium cations in water is a exciting and timely research area of supramolecular chemistry as several are well-known biomarkers (i.e. cadaverine, putrescine, spermidine) or pollutants (i.e. aromatic amines).[1] Nonetheless, the recognition event of charged species in aqueous media is particularly tricky and limited by the competitive nature of water.[2,3] In this respect, an attractive strategy is the design of receptors based on calix[5]arene macrocycles, which provide an hydrophobic cavity that has proven to lead to strong inclusion complexes with linear alkylammonium guests. The stability of these complexes mainly arises from non-covalent interactions, comprising hydrogen bonding of the ammonium ion inside the cavity with the phenolic oxygens, accompanied by cation-π and C-H-π interactions.[4] A key issue is the obviously poor or incomplete solubility of these receptors in water. To this end, here we report our recent work on a new calix[5]arene ionizable receptor bearing at the lower rim five carboxylic groups able to lend a proton to complementary amines, leading to the formation of a host-guest complex with the linear alkylammonium primary guests thus formed. The complexing capabilities of this system were tested in different environments (organic solvent, water and micelles) through NMR experiments.

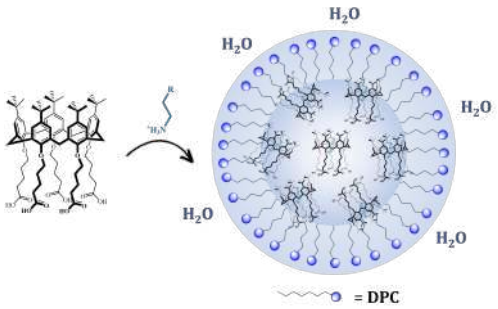

Figure 1: Recognition of primary ammonium in micelles by Calix[5]-pentaacid.

References:

[1] S.A. Gheni, M.M. Ali, G.C. Ta, H.J. Harbin and S.A. Awad, *J. Chem. Health Saf.* **2024**, 8–21.
[2] L. Escobar and P. Ballester, *Chem. Rev.* **2021**, *121*, 2445–2514.
[3] R. Carpentier, S. Lambert, E. Brunetti, I. Jabin, and K. Bartik, *J. Org. Chem.* **2022**, *87*, 12749–12758
[4] D. Garozzo, G. Gattuso, A. Notti, A. Pappalardo, S. Pappalardo, M. F. Parisi, M. Perez, I. Pisagatti. *Angew. Chem., Int. Ed.*, **2005**, *44*, 4892–4896.

ORG-OR-086

Circular Integration of Carbon Dots: From Waste to Value Across Multiple Sectors

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Carbon dots (CDs) are nanomaterials known for their biocompatibility, photostability, and tunable photoluminescence, making them versatile for various applications. With sizes typically below 20 nm, CDs consist of carbon cores with functional surface groups.[1] They exhibit broad absorbance, large photoluminescence, and low toxicity, making them suitable for biomedicine, optoelectronics[2], and environmental applications. Here we outline our activities involving CDs within a sustainable and circular economy framework. We demonstrate the use of CDs as UV protective coatings for food packaging[3], enhancing sustainability. Moreover, we test CDs as charge-regulating layers in organic photovoltaic cells, showcasing their versatility in renewable energy. Additionally, we explore CDs in precision agriculture for enhancing tomato plant growth, drought resistance, and water consumption reduction. Finally, we highlight a circular chemistry approach to synthesize CDs from citric acid sourced from agricultural or biodiesel waste, emphasizing sustainable-by-design principles. These activities integrate innovative nanomaterials within circular economy principles, driving sustainable solutions across diverse sectors.

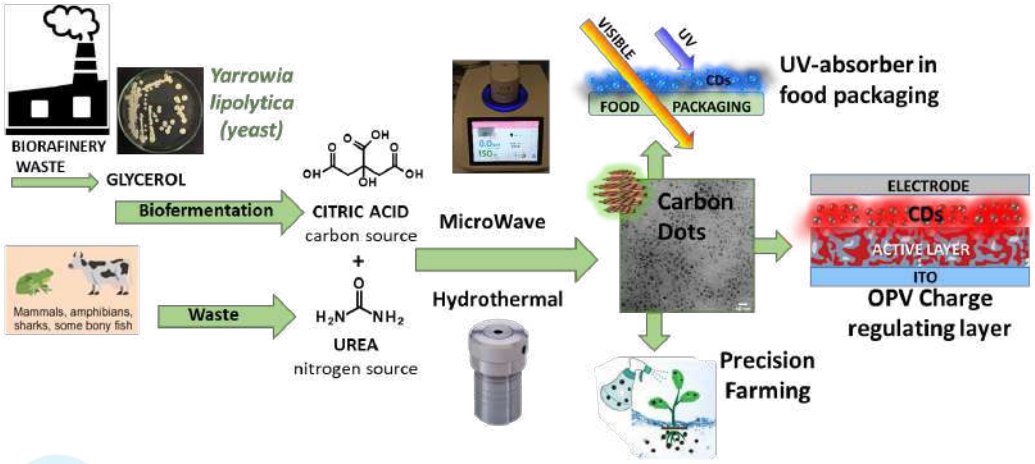

Figure 1: Schematic representation of CDs synthesis and explored applications.

References:

[1] J. Liu, R. Li, B. Yang, ACS Central Science 2020, 6(12), 2179 - 2195.
[2] P. Lagonegro, U. Giovanella, M. Pasini, Coatings 2021, 11(1), 5.
[3] B. Ardini, ... & T. Virgili, Coatings 2023,13(4), 785.

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ORG-OR-087

Barium Alginate Gel Beads: A Homochiral Porous Material from Brown Algae for Heterogeneous Asymmetric Catalysis

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Asymmetric metal- and organocatalysis rely typically on low molecular weight chiral compounds as enantioinducing elements. However, evoking biocatalysis, examples of inherently chiral natural (e.g. double stranded DNA)[1] and synthetic (e.g. chiral organic frameworks)[2] macromolecules as enantioselective catalysts are rapidly emerging. In this context, we report barium alginate gel beads as heterogeneous, and reusable, catalyst for the benchmark addition of indoles to nitroalkenes, affording the corresponding adducts in moderate to good yields and enantioselectivities (up to 93% ee, Figure 1). This rare example of high enantioinduction offered by a polysaccharide in catalysis was realized thanks to the versatility of the alginates, a family of biopolymers derived from brown algae. After the first promising results,[3] we are expanding to different reactions this versatile catalyst, confirming the wide applicability of our new system to prochiral substrates.

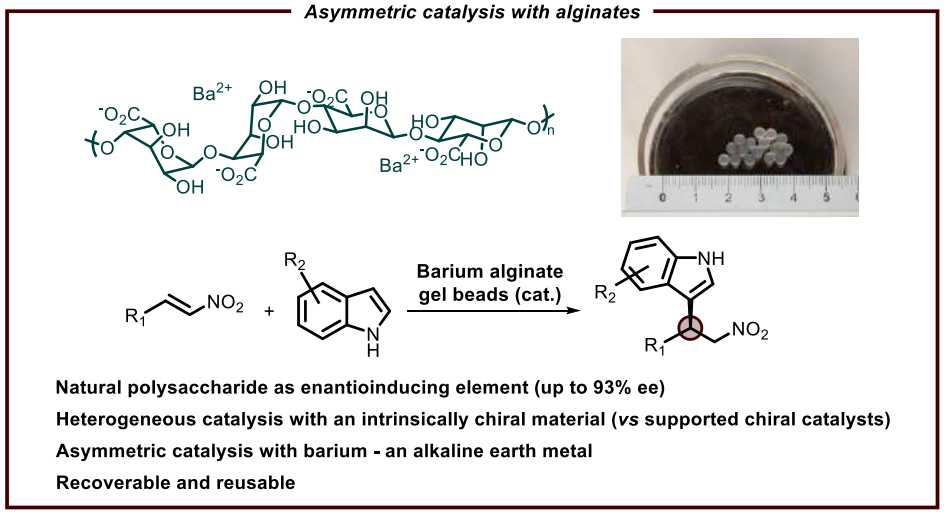

Figure 1: Barium alginate gel beads: a chiral heterogeneous catalyst from brown algae.

References:

[1] A. J. Boersma, R. P. Megens, B. L. Feringa, G. Roelfes, Chem. Soc. Rev., 2010, 39, 2083 – 2092.

[2] W. Gong, Z. Chen, J. Dong, Y. Liu, Y. Cui, Chem. Rev., 2022, 122, 9078 – 9144.

[3] P. Pecchini, D. A. Aguilera, A. Soccio, A. Lombardi, F. S. Azcona, N. Santarelli, M. Fochi, P. Gaudin, N. Tanchoux, L. Bernardi, ACS Catalysis, pending revision.

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ORG-OR-088

Developing Triarylamine-Based Materials for Optoelectronic Technologies: A Step Towards Sustainability

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The drive for cleaner and more efficient chemical processes has led the scientific community to explore greener synthetic methods, aiming to eliminate or minimize the use of hazardous and expensive chemicals, while maintaining high reaction efficiency. Glycerol, a non-toxic and readily available byproduct of biodiesel production, is emerging as a valuable resource for sustainable organic synthesis. It offers a compelling alternative to traditional organic solvents, potentially making organic synthesis greener and more efficient.[1] In this contribution, we present a sustainable approach to the Sonogashira reaction, utilizing glycerol as the solvent. This alternative strategy was successfully applied to the synthesis of a series of novel triarylamine-based derivatives bearing electron-donating or electron-withdrawing substituents (Figure 1). The structure-reactivity relationship of the starting aromatic halides will be discussed. Furthermore, the characterization of the obtained compounds revealed their suitability for cutting-edge optoelectronic applications, such as hole transport materials (HTMs)[2] in wide-band gap perovskite solar cells (PSCs) and luminophores in Luminescent Solar Concentrators (LSCs)[3].

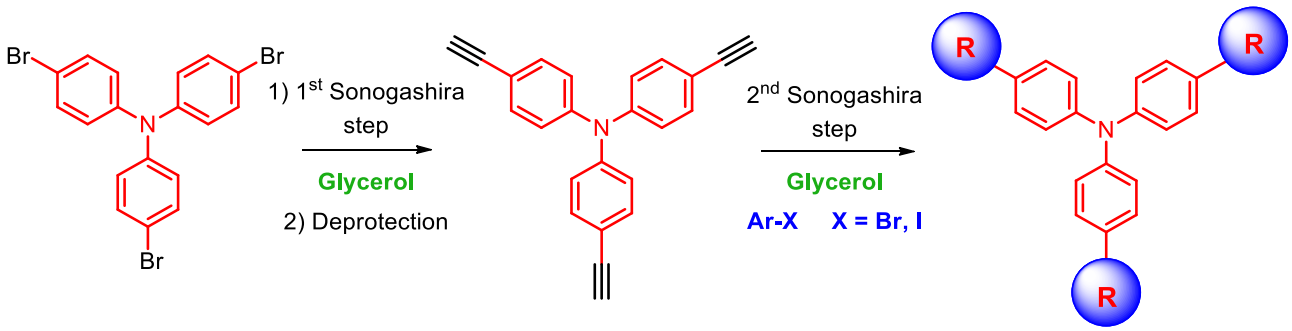

Figure 1: Alternative synthetic approach for the synthesis of functionalized triarylamines.

References:
[1] Yanlong G. and Jerome F. Green Chemistry 2010, 12, 1127-1138.
[2] Rodríguez-Seco C., Cabau L., Vidal-Ferran A., Palomares E. Acc. Chem. Res. 2018, 51, 869-880.
[3] J. Roncali Adv. Energy Mater. 2020, 10, 2001907

ORG-OR-089

Hybrid cellulose nanocrystal–gold nanoparticles as a new generation of multifunctional and programmable glyconanomaterial

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Cellulose nanocrystal (CNC) is a low-cost functional material that has emerged as one of the most appealing natural biopolymeric scaffold for the preparation of advanced nanomaterials in many applicative areas.[1] As such, it has the potential to be exploited as a 'magic bullet' for nanomedicine. In this communication, we discuss on our approach on the design and preparation of a CNC-gold nanoparticles hybrid (CNC-AuNPs),[2] an original, modular, and functional glyconanomaterial that provides a conceptual advance in the field: it combines the complementary physiochemical properties of AuNPs and polysaccharide-based nanomaterials along with preserving the main composition and structure of the pristine CNC. Our CNC–AuNPs surface is easily engineered with different bioactive headgroups under strictly controlled reaction conditions and with high batch-to-batch reproducibility.[2] In particular, the proper arrangement of sugar heads on its surface and the morphological features of this polysaccharide-based glyconanomaterial make our hybrid CNC-AuNPs a unique multivalent scaffold suitable for precision medicine applications.[3] Owing to the support of a multidisciplinary and international network of collaborators[2-3] we studied the specific interactions with lectins, and we explored this programmable glyco-nanotechnology as precision delivery system.

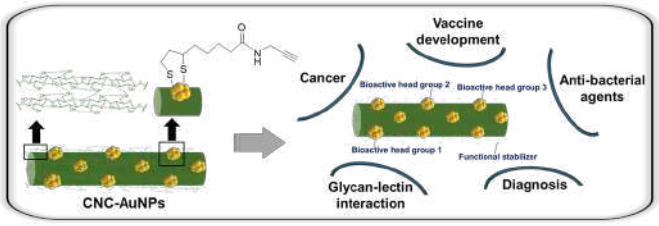

Figure 1: Schematic representation of the hybrid CNC-AuNPs.

References:

[1] G. Delepierre, et.al. Langmuir, 2021, 37, 8393; J. Van Rie, et al. Nanoscale, 2017, 9, 8525–8554.

[2] B. Richichi, G. Biagiotti, D. Berti, P. Andreozzi, S. Moya, S. Minucci, C. Garibaldi, R. Orecchia, A.K.S. Saadeldin Abdelaziz, R. Cazzoli, 2022 Appl N°102022000011450, PCT/IB2023/055515; G. Biagiotti, G. Toniolo, M. Albino, M. Severi, P. Andreozzi, M. Marelli, H. Kokot, G. Tria, A. Guerri, C. Sangregorio, J. Rojo, D. Berti, M. Marradi, S. Cicchi, I. Urbanc̆ic̆, Y. van Kooyk, F. Chiodo, B. Richichi, Nanoscale Horizons, 2023, 8, 776 – 782.

[4] G. Biagiotti, R. Cazzoli, P. Andreozzi, G. Aresta, F. Mattii, C. Mangini, P. di Gianvincenzo, C. Tobia, S. Recchia, L. Polito, M. Severi, S. Cicchi, S. E. Moya, R. Ronca, A. Albini, D. Berti, R. Orecchia, C. Garibaldi, S. Minucci, B. Richichi Nanoscale Horizons, 2024, under rev.

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From models to Lignin depolymerization. Photocatalysis using V-aminotriphenolate complexes.

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The growing shortage of fossil resources leads to the search of a "greener" alternative for high-value chemicals production. The exploitation of biomass waste materials, in particular lignin, is proposed as a valid solution for the replacement of current non-renewable sources. However, the complex and irregular structure of this biopolymer difficult the obtention of target aromatic organic molecules. Recently, photocatalysis in combination with earth-abundant metal catalyst has emerged as a promising methodology for the selective depolymerization of lignin under mild conditions.[1]

In this communication, aerobic oxidative C-C bonds cleavage of Lignin and Lignin models catalysed by aminotriphenolate (TPA) vanadium complexes[2] will be presented. Under visible light irradiation and room temperature, vicinal diols, β-1 and β-O-4 lignin models afforded high-value aromatic products; as carbonyl compounds (aryl aldehydes, aryl carboxylic acids, aryl formates) or phenols with high selectivity. Going ahead, promising results are obtained for depolymerization of lignin itself.

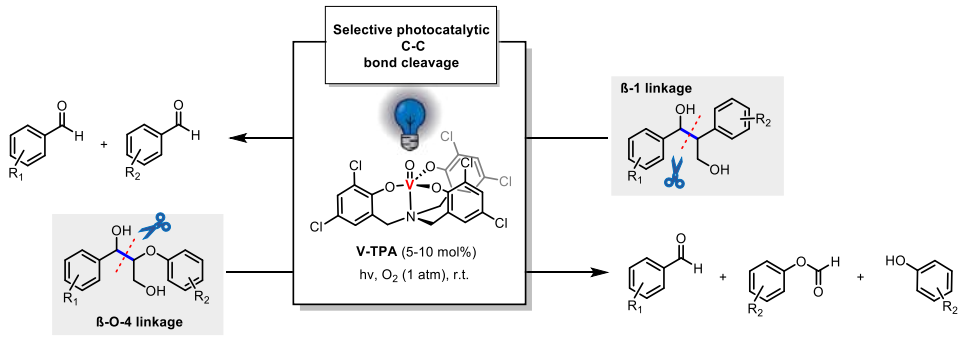

Figure 1: Photocatalytic aerobic oxidative C-C bond cleavage of Lignin models using V-TPA complex.

The project has been carried out in the frame of MICS (Made in Italy – Circular and Sustainable) Extended Partnership. We thank the Progetto PON "Ricerca e Innovazione" 2014-2020 Azione IV.5 – Dottorati su tematiche green (FAS fellowship) and the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3 – D.D. 1551.11-10-2022, PE00000004) (WB and E.C. fellowships) for financial support.

References:

[1] X. Wu, N. Luo, S. Xie, H. Zhang, Q. Zhang, F, Wang, Y, Wang. *Chem. Soc. Rev.* **2020**, *49*, 6198-6223.

[2] R. Carpentier, W. Denis, F. Sanz Azcona, D. Carraro, G. Grauwels, M. Orlandi, C. Zonta, G. Licini, K. Bartik. *ACS Sustainable Chem. Eng.* **2023**, *11*, 23, 8633-8641.

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"Enzyme-Driven Nanostructured Materials: A Promise for Biocatalyst Immobilization and Activation"

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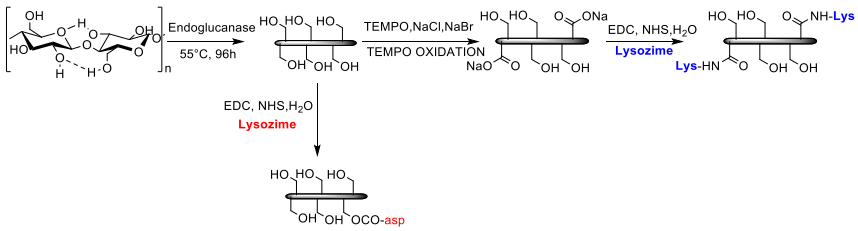
Nanostructured materials hold great promise as substrates for immobilization and activation[1] of biocatalysts. Cellulose nanocrystals (CNCs)[2], obtained from waste or renewable sources, are not only sustainable and biodegradable, but also boast a high specific surface area, making them ideal for anchoring a substantial number of enzyme units. They also exhibit high thermal and mechanical stability. In this communication, we present a comprehensive mechano-enzymatic approach to produce CNCs from cotton linters[3] and the development of antibacterial materials through the immobilization of enzymes, including lysozyme and lipase, on mechano-enzymatic CNCs. The antibacterial property is a much sought-after feature in water-dispersible materials, which makes CNC composites suitable for applications in sustainable paper and textile coatings.[4] Initially, we discuss the use of *Aspergillus niger* endoglucanase[5] for the enzymatic hydrolysis of Avicel. This environmentally friendly approach, compared to hydrolysis with mineral acids, successfully produces neutral CNCs. Next, we delve into the enzymatic self-assembly process, involving chicken egg white lysozyme and lipase from Candida rugosa, with neutral or negatively charged sulfated cellulose nanocrystals.[6] Lysozyme shows interesting protective properties against the proliferation of *Candida albicans*, *Aspergillus niger*, *Staphylococcus aureus* and *Escherichia coli*,[7] while lipase contributes an additional layer of enzyme functionality, enhancing the versatility of nanostructured materials.



Scheme1: Covalent immobilization of lysozyme on nanocellulose

References

1. S. A. Ansari, Q. Husain, Biotech. Adv., 2012, 30, 512-523.
2. A. Dufresne, Nanocellulose from Nature to High Performance Tailored Materials, 2nd Edition, Walter de Gruyter GmbH, Berlin, 2018.
3. L. Spagnuolo, D. Beneventi, A. Dufresne, A. Operamolla, *submitted*.
4. L. Spagnuolo, L. Micheli, D. Beneventi, A. Dufresne, A. Operamolla, *submitted*.
5. L. Spagnuolo, R. D'Orsi, A. Operamolla, "Nanocellulose for paper and textile coating: the importance of surface chemistry", ChemPlusChem,2022,87,202200204.
6. B. Pereira, V. Arantes, Ind. Crops Prod., 2020, 152, 112377.
7. Jebali, S. Hekmatimoghaddam, A. Behzadi, I. Rezapor, B. H. Mohammadi, T. Jasemizad, S. A. Yasini, M. Javadzadeh, A. Amiri, M. Soltani, Z. Rezaei, N. Sedighi, M.Seyfi, M. Rezaei, M. Sayadi, Cellulose, 2013, 20, 2897– 2907.

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Pine needles as a sustainable source of natural phenolic compounds to be used as green corrosion inhibitors for aluminium alloys

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Polyphenols, including lignin and tannins, are natural organic compounds characterized by several interesting properties that make them exploitable in many different fields. In addition, they can be extracted by green and sustainable procedures from a wide variety of waste biomasses. In this context, , the present study was focused on the extraction and characterization of phenolic compounds from pine needles (PN), a largely available and still not fully exploited waste material. Several extraction techniques were compared, aiming to achieve the efficient use of this feedstock while ensuring the sustainability of both the extraction process and of the resulting product.[1] A combination of spectroscopic (UV-Vis, NMR, and EPR) and chromatographic (HPLC) analysis revealed that PN extract mainly consists of phenolic polymers, in particular condensed tannins, identified as propelargonidin/prodelphinidin tannins (Figure 1).

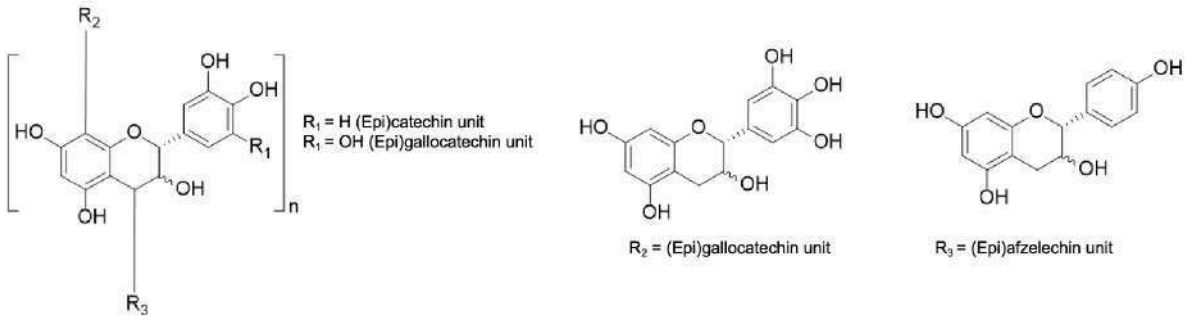

Figure 1. Proposed exemplificative structure for condensed tannins in the PN extract.

These compounds exhibited promising activity as a green alternative to the traditional corrosion inhibitors for the protection of aluminium alloys.[2] Therefore, the obtained results contribute to expand the knowledge of the structure-property relationships of complex phenolic compounds, particularly concerning those derived from largely available and underexploited biomasses.

References:

[1] M. Salzano de Luna, G. Vetrone, S. Viggiano, L. Panzella, A. Marotta, G. Filippone, V. Ambrogi, 2023, 11, 4670−4677

[2] F. Scherillo, G. Vetrone, S. Viggiano, G. Filippone, V. Ambrogi, M. Salzano de Luna, L. Panzella, submitted

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Valorization of natural biomasses and exhausted industrial composites *via* bioorganic approaches

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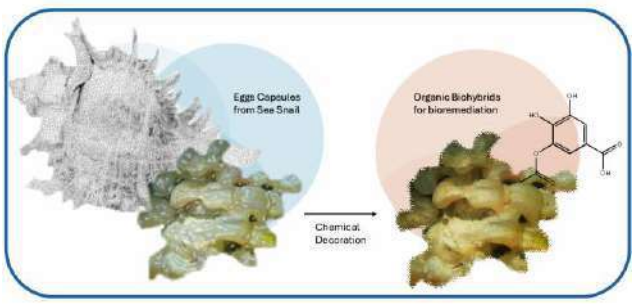

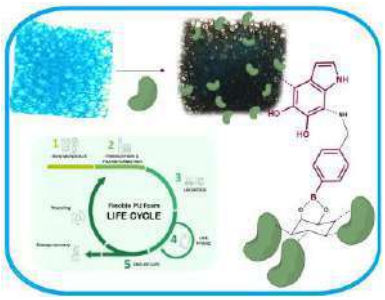

Environmental remediation often requires technology at the interface between material science, chemistry and biology, aiming to cheap materials with low environmental impact themselves.[1] Artificial sources or non-Nature derived matrices should be optimized to avoid delivery of toxic side metabolites, produced with eco-compatible chemical conversion, and possibly imply resorption or recycle. Here we present two different time-cost efficient, environmentally friendly, sustainable, and effective biohybrid systems produced *via* various approaches. The first exploits the naturally porous eggs capsules produced by *Hexaplex trunculus* (known as the banded dye-murex), a well-known marine gastropod mollusks, in the Muricidae family. After the eggs release, these porous capsuled structures exhibit a sponge-like, biomineralized, proteinaceous bulk whose sacculae are considered here as a powerful natural, unexplored matrix to be used for removing pollutants from water, due to its rehydratable property. The bioorganic chemistry tool here helped to improve the selectivity of this material towards the adsorption of specific organic pollutants, introducing poly-phenolic moieties as additive chemical functions. In a second tale, exhausted polyurethane elastic foam has been valorised and utilized as a polymeric bulk to chemically immobilize *Pseudomonas fluorescens* bacteria for soil bioremediation purposes. The exploited chemistry here consisted of a hydroxy-indole-based polymer, processable in water with strong sticky properties [2] and biocompatibility, bearing methyn-aminophenyl boronic units [3] for linking the bacterial external glycocalyx. This biomimetic, melanin like polymer resulted efficient also in decreasing the delivery of microplastics from polyurethane foam structures. Both the investigated materials efficiently bioremoved *via* adsorption inorganic and organic model pollutants from contaminated waste water sources and soils. These works refer to Agritech National Research Center funding from the European Union Next-Generation EU and "Dipartimenti di Eccellenza-progetto MAR.V.E.L. (MARginal areas: Valorization of Ecosystem resources for fair and sustainable Livelihood, ICT-2018-20)".

[1] I. D. Barbosa Segundo, F. C. Moreira, T. F. C. V. Silva, A. D. Webler, R. A. R. Boaventura, V. J. P. Vilar, *Development of a treatment train for the remediation of a hazardous industrial waste landfill leachate: A big challenge*, Science of The Total Environment 2020, 741, 140165. [2] D. Vona, S. R. Cicco, R. Ragni, C. Vicente-Garcia, G. Leone, M. M. Giangregorio, F. Palumbo, E. Altamura, G. M. Farinola, *Polydopamine coating of living diatom microalgae*, Photochemical&Photobiological science, 2022, 21, 949. [3] D. Vona, S. R. Cicco, R., Labarile, A. Flemma, C.V. Garcia, M. M. Giangregorio, P. Cotugno, R. Ragni, *Boronic Acid Moieties Stabilize Adhesion of Microalgal Biofilms on Glassy Substrates:A Chemical Tool for Environmental Applications,* 2023, 24, e202300284.https://doi.org/10.1002/cbic.202300284

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Quinoxaline-Based Organic Dyes for Dye-Sensitized Photoelectrochemical Cells (DS-PECs)

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In the search for sustainable approaches to energy great interest has been given to DS-PECs, mimetics of natural photosynthesis, where O_2, H_2 and carbon-based chemicals are produced from cheap and abundant sources (water, carbon dioxide) and solar radiation[1]. In DS-PECs for *water splitting*, the photoanode combines visible light-absorbing photosensitizers for light harvesting and charge separation and a water oxidation catalyst (WOC). Due to the pivotal role of the dye in the device's operation, the development and synthesis of new sensitizers with broad optical responsiveness, suitable energy levels, and robust stability stand as crucial aspects[2]. Here we report the design and synthesis of three new quinoxaline-based organic dyes featuring a D-π-A architecture. As a result of a specific bottom-up synthetic strategy, we were able to finely tune HOMO energy level by varying the substituents of the donor moiety. Furthermore, dyes **1a-c** (*Figure 1*) have been fully characterized from a photo-electrochemical point of view and employed in combination with the WOC Ru(bda)(pyP)$_2$ for the successful assembly of a photoelectrochemical cell.

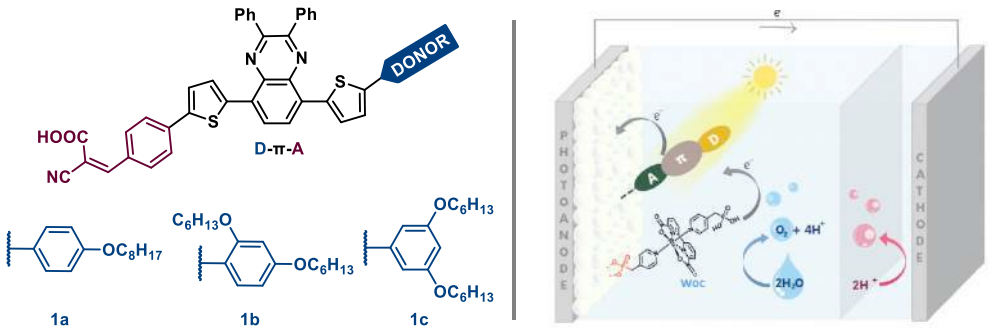

Figure 1: Quinoxaline-Based Dyes (left); schematic representation of a DS-PEC for water splitting (right).

Acknowledgments: This research was funded by CNR ("RIPRESA" project, "@CNR" call) and the European Union, NextGeneration EU through the Italian Ministry of Environment and Energy Security, POR H_2 AdP MASE/ENEA-CNR-RSE, PNRR - Mission 2, Component 2, Investment 3.5 "Ricerca e sviluppo sull'idrogeno", CUP: B93C22000630006.

References:

[1] C. Decavoli, C.L. Boldrini, N. Manfredi, A. Abbotto, *Eur. J. Inorg. Chem.* **2020**, 978–999
[2] J. T. Kirner, R. G. Finke, *J. Mater. Chem.* **2017**, *5*, 19560–19592.

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ORG-OR-095

Waste-Minimized Approach for Csp^2 – N Bond Formation via Heterogeneous Buchwald-Hartwig Coupling to Access Di- and Triarylamines

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The Csp^2–N bond is crucial in the synthesis of active pharmaceutical ingredients. The Buchwald–Hartwig coupling emerges as a preeminent and extensively utilized method for introducing nitrogen-containing functionality into molecules.[1] Despite its wide applicability, the pressing need to enhance energy efficiency and environmental sustainability remains paramount. In response to these imperatives, we report herein a Buchwald-Hartwig Coupling catalysed by commercially available Pd/C as a recoverable catalyst, thereby facilitating the synthesis of di- and triarylamines through waste-minimized protocols. This strategy employs a recoverable and low-energy-consuming azeotropic mixture of CPME: water.[2] The synergistic interplay between heterogeneous catalysts and recoverable reaction media enables application under flow conditions, addressing concerns associated with the solubility of inorganic species involved.

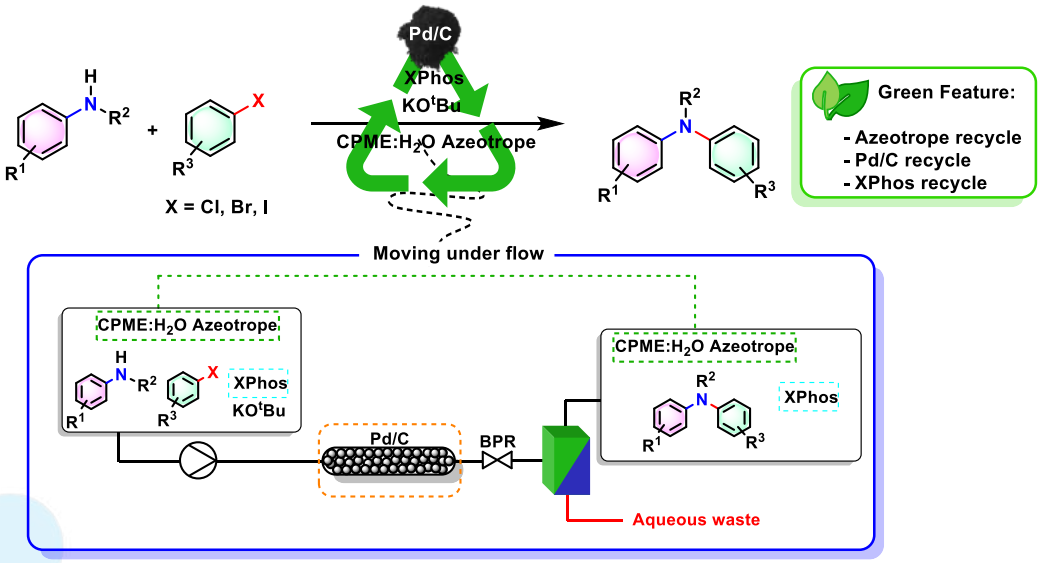

Figure 1: Schematic representation of the heterogeneous Buchwald-Hartwig coupling to access di- and triarylamines in a waste-minimized approach under batch and flow conditions.

References:

[1] R. Dorel, C. P. Grugel, A. M. Haydl Angew. Chem. Int. Ed. 2019, 58, 17118–17129
[2] F. Ferlin, F. Valentini, D. Sciosci, M. Calamante, E. Petricci, L. VaccaroACS Sustainable Chem. Eng.2021, 9, 12196−1220412200

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Molecular interaction between heparan sulfate mimetics and the recognition spike protein of SARS-CoV-2 virus

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Heparan sulphate (HS) is a linear highly sulphated polysaccharide, belonging to the glycosaminoglycan (GAG) family. Its repeating unit is the disaccharide of uronic acid (D-glucuronic or L-iduronic) β(1→4) linked to D-glucosamine (GlcN) residues and characterized by a variable degree of sulfation.

In the extracellular matrix, HS is organized in proteoglycans (HSPGs) or glycoproteins and forms long chains, that covers the entire external surface of cells. HS is polyanion and its negative charges, allow it to bind viral and/or bacterial recognition proteins.

SARS-CoV-2 is a single-stranded RNA virus whose recognition glycoprotein (S or spike) decorates the outer surface of the viral capsid, forming the characteristic *crown*. The distal tip of the spike (receptor binding domain S1-RBD) specifically binds the angiotensin-converting enzyme 2 (ACE2) and activates the internalization of the virus. Early evidence suggests that HS acts as the first anchor point for the virus particles and as a co-receptor, mediating the interaction between S1-RBD and the ACE2 [1] which is located on the cell surface hidden by HS chains.

Our study focuses on characterizing the interaction between HS oligosaccharides and S1-RBD of the Omicron, Delta, and WT variants of SARS-CoV-2 to understand how the viral genetic evolution affects the co-receptor role of HS. Both saturation transfer difference (STD) NMR and MD simulation were used to achieve this goal. Two hexasaccharides, referred to here as IAGAIA [2] and PPS [3], were selected as mimetics of HS and a poly-xylane-sulfate, respectively. Both compounds have been shown to inhibit the SARS-CoV-2 infection of cells in vitro.

Complexes between the S1-RBD variants and IAGAIA, or PPS were generated using a docking procedure, in which the ligand is treated as semi-flexible (Glide SP - Schrödinger). A selection of top-ranked poses has been further refined by molecular dynamics simulations in explicit solvent (Amber18), using the force fields: Glcycam06 and Amber ff14SB for the glycan and protein description, respectively. This allows us to estimate their binding free energy (MMGBSA) and to identify key ligand-protein interactions. In parallel, STD-NMR interaction experiments between S1-RDB (Omicron) and IAGAIA have been performed to determine the glycan epitopes binding. The experimental STD initial slope (STD_0 values) measured in this experiment have been compared with the corresponding simulated STD using selected MD simulation trajectories of the IAGAIA-S1-RBD complex (RedMat)[4] allowing the validation of the predicted glycan-S1-RBD epitope binding.

References:

[1] T.M. Clausen, 2020,183(4),1043-1057
[2] M. Parafioriti, M. Ni, M. Petitou, et al., 2022,29(1)
[3] S. Bertini, A. Alekseeva, S. Elli, et al., 2022, 122(6) , 984-997
[4] R. Nepravishta, J. Ramírez-Cárdenas, G. Rocha, et al., 2024, 96(2), 615-619

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ORG-OR-097

Infrared Irradiation as Sustainable Energy Source in transition metal-catalyzed direct arylation reactions

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The use of non-conventional energy sources versus traditional thermal heating has recently gained significant attention due to the possibility of minimizing reaction times, enhancing product yield and avoiding undesired by-products. In this frame, infrared (IR) irradiation is very appealing, as a highly efficient form of heating emitted from an inexpensive lamp, with high heat transfer rate, good heating homogeneity, low energy consumption and short heating time [1]. IR irradiation potential in transition metal-catalyzed organic reactions has not been yet extensively investigated. We have recently demonstrated its suitability in solvent-free Pd-catalyzed (hetero)aryl-aryl reactions via Csp^2-H bond activation [2,3].

Here we report our preliminary studies proofing the high efficiency of IR irradiation in promoting (a) transition-metal catalyzed direct arylation reactions between Csp^3-H bonds and aryl iodides in the presence of transient directing groups and (b) Buchwald type arylation reactions of indoles with aryl iodides.

References:

[1] R. Escobedo, R. Miranda, J. Martínez, Int. J. Mol. Sci. 2016, 17, 453
[2] G. Albano, G. Decandia, M.A.M. Capozzi, N. Zappimbulso, A. Punzi, G.M. Farinola, ChemSusChem 2021,14, 3391-3401.
[3] N. Zappimbulso, M.A.M. Capozzi, A. Porcheddu, G.M. Farinola, A. Punzi, ChemSusChem 2021,14, 1363-1369.

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Designing of quaternary ammonium salts and functionalized silica materials for marine antifouling coatings

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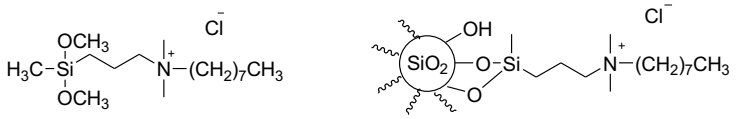
Biofilms consist of microbial cells living as a community with a very high intrinsic tolerance and resistance to abiotic and biotic stresses, severely impacting human health.[1] In marine environments, biofilm-coated surfaces facilitate the attachments of macro-organisms such as algae, barnacles, and mussels with consequent material erosion, reduction of vessel speed, and increased fuel consumption. Furthermore, fouled ships can spread marine organisms in new environments, increasing the chances of biocontamination.[2]

Here, we focused on developing greener antifouling coatings known as contact-killing surfaces. In these systems, non-leaching biocidal motifs, such as superficial quaternary ammonium compounds (QASs), can ensure long-term protection since featuring fouling release properties.[3]

In the synthesis of QASs, the number and type of cationic heads (aliphatic or aromatic), the anion, and substituents on nitrogen have been systematically changed to obtain a set of molecules with antimicrobial activity against a Gram-negative bacterial strain highly resistant to environmental stresses.

The antibacterial silane **1** was used to design crosslinked polydimethylsiloxanes and siliceous materials **2** which resulted in materials capable of preventing the onset of microbial biofilms.

Finally, we explore the synthesis of more hydrophobic ionic liquids as antibacterial additives for base oil in super-repellent and contact-killing slippery liquid-infuses porous surfaces (SLIPS).[4,5]



1 **2**

Figure 1: Antibacterial silane-based QAS (**1**) and silica particles grafted with 1 (**2**)

References:

[1] S.L. Percival, L. Suleman, et al. Journal of Medical Microbiology 2015, 64, 323-334.
[2] M.P. Shultz, J.A. Bendick, et al. Biofouling 2011, 87-98.
[3] E.K. Riga, M. Vöhringer, et al. Macromolecular Rapid Communications 2017, 38, 1700216.
[4] S. Waheed, A. Ahmed, et al. Journal of Molecular Structure 2024, 1301, 137307.
[5] B. Zhang, Y. Zhang, et al. Colloids and surfaces. B, Biointerfaces 2022, 220, 112878.

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ORG-OR-099

Pd-Catalyzed Carbonylative Double Cyclization to a New Class of Tricyclic Heterocycles

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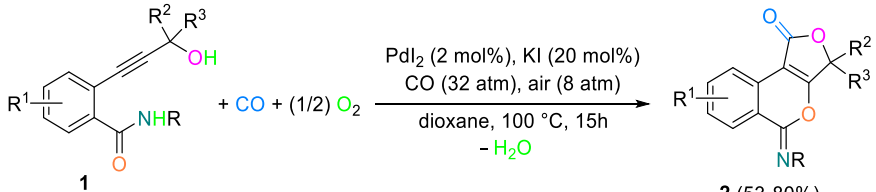
Carbonylation reactions are known to play a major role in the direct synthesis of carbonyl compounds of industrial interest as well as for the sustainable preparation of fine chemicals.[1] In particular, carbonylative double cyclizations are powerful synthetic methodologies that allow the construction of two new cycles in one synthetic procedure with formation of carbonylated polycyclic structures starting from suitably functionalized substrates.[2,3]

We report here a new carbonylative oxidative double cyclization process which leads to the formation of 5-imino-3,5-dihydrofuro[3,4-*c*]isochromen-1-ones **2** in one step starting from readily available 2-(3-hydroxyprop-1-yn-1-yl)benzamides **1**, CO and O_2 (from air) under the catalytic action of PdI_2 in conjuction with an excess of KI. Products are obtained in chemo- and regio-selective manner under relatively mild conditions (at 100 °C for 15 h under 40 atm of a 4:1 mixture CO–air) and with 53-80% isolated yields (Scheme 1).



1 **2** (53-80%)

(R = H, alkyl, aryl; R^1 = EWG, EDG; R^2, R^3 = H, alkyl)

Scheme 1

Tricyclic heterocycles **2** represent an interesting new class of polyheterocycles, with potential applications in different fields, including medicinal chemistry and material science. The structure of a representative product has been confirmed by X-ray crystallographic analysis.

References:

[1] B. Gabriele (Ed.) *Carbon Monoxide in Organic Synthesis - Carbonylation Chemistry*, Wiley-VCH: Weinheim, Germany, **2022** (ISBN 9783527347957).
[2] B. Gabriele, R. Mancuso, N. Della Ca', L. Veltri, I. Ziccarelli *Catalysts* **2023**, *13*, 1025.
[3] B. Gabriele, R. Mancuso, L. Veltri, I. Ziccarelli, N., Della Ca' *Eur. J. Org. Chem.* **2019**, 5073 – 5092.

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ORG-PO-001

Predicting PROTAC-mediated ternary complex structures through *in silico* approaches

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Degradation of proteins by PROteolysis TArgeting Chimera (PROTAC) technology has recently emerged as a promising new approach with more advantageous over occupancy-based inhibitors. PROTACs are heterobifunctional compounds featuring two binders connected by a chemical linker: one binds the protein of interest (POI) and the other recruits an E3 ubiquitin ligase[1]. Hijacking POI in close proximity to E3 ligase, a PROTAC molecule promotes the degradation of the target protein by the ubiquitin-proteasome system (UPS). In this mechanism, the formation of a stable ternary complex is essential to have an efficient POI ubiquitination and therefore, the knowledge of its 3D structure is a key aspect for the rational design[2]. To date, structural data (e.g., by X-ray) of few ternary complexes are available and they are limited to small number of target proteins, e.g., BRD4, SMARCA2/4, BTK, and WDR5.

We here propose an innovative computational methodology to predict PROTAC-mediated ternary complex structures. Our method uses protein-protein docking experiments to determine all possible interactions between POI and E3 ubiquitin ligase, then inserts the PROTAC molecule so that each ligand reproduces its binding mode in the respective target binding pocket. Finally, the obtained ternary complex models are refined by multiple rounds of metadynamic simulations, which show the conformational changes of the two proteins and PROTAC occurring until they converge to a thermodynamically favoured state (Figure 1). The applicability and the accuracy of this approach is evaluated reconstructing a series of experimentally determined ternary structures, which differ by both target protein and E3 ubiquitin ligase. This computational methodology could be a useful tool to guide and accelerate the rational design of new PROTACs related to proteins undruggable or not extensively studied. In addition, it could elucidate the mechanism of actions of already developed PROTACs whose 3D structures have not been resolved, aiding the design of novel derivatives with improved pharmacological features.

Figure 1: General workflow of new computational methodology

References:

[1] Békés, M.; Langley, D. R.; Crews, C. M., Nat. Rev. Drug Discov. 2022, 21, 181–200.
[2] Roy, M. J.; Winkler, S.; Hughes, S. J.; Whitworth, C.; Galant, M.; Farnaby, W.; Rumpel, K.; Ciulli, A., ACS Chem. Biol. 2019, 14, 361–368.

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ORG-PO-002

Chitosan-Supported Calcium Hydroxide Hybrid Material as New, Efficient, and Recyclable Catalyst for Biodiesel Production

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Recent dramatic geopolitical situations have shown that the only winning strategy for an industrially competitive country is to diversify energy sources to resist any asymmetries in the supply chain. In this context, biofuels can be crucial in achieving the right energy supply mix. Among them, fatty acid methyl esters (FAMEs) are certainly the most studied, being ideal substitutes of petro-diesel as they can be used without any engine modification, giving also reduction of emissions of SO_x, NO_x, particulate matter, dangerous aromatic compounds, and sulfur derivatives into the environment[1]. The major drawbacks of biodiesel production are the threatening of food storages, due to the lands use changes, the high energy costs of the transesterification process and the use of strongly acidic or alkaline homogeneous catalysts, often employed under stoichiometric conditions and hard to be recycled[2].

In this work, a novel supported catalyst was prepared starting from calcium chloride and chitosan flakes using a very mild approach in an aqueous medium without final calcination. The catalyst was fully characterized and proved to be very efficient in biodiesel production. The catalyst was also recycled ten times without any loss of activity.

References:
[1]A.G. Alsultan, N. Asikin Mijan, et al., ACS Omega 2021, 6, 408–415.
[2]L. Leng, W. Li, H. Li, et al., Energy and Fuels 2020, 34, 10364–10383.

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ORG-PO-003

Expanding the scope of a new bio-orthogonal templated reaction

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The desire to explore biomolecules and biological processes within their natural contexts has driven the development of reactions that are compatible with such environments. This pursuit presents a substantial challenge owing to the complexity of cellular systems. Reactions capable of proceeding within a biological system without disrupting native biological processes are termed "bioorthogonal reactions". Components involved must exhibit rapid and selective reactivity in water under phisiological conditions, in contexts of high molecular crowding.

Despite the remarkable advancements in bioorthogonal chemistries, so far very few ligation reactions have proven to be efficient at cellular level. Within current methodologies, challenges related to interference amidst the numerous functionalities present in vivo, and the requirement to remain non-toxic to the biological system, persists.

Our aim is to improve a recently discovered bio-orthogonal templated reaction which requires "proximiy" as sole trigger and expand his reactivity, ultimately extending its applicability to cellular studies.[1,2] The chosen reaction involves the ligation between 2,5-dioxopentanyl (DOP) moiety and an alpha nucleophile, resulting in the formation of piridazinium or pyrrole linkage (Fig.1). This reaction, which has been successfully tested in cell lysate, has demonstrated its ability to proceed exclusively under the guidance of a template, such as (peptide) nucleic acids or coiled-coil system formation, with high specificity and without off-target reactivity.

Here, we will present preliminar results regarding the synthesis of various alpha nucleophiles building blocks and preliminary ligation experiments performed on peptide nucleic acids (PNAs) models.

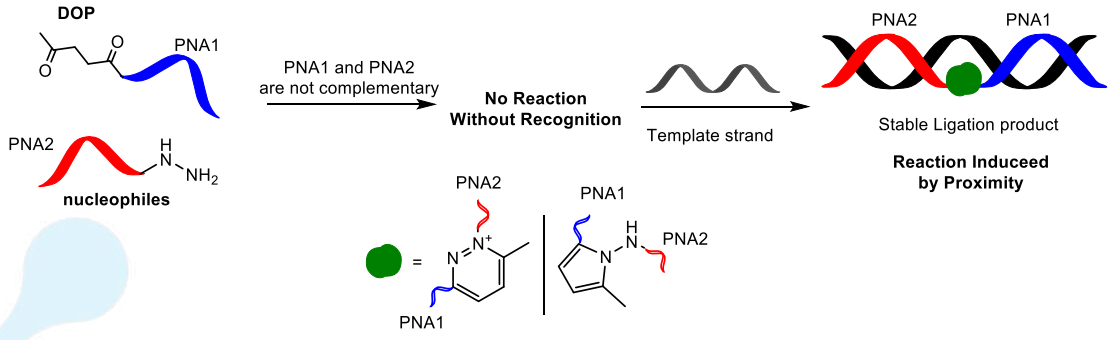

Figure 1: Templated Bio-Orthogonal Ligation.

References:

[1] A. Manicardi, E. Cadoni, A. Madder, Communications Chemistry 2021, 4 (1), 146.
[2] A. Manicardi, A. Theppawong, M. Van Troys, A. Madder, Organic Letters 2023, 25 (36), 6618 – 6622.

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ORG-PO-004

Electrochemical enantioselective α-chlorination of aldehydes

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Organic electrochemistry offers several advantages over traditional chemical oxidation methods, such as the possibility to avoid the use of stoichiometric oxidizing agents and toxic or hazardous reagents[1]. Typically, organic electrochemistry transformations require milder reaction conditions compared to traditional oxidation approaches, since electrons are used as traceless redox equivalents to perform the process without the need for additional redox reagents[2]. In this context, we focused our attention on the development of a stereoselective synthesis of α-chloroaldehydes by organo electrochemical approach, taking advantage of linchpin catalysis.

α-chloroaldehydes have been synthetized with high level of enantioselectivity starting from unactivated aldehydes using a chiral amine as organocatalyst in the presence of a cost-effective and environmentally friendly Cl^- source. The α-chloroaldehydes could be rapidly converted (in-situ) into several significant building blocks such as aziridines, epoxides, and amino acids.

Desired products were obtained in good yields (from 75 % to 95 %) and up to 97% ee (determined on the corresponding chlorohydrin derivatives) (**Figure 1**). The methodology was also investigated under flow conditions, to enhance productivity and space-time yields for gram-scale production.

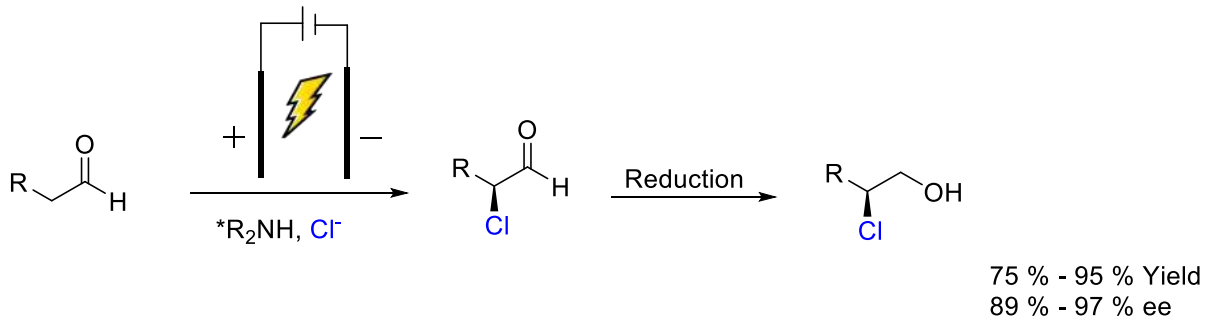

Figure 1: Synthetic route for the synthesis of chlorohydrins

References:

[1] C. Kingston, M. D. Palkowitz, Y. Takahira, J. C. Vantourout, B. K. Peters and P. S. Baran, Acc. Chem. Res. 2020, 53, 72-83

[2] H. E. Burks, J. P. Morken, Chem. Commun. 2007, 45, 4717 - 4725

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ORG-PO-005

Synthesis and Characterization of Luminescent Iridium Complexes for Electrochemiluminescence Applications

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The current developments of optoelectronics and bionanoscience (including electrochemiluminescence -ECL- technology) take great advantage from the ability of organic, organometallic and hybrid compounds to fulfill specific needs and requirements. Phosphorescent transition-metal complexes, in particular octahedral iridium(III) ones, have been the target of intense researches given their high thermal and chemical stability and the excellent photophysical properties, such as high luminescence quantum efficiency and short radiative lifetime[1]. Furthermore, due to the potential of Ir(III) complexes to emit in the whole visible (from blue to red) and near-infrared (NIR) range there is a growing interest in their use in ECL applications, which today mostly rely on orange/red emissive Ru(II)polypyridine complexes[2,3].
In this contribution, we present the synthesis of a family of cyclometalated heteroleptic Ir(III) complexes with emission centered in the blue, green and NIR spectral regions according to the nature of the C^N ligand (Figure 1a) while carrying an ancillary N^N ligand that enables to anchor the complex to an electrode surface or to a particle. Moreover, we present the synthesis of a new CN-functionalized ligand, accomplished exploring an innovative palladium-free cross-coupling reaction that allows to reduce the number of steps from three to one (Figure 1b)[4].

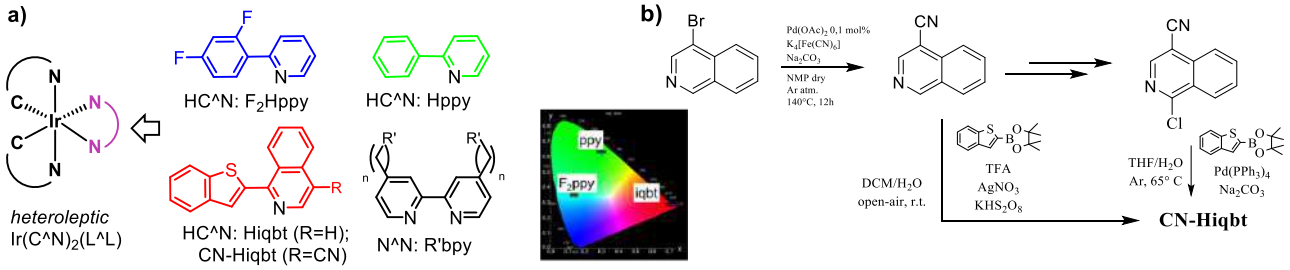

Figure 1. a) general structures of the heteroleptic Ir(III) complexes and their corresponding emission colors. **b)** Palladium-free synthetic pathway for the preparation of CN-Hiqbt ligand.

References:
[1] Iridium(III) in Optoelectronic and Photonics Applications, 2017, Ed. E. Zysman-Colman, Wiley. [2] S. Kesarkar, E. Rampazzo, G. Valenti, M. Marcaccio, A. Bossi, L. Prodi, F Paolucci, *ChemElectroChem*, **2017**, *4(7)*, 1690. [3] M. Penconi, A. B. Kajjam, M. Jung, M. Cazzaniga, C. Baldoli, D. Ceresoli, M. E. Thompson, A. Bossi, *Chem. Mater.* **2022**, *34*, 2, 574–583. [4] I. B. Seiple, S. Su, R. A. Rodriguez, R. Gianatassio, Y. Fujiwara, A. L. Sobel, P. S. Baran, *J. Am. Chem. Soc.* **2010**, 132, 13194–13196.
Acknowledgement: PRIN2022 Mechanism Enhanced ECL Technology "MEET". Prot. 20225P4EJC

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Improving ligand affinity through covalent strategies: the case of BC2L-C bacterial lectin

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The opportunistic Gram-negative pathogen *Burkholderia cenocepacia* is a globally spread multidrug-resistant bacterium that causes severe lung infections in immunocompromised or cystic fibrosis patients.[1] This bacterium employs lectins as virulence factors to target host tissues through recognition of and adhesion to the glycoconjugates on the host cells' surface. Among these lectins, the *superlectin* BC2L-C has been proposed as a major player in the adhesion process and in the formation of bacterial biofilm.[2] In particular, its N-terminal fucose-binding domain (BC2L-C-Nt) represents an interesting target for the design of new antimicrobials that may prevent lectin-mediated bacterial adhesion to the host cells.

Recently, we reported the development of a first generation of synthetic ligands targeting BC2L-C-Nt, based on fragment- and structure-based design studies.[3,4] Despite the promising results shown by these ligands, the affinity for the N-terminal domain of the target lectin remains in the sub-millimolar range.[4,5]

With the aim of improving the binding affinity, a new generation of ligands was designed to covalently target specific nucleophilic amino acid residues (Cys72 and Lys108) located near the fucose binding region of BC2L-C-Nt. The new glycomimetics, which contain a L-fucose scaffold connected through a linker to a spacer bearing an electrophilic warhead, were screened in silico through non-covalent and covalent docking protocols, and the most interesting ones were synthetized and subjected to biophysical studies displaying promising results.

In particular, the new ligands showed up to a 100-fold affinity gain over the parent monosaccharide resulting in the first synthetic BC2L-C-Nt ligands that reach the micromolar affinity of the fucosylated histo-blood oligosaccharides.

Acknowledgments: the project is supported by EU funding within the NextGeneration EU-MUR PNRR Extended Partnership initiative on Emerging Infectious Diseases (Project no. PE00000007, INF-ACT).

References:

[1] S.A. Sousa, A. M. M. Seixas, et al., *Vaccines*, **2020**, *8*, 1–22
[2] O. Sulak, G. Cioci, et al., *PLoS Pathog*., **2011**, *7*:e1002238
[3] K. Lal, R. Bermeo, et al., *Chem. Eur. J.*, **2021**, *27*, 10341-10348
[4] R. Bermeo, K. Lal, et al., *ACS Chem. Biol*., **2022**, *17*, 2899−2910
[5] S. Mazzotta, G. Antonini et al.; *Molecules*, **2023**, *28*, 1494

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ORG-PO-007

Quadrupolar dyes for non-linear optical imaging of cardiac cells

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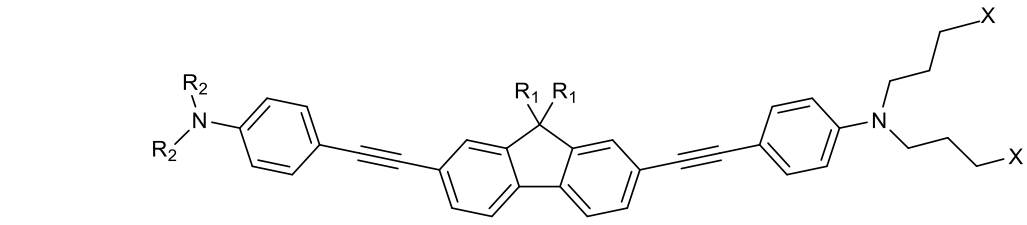
Fluorescent potential-sensitive probes (voltage sensitive dyes) are widely used in mapping myocardial contraction. Most of the commercially available systems exploit two mechanisms: electrochromism or photoinduced electron transfer. Despite the great time resolution provided by these systems, they are affected by a low signal to noise ratio. Our project aims to overcome this problem by developing a non-linear optical method to study cardiomyocytes contraction with four-dimensional resolution (in space and time). We decided to use quadrupolar fluorescent molecules[1] that can stain the phospholipidic bilayer of cardiac cells. These molecular sensors are based on a double mechanism: first, a variation in the potential of the cell should result in a different fluorescent response. Second, the cell contraction should lower the symmetry order, with the consequence that the resulting non-centrosymmetric system would be able to generate non-linear second order responses, such as second harmonic generation.[2]

In this poster presentation, we report the synthesis and spectroscopic properties of a selected library of quadrupolar dyes. They all contain a central fluorescent core, asymmetrically functionalized via a statistical Sonogashira coupling, with two electron-donating arms, one bearing a lipophilic and the other a polar end, to ensure a homogeneous orientation of the probe within the cell membrane.



R_2= CH_3; $(CH_2)_5CH_3$ R_1= $(CH_2)_7CH_3$; $(CH_2)_2CH_3$; CH_3 X=$CH_2OSO_3^-$;COO^-, Py^+

Figure 1: molecular structure of the quadrupolar dyes.

REFERENCES

[1] O. Mongin, L. Porrès, M. Charlot, C. Katan, M. Blanchard-Desce, Chem, Eur. J., 2007, 13, 1481 – 1498.
[2] A. Painelli, F. Terenziani, ChemPhysChem, 2009, 10, 527 – 531.

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ORG-PO-008

$(BO)_2$-doped thiahelicenes: synthesis and properties-change induced by BO bonds inversion

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The introduction of a trigonal boron atom into polyaromatic hydrocarbons is an extremely powerful tool to provide organic scaffolds with enhanced spectroscopic and electrochemical features as well as optimal packing in the solid state.[1] As a drawback, such flat polyaromatics often display low processability due to their poor solubility in common organic solvents. The distortion of the molecular scaffold represents a suitable strategy to improve the solubility and stacking properties of boron-doped polyaromatics while maintaining good electronic interactions. Extreme structural distortion can be achieved in helical-shaped compounds such as helicenes,[2] which are inherently chiral polycycles, formed by ortho-fused aromatic or heteroaromatic rings. The introduction of boron in these compounds represents a topic of huge interest since borahelicenes show intriguing physico-chemical properties[3] promising for manifold applications in material science. However, the borahelicene structural diversity is still limited to a reduced number of molecules, mainly consisting of tetracoordinate boron-based carbohelicenes.[4]

Our innovative contribution to this field concerns the synthesis of the first doubly BO-doped tetrathia[7]helicenes **1**[5] and **2** (Figure) incorporating two oxaborine rings into the parent tetrathia[7]helicene scaffold. The two structures are isomers characterized by the inversion of the B-O bonds in the oxaborine rings. Spectroscopic measurements, electrochemical characterization and theoretical calculations carried out on **1** and **2** showed that their properties are strongly affected by the orientation of the BO bonds into the scaffold. In addition, the enantiomers of **1** and **2** were separated by chiral HPLC and their chiroptical properties as well as racemization kinetics were investigated.

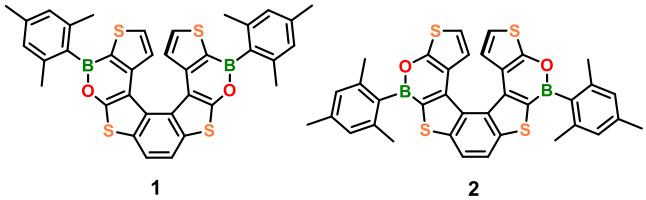

Figure. Structure of $(BO)_2$-tetrathia[7]helicenes **1** and **2**.

[1] E. von Grotthuss, A. John, T. Kaese, M. Wagner, *Asian J. Org. Chem.* **2018**, *7*, 37- 53.
[2] C.-F. Chen, Y. Shen, Helicene Chemistry, *Springer*, Berlin **2017**.
[3] T. Hatakeyama, S. Hashimoto, T. Oba, M. Nakamura, *J. Am. Chem. Soc.* **2012**, *134*, 19600-19603.
[4] J. Full, S. P. Panchal, J. Götz, A.-M. Krause, A. Nowak-Król, *Angew. Chem. Int. Ed*. **2021**, *60*, 4350-4357. b) K. Dhbaibi, L. Favereau, J. Crassous, Chem. Rev. **2019**, *119*, 8846-8953.
[5] L. Menduti, C. Baldoli, S. Manetto, M. Bolte, H.-W. Lerner, G. Longhi, C. Villani, E. Licandro, M. Wagner *Angew. Chem. Int. Ed.* **2023**, *62*, e202215468.

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Dual Emission of Fluorinated beta-Diketonate Sm(III) Complexes: Effect of the Bidentate Ancillary Ligands

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Samarium complexes have attracted significant attention across various fields due to their diverse applications and unique properties. Research has demonstrated the synthesis and characterization of different samarium complexes, showcasing their potential in catalysis, luminescence, biological studies, and materials science.[1] The luminescent properties of samarium(III) complexes, characterized by an orange-reddish emission, make them particularly attractive for bioimaging and optoelectronic applications.[2] Despite the modest luminescence quantum yields, typically not exceeding 5%, samarium complexes have shown unexpected efficiency for combined visible and near-infrared biphotonic microscopy.[3] In fact, these complexes exhibit emission bands in both the visible ($^4G_{5/2} \rightarrow {}^6H_{5-11/2}$) and NIR ($^4G_{5/2} \rightarrow {}^6F_{1-11/2}$) spectral ranges, making them valuable for imaging purposes.[4]

Here we report on the design, synthesis, chemical and photophysical characterization of a large series of samarium(III) β–diketonate complexes of general formula $[Sm(hfaa)_3(L)_n]$, where hfaa is 1,1,1,5,5,5-hexafluoroacetylacetone and L is a polypyridine co-ligand.

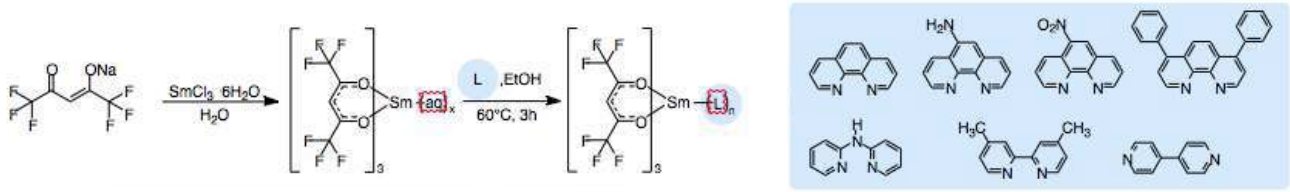

Figure 1: Scheme of the synthetic pathway and the poly-pyridine co-ligands.

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References:

[1] Y. Hasegawa, Y. Kitagawa, T. Nakanishi, NPG Asia Mater. 2018, 10, 52–70.
[2] P. Hooda, V. B. Taxak, R. K. Malik, S. Khatri, P. Kumari, S. P. Khatkar, R. Kumar, J. Fluoresc. 2022, 32, 613–627.
[3] A. Bui, A. Grichine, S. Brasselet, A. Duperray, C. Andraud, O. Maury, Chem. Eur. J. 2015, 21, 17757–17761.
[4] S. S. Mortensen, M. A. M. Nielsen, P. Nawrocki, T. J. Sørensen, J. Phys. Chem. A 2022, 126, 8596−8605.

ORG-PO-010

Investigating novel dyes for indoor DSSCs : study of the devices long term performance upon hydroxamic acid pre-adsorption

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Th With the development of the Internet of Things and the emergence of self-powered devices operating under ambient light conditions, indoor photovoltaics (PV) have been developed to meet these new energy requirements. Among the various PV technologies developed thus far, Dye Sensitized Solar Cells (DSSCs) have quickly emerged as one of the most efficient and practical solutions[1]. Consequently, there is now significant industrial-scale development of DSSCs, with considerable effort dedicated to achieving optimal efficiency and stability under low illumination.

SL9 and SL10 are two recently published dyes[2] that have shown high Power Conversion Efficiency (PCE) in co-sensitized devices. In this study, these dyes were synthetised and characterized using NMR, HRMS, UV-Vis absorption and cyclic voltammetry. They were then integrated in industrially processed DSSCs to evaluate their long-term stability and performance under white LED light. As a result, co-adsorbed SL9 and SL10 displayed high PCE at 1000 lux of more than 25% after 2000 hours, making them comparable to benchmark dyes. Even at 130 lux, more than 22% PCE was recorded, exceeding most of other commercialized technologies.

Additionally, the effect of bufexamic acid on cell stability was investigated, since it has been shown to improve the dense packing of the dye monolayer at the surface of the titania mesoporous film[3]. Consistently with previous findings, BPHA pre-adsorption contributed to enhance the Jsc, with no detrimental effect on other PV parameters[2]. Furthermore, a noticeable increase in electron lifetime was also observed by using intensity modulated photovoltage spectroscopy (IMVS), suggesting that bufexamic acid has an interfacial passivating effect toward charge recombination. Finally, the long-term stability of the cells under harsh light soaking and temperature conditions is being monitored. Preliminary results show that bufexamic acid has a beneficial effect regarding fill factor retention under stressing conditions, which contributes to slow down the decrease of cell performance.

References:

[1] M. Freitag, J. Teuscher, Nature photonics **2017**, 11, 372 – 378.
[2] Y. Ren, D. Zhang, Nature **2023**, 613, 60 – 65.
[3] S. H. Aung, Y. Hao, ACS Omega **2017**, 2, 1820 – 1825.

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Synthesis of functionalized benzodithiophene derivatives for nanofabrication of ordered monolayer surfaces

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Nanofabrication of long-ordered structures displaying specific functional properties is extremely relevant in nanotechnology and electronics miniaturization. The intense scientific research on this subject is driven by new potential applications, especially in organic electronic devices and sensors. The peculiar properties of a molecular system can be enhanced at monolayer level, where the control on the spatial arrangement and orientation of the molecules is of fundamental importance. We present new molecular systems able to be used in bottom-up nanofabrication of long-range ordered monolayer surfaces through a two-step approach: a first in-plane pattern of metal porphyrins that coordinate a second out-of-plane monolayer of functional organic molecules guided by metal-ligand interaction. A linear and planar conjugated BDT (benzo[1,2-*b*:4,5-*b*']dithiophene) unit will be used to mimic the structure of the DPNDI (naphthalene diimide derivative) already exploited by the proponents,[1] while a chiral tetrathia[7]helicene core[2] will be chosen for the preparation of homochiral surface. The two scaffolds have been asymmetrically functionalized at the α-positions of the thiophene rings to fulfil the specific requirements: i) the head of the molecule has been engineered to guarantee axial coordination at the metal atom of the porphyrin, ii) the tail has been decorated with functional groups able to provide information on molecular orientation by X-ray and photoemission spectroscopies.

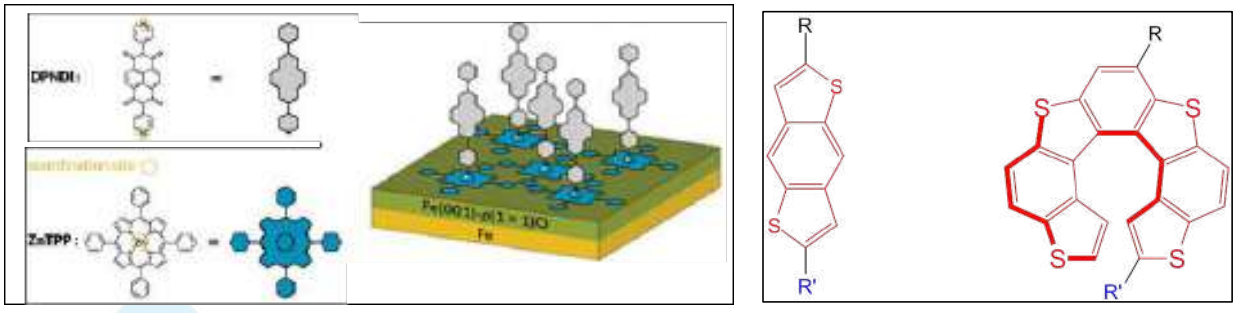

Figure 1: (left) bottom-up growth of organic monolayer on metal porphyrin, (right) newly synthesized molecular systems.

References: [1] A. Orbelli, A. Calloni, A. Bossi, M. S. Jagadeesh, G. Albani, L. Duò, F. Ciccacci, A. Goldoni, A. Verdini, L. Schio, L. Floreano, G. Bussetti, *Adv. Funct. Mater*. 2021, 31, 2011008. [2] E. Licandro, S. Cauteruccio, D. Dova, *Adv. Heteroc. Chem.* 2016, 118, 1–46. **Acknowledgements:** Progetto PRIN 2022 – grant no. 2022FWZCHK – 'FUTURO: Functionalized surfaces by true molecular bottom-up growth'. Finanziato dall'Unione europea – Next Generation EU.

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Tuning αvβ6 *vs* αvβ8 Integrin Selectivity: New Small Molecule Cyclopeptide Ligands

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In the vast family of integrin receptors, the αvβ6 and αvβ8 integrins are members of high clinical interest.[1,2] These integrins are mainly expressed in epithelial cells and fibroblasts, and both belong to the RGD integrin subfamily, and recognize, among others, the matrix ligand fibronectin and the ECM-bound latent TGFβ complex. Their overexpression and dysregulation have been recognised as valuable prognostic biomarkers of pathological conditions: αvβ6, for example, binds and activates the pro-TGFβ1 promoting deposition of collagen in chronic pulmonary inflammation, lung cancer and fibrosis, while αvβ8 integrin dysfunctions in neuronal cells are associated to brain pathologies. Compounds that can discriminate between homologous αvβ6 and αvβ8 and other RGD integrins, could have considerable utility in the development of new therapeutic agents or diagnostic probes according to the modern paradigm of precision medicine.

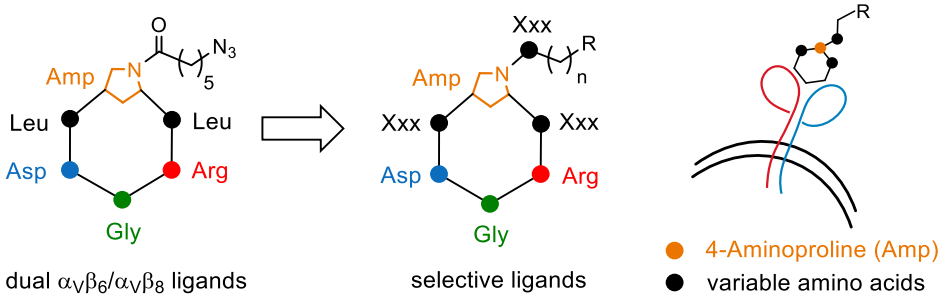

Figure 1: Design of RGD-Amp-based cyclopeptides selectively targeting αvβ6 and/or αvβ8 integrins.

Starting from our previous results on αvβ6 integrin-targeting ligands,[3] guided by in-solution NMR-based conformational analyses and molecular modeling studies, we designed the structural features within the RGD-Amp-based cyclopeptide family (Figure 1) to gain the desired high affinity and selectivity profile.

References:

[1] M. Nieberler, U. Reuning, et al. *Cancers* **2017**, *9*, 116.
[2] K.P. Conroy, L.J. Kitto, N.C. Henderson. *Cell Tissue Res.* **2016**, *365*, 511–519.
[3] K. Bugatti, A. Bruno, et al. *Chem. Eur. J.* **2020**, *26*, 13468–13475.

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Biomass valorization through an ortho-alkylation of phenols strategy using primary alcohol.

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The decrease in the availability of oil resources, combined with the increase in demand for oil from emerging economies and environmental concerns regarding the use of fossil fuels,[1] has led to the need for the development of efficient processes to produce fuels and chemicals from renewable resources. In this context, plant biomass, particularly lignocellulosic biomass, is currently the best sustainable source of organic carbon.[2] Lignin, one of the constituents of lignocellulosic biomass, can be seen as a renewable source of functionalized aromatic units and, above all, phenols.[3] Phenols are present as structural motifs in a wide variety of molecules of both natural and industrial origin. Whitin aromatic starting materials and phenols are simple precursors for the synthesis of other value-added chemicals.[4] Consequently, the synthesis of site-specifically substituted phenols is challenging, and the development of new methods for this purpose would be highly desirable. Herein, we present an acid- or basic-[5] catalyzed *ortho*-alkylation of phenols strategy using primary alcohol and a Pd catalyst.

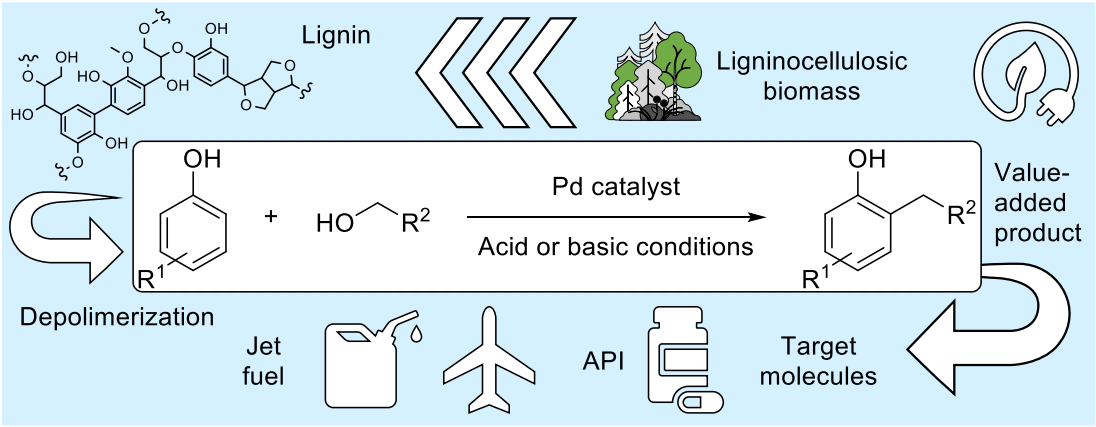

Figure 1: *ortho*-alkylation of phenols strategy as a tool for the valorization of waste biomass.

References:

[1] G. W. Huber, S. Iborra, A. Corma, Chem Rev 2006, 106, 4044 – 4098.
[2] Z. Sun, B. Fridrich, A. De Santi, S. Elangovan, K. Barta, Chem Rev 2018, 118, 614 – 678.
[3] C. Zhang, X. Shen, Y. Jin, J. Cheng, C. Cai, F. Wang, Chem Rev 2023, 123, 8, 4510 – 4601.
[4] N. A. McGrath, M. Brichacek, J. T. Njardarson, J Chem Educ 2010, 87, 1348 – 1349.
[5] J. Yu, C. J. Li, H. Zeng, Angewandte Chemie - International Edition 2021, 60, 4043 – 4048.

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ORG-PO-014

Nanocomposite hydrogels for tissue engineering applications

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Carbon nanomaterials including carbon nanotubes (CNTs), reduced graphene oxide (rGO) and carbon nanohorns (CNHs) possess exceptional mechanical, electrical and thermal properties, and for this reason, they can be inserted into biomaterials for tissue engineering applications, improving the mechanical properties and conductivity of the resulting materials.[1] The properties of carbon nanostructures can be tuned by chemical functionalization. The functionalization allows them to be dispersible in the matrix, introduce biocompatibility, and reduce the toxicity issues related to unfunctionalized carbon nanostructures.[2]

The purpose of this project is the compatibilization of different carbon nanostructures with hydrogel phases through surface functionalization with different moieties. Hydrogels are ideal matrices for biomedical applications due to their biocompatibility and ability to mimic natural tissue.

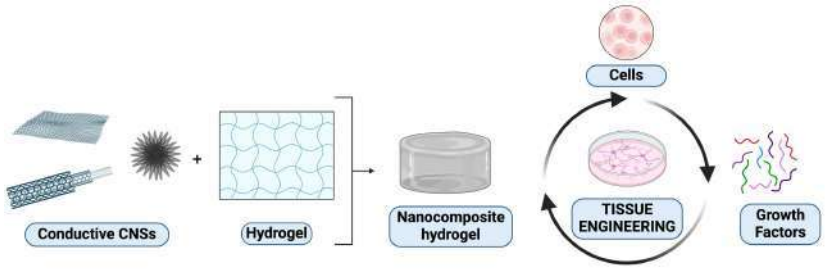

Figure 1: schematic representation of the application of carbon nanostructures for tissue engineering.

Carbon nanostructures have been functionalized with different functional groups by diazotation reaction and characterized through TGA, IR, Raman, DLS and Z potential measurements; the resulting derivatives have been successfully inserted into different types of hydrogels based on self-assembling peptides and on gelatin/chitosan. The obtained materials have been characterized by rheometric measurements and TEM. On the basis of these promising results, tests for cell adhesion and growth shall be taken into consideration.

References:

[1] G. Suarato, S. Pressi, E. Menna, M. Ruben, E. M. Petrini, A. Barberis, Miele D., Sandri G., Salerno M., Schirato A., Alabastri A., Athanassiou A., Proietti Zaccaria R., Papadopoulou E. L.; *ACS Appl. Mater. Interfaces* 2024, 16, 3093−3105.
[2] Bellet P., Gasparotto M., Pressi S., Fortunato A., Scapin G., Mba M., Menna E., Filippini F., *Nanomaterials* **2021**, 11, 404-445.

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Arylazo Sulfones as Photoacid Generators (PAGs) in Fischer Esterification

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Photoacid generators (PAGs) are compounds designed to generate acid upon exposure to light. In the last decades, PAGs have gained importance in different fields as photolithography, 3D printing, chemistry and material science. They play an important role in the fabrication of microelectronic devices, in microfluidics, and to generate acids that can promote different chemical reactions. PAGs are classified into two different groups, according to their characteristics: ionic, and non-ionic. The first are sulfonium, iodonium, phosphonium or diazonium salts, they have excellent PAG properties but restricted application due to the limited solubility in organic media. On the other hand, non-ionic PAG have been extensively used as their high solubility in organic solvents and polymer matrices, especially for polymer initiation and surface curing[1]. In this work Arylazo Sulfones have been employed as non-ionic PAG, for their ability to generate sulfonic acid after visible-light absorption in presence of oxygen[2,3], to catalyze one of the most renowned reactions employed in organic synthesis: Fischer Esterification. Different carboxylic acids were tested, including aliphatic and aromatic derivatives, dicarboxylic acids and amino acids, as well as saturated and unsaturated long-chain fatty acids and esterification proceeds efficiently in the presence of a wide range of differently substituted alcohols.

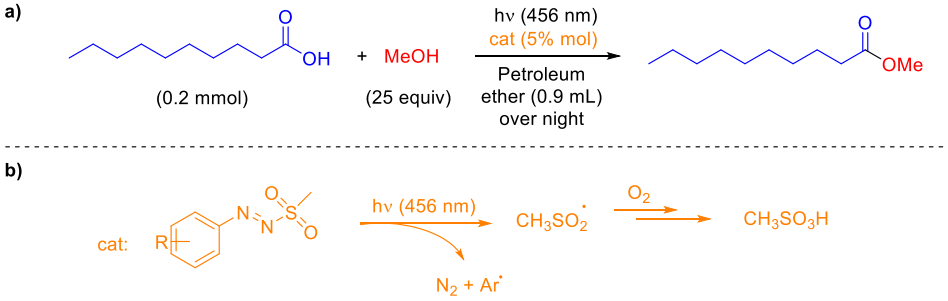

Figure 1: a) Model reaction employed for optimization of reaction conditions b) Proposed reaction mechanism for the photochemical generation of methanesulfonic acid from arylazo sulfones.

Acknowledgements. We gratefully acknowledge the support from: *Fondazione Cariplo* (Photo and Mechano-Chemistry for the Upgrading of Agro- and Sea-food Waste to advanced polymers and nanocarbon materials, CUBWAM, project 2021–0751) and *Hellenic Foundation for Research and Innovation (HFRI)*, 1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and the procurement of high-cost research equipment grant (grant number 655).

References:

[1] N. A. Kuznetsova, G. V. Malkov, B. G. Gribov, Russ. Chem. Rev. 2020, 89, 173–190.
[2] L. Di Terlizzi, A. Martinelli, D. Merli, S. Protti, M. Fagnoni, J. Org. Chem. 2023, 88, 6313–6321.
[3] E. M. Galathri, L. Di Terlizzi, M. Fagnoni, S. Protti, C. G. Kokotos, Org. Bioorg. Chem. 2023, 21, 365–369.

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ORG-PO-016

Metal complex polymers as hole conductors for perovskite solar cells

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Perovskite solar cells (PSCs) have surged in the past 12 years as the most promising third generation solar cell technology, capable or rivaling with silicon solar cells in lab-scale devices and only requiring a fraction of the energy for their fabrication. Although several companies are nowadays conducting research on them and larger-scale modules and panels are being manufactured, commercialisation of this technology is still impeded by the poor long-term stability of the perovskite light absorber. The hole transporting layer is one of the main causes of this instability. Organic small molecules, which allow PSCs to reach top performances, require hygroscopic additives that degrade the perovskite material to reach the desired conductivity, and can migrate into the light absorbing layer.[1] Polymeric materials are intrinsically more conductive and can avoid the use of dopants. Although they can work efficiently in PSCs, their synthesis remains complex, which reflects into their commercial prices.[2] Metal complexes are a viable alternative to organic molecules, as their energy levels can be fine-tuned by tweaking the ligand environment or changing the metal centre.[3] They can be intrinsically doped by adding two different oxidation states of the metal centre to the hole transporting layer, being able to overcome state-of-the-art organic small molecules both in efficiency and stability.[4]

In this work, I developed covalent polymers based on metal complex monomers to use as hole transporters in perovskite solar cells. These materials take advantage of the higher conductivity of metal complexes compared to organic compounds and couple them with the greater stability of polymers compared to small molecules. Careful design of the ligand environment allows the formation of robust macromolecules that can be dissolved in perovskite-compatible solvents and that present a good degree of hydrophobicity, to help with the preservation of the light abosrbing layer over time.

References:

[1] F. M. Rombach, S. A. Haque, T. J. Macdonald, Energy Environ. Sci. 2021, 14, 5161–5190.
[2] M. M. H. Desoky, M. Bonomo, N. Barbero, G. Viscardi, C. Barolo, P. Quagliotto, Polymers 2021, 13, 1652.
[3] Z. Yu, A. Hagfeldt, L. Sun, Coordination Chemistry Reviews 2020, 406, 213143.
[4] J. Cao, X. Lv, P. Zhang, T. T. Chuong, B. Wu, X. Feng, C. Shan, J. Liu, Y. Tang, Adv. Mater. 2018, 30, 1800568.

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LIGHT-DRIVEN REGIOSELECTIVE [2+2] CYCLOADDITION OF ARYL-ENONES BY EOSIN Y

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The use of light as energy source for organic synthesis has been emerged as a powerful tool to both explore new reactivity and have environmentally friendly processes.[1] In the same way, the development of flow chemistry in combination with light-driven processes allows to enhance the efficiency and the scalability of the reaction.[2] In this context, photocyclization of aryl-enones promoted by visible light in the presence of photocatalysts provides an innovative strategy for the synthesis of cycloalkanes, through radical intermediates.[3] After exploiting reactivity of different substituted aryl-enones to effort the [2+2] photocycloaddition by the use of Eosin Y as photocatalyst using visible light irradiation, we decided to transport this reaction under flow conditions in order to have a more efficient process.

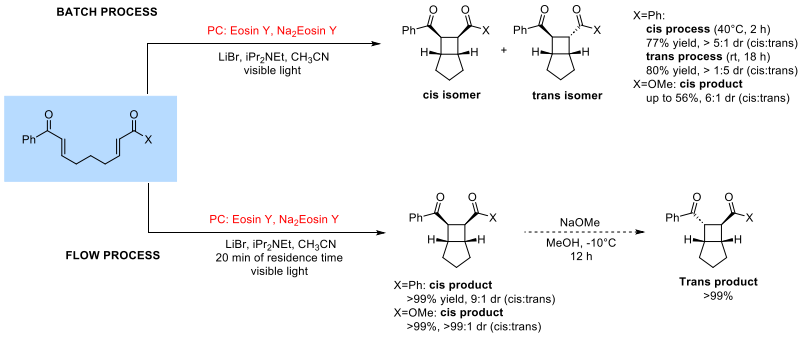

Figure 1: [2+2] photocycloaddition of aryl-enones in batch and in flow.

Different reaction conditions have been tested using symmetric and asymmetric substrates to achieve the bicycle products in good yields as a mixture of isomers. With our delight, for the symmetric aryl-enone, it was possible to find the conditions to selectively drive the cycloaddition towards one or the other isomer. Also, the best reaction conditions have been used in flow leading to reduced reaction time, increased productivity and selectivity towards the *cis* isomer preferentially, both for symmetric and asymmetric substrates. The *cis* isomer can be quantitatively converted into the *trans* isomer under basic conditions.

References:

[1] M. Neumann, K. Zeitler, *Chem. Eur. J.* **2013**, *19*, 6950.
[2] K. Jähnisch, V. Hessel, H. Löwe, M. Baerns, *Angew. Chem. Int. Ed.* **2004**, *43*, 406–446.
[3] F. Medici, S. Resta, P. Presenti, L. Caruso, A. Puglisi, L. Raimondi, S. Rossi, M. Benaglia, *Eur. J. Org. Chem.* **2021**, *32*, 4521.

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Development of supramolecular catalysts containing *N*-hydroxyphthalimide for the selective functionalization of C-H bonds

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Selective functionalization of C-H bonds in hydrocarbons represents an outstanding challenge in synthetic organic chemistry. In this contest, N-hydroxyphthalimide (NHPI) has attracted increasing interest as an effective organocatalyst for C-H activation by hydrogen abstraction (HAT) [1]. NHPI acts as a precursor of the phthalimide N-oxyl (PINO) radical, which is the effective catalyst promoting hydrogen abstraction processes. C-H bonds with similar electronic and steric environments exhibit a comparable intrinsic reactivity making selective functionalization extremely difficult [2]. This is particularly true for the positions located far away from other functional or directing groups (remote sites). A supramolecular, geometric approach can provide a way to overcome these challenges. In this context, we developed two catalysts based on *N*-hydroxyphthalimide with a crown or aza-crown ether as a supramolecular recognition site (figure 1).

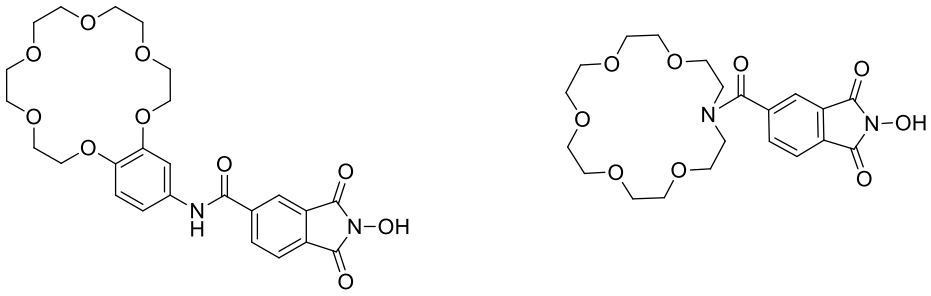

Figure 1

The 18-crown-6 or the 1-aza-18-crown-6 receptors recognize the heads of primary, linear alkylammonium chains and, when coordinated to Ba^{2+} ions, can also establish electrostatic interactions with substrates containing carboxylates, sulfates and sulfonates functional groups. In this way, by an intramolecular HAT, it will be possible to selectively abstract H atoms from specific C–H bonds that are properly oriented towards the in situ-generated *N*-oxyl radical (figure 2).

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Aerobic oxidative C-C bond cleavage of 1,2-diols: photoactivated Vanadium-driven catalysis

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This research group has developed a new methodology for the aerobic oxidative cleavage of 1,2-diols based on homogeneous catalysis employing vanadium aminotriphenolates.[1,2] In this communication we will report results obtained in the aerobic C-C-bond cleavage of 1,2-diols yielding bis-carbonyl derivatives under photo-induced conditions at room temperature. The influence of different reaction parameters (temperature, solvent, wavelength, substrate) on the reaction course will be reported as well as the scope of the reaction.

Preliminary results on mechanistic studies on the photoactivated mechanism of the reaction will be also reported. Radical trapping experiments confirmed the radical nature of the reaction, and the role oxygen is playing in the conversion of the substrates, while computational methods are being used to shine light on the photoactivation process of the catalyst-substrate adduct.

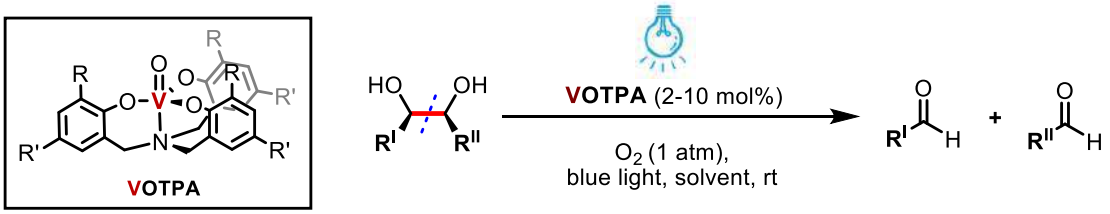

Figure 1. Photoinduced aerobic oxidative C-C bond cleavage of 1,2-diols catalysed by **VOTPA**.

The project has been carried out in the frame of MICS (Made in Italy – Circular and Sustainable) Extended Partnership (PE11). We thank the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3 – D.D. 1551.11-10-2022, PE00000004) (AR and WB fellowships) and Progetto PON "Ricerca e Innovazione" 2014-2020 Azione IV.5 – Dottorati su tematiche green (FAS fellowship) for financial support.

References:

[1] Amadio, E.; González-Fabra, J.; Carraro, D.; Denis, W.; Gjoka, B.; Zonta, C.; Bartik, K.; Cavani, F.; Solmi, S.; Bo, C.; Licini, G. *Adv. Synth. Catal.* **2018**, *360*, 3286–3296.

[2] Carpentier, R., Denis, W., Sanz Azcona, F., Carraro, D., Grauwels, G., Orlandi, M., Zonta, Licini, G., Bartik, K, *ACS Sustainable Chem. Eng.*, **2023**, *11*, 8633 – 8641.

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ORG-PO-020

Antibacterial nanocellulose for the production of new anti-biofilm materials

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Cellulosic nanomaterials have stimulated interest in the scientific community thanks to their properties that make them particularly promising among nanostructured materials. Nanocellulose-based materials are naturally available, from waste materials, at low price and are, generally, characterized by a high biocompatibility.[1] Moreover, nanocellulose can be easily functionalized to produce materials with new properties and applications. In this work we focused on materials with antimicrobial properties. Actually, the antibiotic resistance in the treatment of chronic infections related to the chirurgical introduction of medical devices, generates in Europe almost 25.000 thousand deaths per year.[2] The develop of medical devices, such as catheters, coated with nanocellulosic materials with antibacterial properties, may prevent the formation of biofilms, a kind of aggregation of bacteria that makes them insensitive to antibiotic treatments.

Our project aims to the production of a multilayered material composed by differently functionalised nanocellulose to obtain an efficient antibiofilm device. Finally, we developed a catheter prototype made with a base in polydimethylsiloxane (PDMS) covered by a plastic polymeric layer made of Evatane® 40-55 and two nanocellulosic layers kept together by electrostatic interactions.

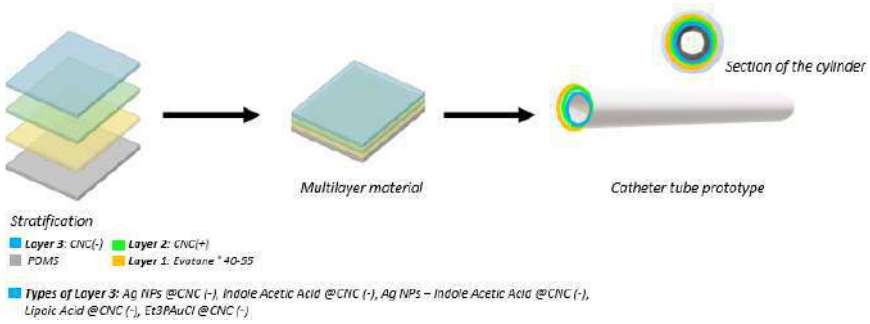

Figure 1: Stratification and formation of the catheter prototype.[3]

References:

[1] B. Thomas, M.C. Raj, J. Joy, A. Moores, G.L. Drisko, C. Sanchez, 2018, Chemical Reviews, 118.24, 11575-11625.
[2] A. Macgowan, E. Macnaughton, 2017, Medicine 45.10, 622– 628.
[3] Created with Biorender.com

Funder: Project funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 - Call for tender No. 3277 of 30 December 2021 of Italian Ministry of University and Research funded by theEuropean Union – NextGenerationEU. **Award Number**: Project code ECS_00000017, Concession Decree No. 1055 of 23 June 2022 adopted by the Italian Ministry of University and Research, CUP: B83C22003920001, project title "Tuscany Health Ecosystem – THE"- SPOKE4_Nanotechnologies for diagnosis and therapy.

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ORG-PO-021

Synthesis of original open-shell luminescent derivatives

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Open-shell molecules possessing doublet ground states such as organic radicals have attracted growing interest as a unique class of molecular emitters. They can exhibit properties which are difficult to achieve with conventional closed-shell molecules. Improvement of luminescence efficiency, electroluminescence with nearly 100% electron–photon conversion, absence of heavy atom effects, magnetoluminescence are the principal characteristics of these type of systems. Therefore, these emitters have great potential to expand the variety and design strategies of luminescent molecules to broaden their utility for photofunctional applications.[1]

Perchlorotriphenylmethyl radical (PTM) and tris(2,4,6-trichlorophenyl) methyl radical (TTM) are typical examples of stable radicals that show distinct photoluminescence in solution at r.t. By fine tuning the substituent groups, it is possible to change the photochemical properties of the system and lower the energies of the frontier molecular orbitals, increasing their photostability over time. For example, pyridyl bis(2,4,6-trichlorophenyl) methyl radical (PyBTM) family shows a significantly increased stability.[1]

This contribution will describe the preparation of selected derivatives in order to expand the spectrum of open-shell emitters.

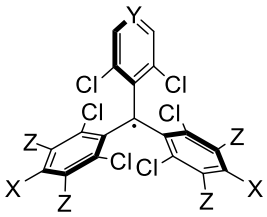

Figure 1: core structure of selected structures. X = BPin, Cl, Br; Y = N; C-SO_2-CH_3; Z = H, Cl

References:

[1] R. Matsuoka, A. Mizuno, T. Mibu, T. Kusamoto, Coordination Chemistry Reviews 2022, 467, 214616.

ORG-PO-022

Ultrasound-assisted iodination of anilines

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Aromatic iodination plays a significant role in the realm of synthetic organic chemistry. Iodo compounds find frequent application in cross-coupling reactions, copper-catalyzed reactions, and Grignard reactions, where C-C bonds are formed. Due to this versatility, they hold immense utility across various chemical disciplines.[1] Additionally, these compounds assume an important role in medicine, either as integral components of pharmaceuticals or as radioactive diagnostic markers.[2] Throughout history, multiple methods have been developed for conducting electrophilic iodination. A large number of electrophilic iodinating agents have been devised and implemented in organic synthesis, including *N*-iodosuccinimide[3] or iodochloride (ICl).[4] In our current study, we present a novel approach to electrophilic iodination. Our focus lies in waste reduction and the adoption of reaction conditions aligned closely with the principles of green chemistry. Our aim is to maintain a sufficiently high concentration (1 M), employ a non-toxic solvent derived from biomass (2-MeTHF), and utilize a non-toxic acid additive (AcOH). Furthermore, we seek to minimize energy consumption by employing sonication instead of temperature control.

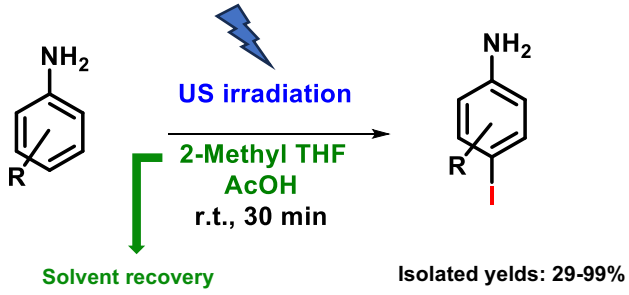

Figure 1: Ultrasound assisted synthesis of substituted anilines.

References:

[1] E. B. Merkushev, Synthesis, 1988, 923.
[2] Welch, Michael J., and Carol S. Redvanly, eds. Handbook of radiopharmaceuticals: radiochemistry and applications. John Wiley & Sons, 2003.
[3] S. C. VirgilIn, Encyclopedia of Reagents for Organic Synthesis, Vol. 4; Paquette, L. A., Ed.; Wiley: Chichester, 1995, 2845–2846.
[4] R. Johnsson, A. Meijer, U. Ellervik, Tetrahedron 2005, 61, 11657.

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Synthesis and Investigation of Naphthalene-based Chromophores as a Down-Color Converter in Hybrid White LED

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Down-color converters, also known as down-conversion materials or phosphors, are substances that absorb light of shorter wavelengths, such as ultraviolet (UV) or blue light, and re-emit it at longer wavelengths in the visible spectrum. These materials play a crucial role in various lighting applications, including solid-state lighting, display technologies, and fluorescence-based sensing. Organic chromophores have emerged as promising candidates for down-conversion color converters in various optoelectronic applications, owing to their tunable optical properties, cost-effectiveness, and environmental friendliness.

This study explores the synthesis and characterization of naphthalene-based chromophores tailored for their potential application as down converters in hybrid white light-emitting diodes (LEDs). The design and synthesis of these chromophores were thoroughly carried out to optimize their photophysical properties, aiming at efficient energy absorption and subsequent emission at longer wavelengths. Through a systematic approach, the photophysical properties of the synthesized chromophores were thoroughly investigated employing various techniques, including UV-Vis absorption spectroscopy, fluorescence spectroscopy, and quantum yield measurements. The results unveil successful tuning of absorption and emission wavelengths, alongside enhancements in fluorescence quantum yields, achieved through strategic structural modifications of the naphthalene core and its substituents. However, challenges such as photostability, aggregation-induced quenching, and limited thermal stability still need to be addressed to realize the full potential of naphthalene-based converters. The findings underscore the promising potential of naphthalene-based chromophores in bolstering the efficiency and color quality of hybrid white LEDs, thereby fostering advancements in energy-efficient lighting technologies. This research lays a foundation for further exploration and development of novel chromophores for next-generation lighting applications.

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ORG-PO-024

Cyanine Dyes for Dye-Sensitized Solar Cells: Synthesis and Spectral Characterization

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This study focuses on the synthesis and characterization of cyanine dyes derived from carboxy indole, featuring cyclopentene and cyclohexene central moieties. These dyes exhibit notable differences in their absorption properties, with the cyclopentene-based dye showing a pronounced red shift and higher extinction coefficient compared to its cyclohexene counterpart[1]. Our research aims to elucidate the structural influences on the optical properties of these dyes and explore their potential application as sensitizers in dye-sensitized solar cells (DSSCs). By leveraging the distinctive absorption characteristics of these cyanine dyes, we seek to optimize their performance for enhanced light harvesting and photovoltaic efficiency in DSSC devices. DSSCs offer several benefits, including low production costs, ease of fabrication, and flexibility in design and integration[2]. Furthermore, DSSCs exhibit excellent performance under low-light conditions and have the potential for use in a wide range of applications, including portable electronics, building-integrated photovoltaics, and off-grid power generation in remote areas. This investigation contributes to the development of efficient and cost-effective solar energy conversion technologies, with implications for sustainable energy production and expanded access to clean energy solutions.

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References:

[1] W. Naim, V. Novelli, I. Nikolinakos, N. Barbero, I. Dzeba, F. Grifoni, Y. Ren, T. Alnasser, A. Velardo, R. Borrelli, S. Haacke, S. M. Zakeeruddin, M. Graetzel, C. Barolo, F. Sauvage, JACS Au 2021, 1, 4, 409 – 426.

[2] F. Grifoni, M. Bonomo, W. Naim, N. Barbero, T. Alnasser, I. Dzeba, M. Giordano, M. Urbani, T. Torres, C. Barolo, F. Sauvage, Adv. Energy Mater, 2021, 2101598.

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Water-soluble photosensitizers for application in X-ray promoted photodynamic therapy

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Photodynamic therapy (PDT) is a clinical approach to treat cancer by activating a photosensitizer (PS) through light exposure ranging from UV to near-infrared. This activation induces the production of reactive oxygen species (ROS), particularly singlet oxygen ($^1O_2$), well known for its cytotoxic impact on cancer cells. Studies reported in the literature highlighted the possibility to enhance singlet oxygen production by combining photosensitizers with metal nanoparticles under laser irradiation. The principal drawback of conventional PDT lies in the limited penetration of visible light in biological tissues, impeding effective photosensitizer excitation in deeper tissues. Consequently, substantial efforts have been directed towards overcoming this limitation through X-ray irradiation. Metal nanoparticles with elevated Z values exhibit efficient X-ray absorption, facilitating energy delivery to surrounding tissues[1]. It has been reported that the presence of photosensitizers and metal nanoparticles (NPs) enhances singlet oxygen and ROS generation. Gold nanoparticles (AuNPs) have gained prominence due to their biocompatibility, making them widely used as contrast agents.

This study presents the synthesis of new water-soluble nanosystems achieved by conjugating either a porphyrin derivative or a rose bengal (RB) derivative to AuNPs. The water soluble porphyrin was synthesized by modifying tetra(4-hydroxyphenyl)porphyrin (THPP) with three PEG chains and a short linker terminating with a thiol or disulfide group. The RB derivative was prepared by reacting a thiol or disulfide ending linker with the carboxylic moiety of RB. The thiol or disulfide moiety is needed for effective binding to the water-soluble AuNPs due to the strong affinity between sulfur and gold. A preliminary investigation was conducted to evaluate singlet oxygen and ROS production by the nanosystems under X-ray irradiation, using different probes.

Figure 1: THPP and RB based nanosystems

References:
[1] S. J. McMahon, W. B. Hyland, M. F. Muir, J. A. Coulter, S. Jain, K. T. Butterworth, G. Schettino, G. R. Dickson, A.R. Hounsell, J. M. O'Sullivan, K. M. Prise, D. G. Hirst, F. J. Currell, Sci Rep 2011, 1, 18.

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ORG-PO-026

Visible Light Driven Ring-Opening Polymerization (photoROP) of Lactones by using Arylazo Sulfones as Photoacid Generators (PAGs)

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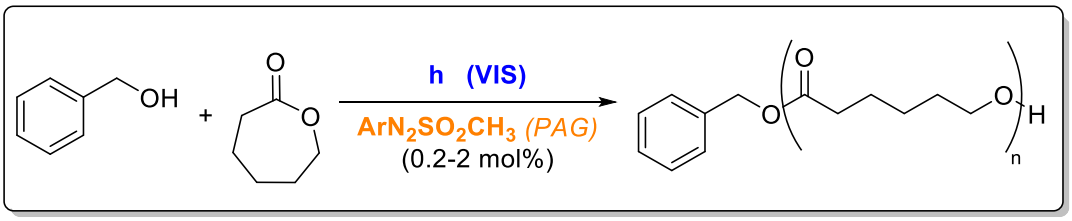
Photopolymerization offer several advantages over classical thermal polymerizations such as rapidity of execution, solvent-free conditions and thus reduced emission due the room temperature used. Photopolymerization is currently dominated by non-degradable UV-curable resins based on acrylates, methacrylates and epoxides that are usually polymerized by radical or cationic pathways, mainly due to their fast reaction rates. In the last decade, biodegradable polymers such as poly(ε-caprolactone) (PCL), polylactic acid (PLA) and polyaminoacids (PAA) have found applications in several fields including, among the others, nanomedicine, tissue engineering and 3D printing.[1] In this context, ring-opening polymerization (ROP) of the cyclic monomers in the presence of an initiator (usually an alcohol or amines) and a Bronsted/Lewis acid as the catalyst may induce a spatial and temporal control, and controlled polymerizations in term of polymeric architectures and polydispersity indexes.[2]

Arylazo sulfones are thermally stable derivatives of aryl diazonium salts previously used as photoinitiators in free-radical polymerization of methacrylates,[3] as well as visible light Photoacid Generators (PAGs) in organic synthesis.[4] Herein, we present an efficient protocol for the ring-opening polymerization of different cyclic monomers (eg. ε-caprolactone) upon visible light irradiation, initiated by various alchools and using differently substituted arylazo sulfones as the PAGs (an example is illustrated in Scheme 1). The efficiency of the designed procedure will be discussed in terms of polymerization yields, dispersity and degree of polymerization.



Scheme 1: Light driven ring-opening polymerization of ε-caprolactone using arylazo sulfones as PAGs.

References

[1] A. Martinelli, A. Nitti, G. Giannotta, R. Po, D. Pasini, *Mater. Today Chem.* **2022**, *26*, 101135.
[2] N. Yadav, T. S. Chundawat, *Polym. Chem.* **2023**, *14*, 2435-2451.
[3] A. Nitti, F. Batteaux, A. Martinelli, S. Protti, M. Fagnoni, D. Pasini, *Polym. Chem.* **2021**, *12*, 5747-5751.
[4] L. Di Terlizzi, E. Galathri, S. Protti, C. G. Kokotos, M. Fagnoni, *ChemSusChem,* **2023**, *16*, e202201998.

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ORG-PO-027

Synthesis of the first Epothilone Analogue Utilizing Amide–Triazole Bioisosterism

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Epothilones are 16-membered macrolides that can act as microtubule-targeting agents to tackle cancer[1-6]. Many synthetic analogues have been investigated for their activity, yet often based on macrolide structures. A notable exception is Ixabepilone, an azalide representing the only epothilone-like molecule approved by the FDA as a chemotherapeutic[7]. Exploiting the amide-triazole bioisosterism[8], in this work we report the synthesis of the first generation of epothilones lacking the macrolide or azalide structure, with the ester or amide linkage replaced by a triazole unit. Together with the synthesis of this new analogue, computational and biological evaluations have been performed too.

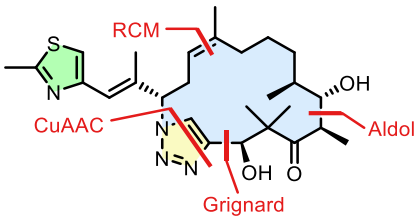

Figure 1: Target Epothilone analogue and synthetic strategy involved.

References:

[1] N N. M. Verrills, C. L. Flemming, M. Liu, M. T. Ivery, G. S. Cobon, M. D. Norris, M. Haber, M. Kavallaris, Chem. Biol., **2003**, 10, 597-607.
[2] K.-H. Altmann, B. Pfeiffer, S. Arseniyadis, B. A. Pratt, K. C. Nicolaou, ChemMedChem, **2007**, 396-423.
[3] C. F. Brogdon, F. Y. Lee, R. M. Canetta, Anticancer Drugs, **2014**, 25, 599-609.
[4] K.-H. Altmann, F. Z. Gaugaz, R. Schiess., Mol. Divers., **2011**, 15, 383-399.
[5] K.-H. Altmann, K. Memmert, Prog. Drug Res. **2008**, 66, 273-334.
[6] C. Villegas, I. González-Chavarría, V. Burgos, H. Iturra-Beiza, H. Ulrich, C. Paz, Int. J. Mol. Sci., **2023**, 24, 6063.
[7] M. V. Cobham, D. Donovan, *Cancer Manag. Res*. **2009**, *1*, 69-77.
[8] F. Arioli, S. Borrelli, F. Colombo, F. Falchi, I. Filippi, E. Crespan, A. Naldini, G. Scalia, A. Silvani, G. Maga, F. Carraro, M. Botta, D. Passarella, *ChemMedChem* **2011**, *6*, 2009-2018.

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ORG-PO-028

Enzymatically crosslinked hydrogels for meniscal regeneration

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The menisci are crescent-shaped fibrocartilaginous cushions found in the knee articulation between the femoral condyles and the tibial plateau which main function is weight distribution[1]. Their extracellular matrix is highly hydrated and mainly composed of collagen, glycosaminoglycans (GAGs), adhesion glycoproteins and elastin. They are composed of three distinct regions with different cell populations, extracellular matrix (ECM) components and morphological features[2].

Here in this work, bioprintable hydrogels were formulated using the horseradish peroxidase phenol coupling to crosslink gelatin and hyaluronic acid both functionalized with tyramine. The effectiveness of the oxidative coupling was checked with NMR, UV-VIS and FTIR analyses. Then, different formulations of the hydrogel were compared with a SEM analysis to investigate the morphology and the porosity and with an amplitude sweep test to determine the storage modulus (G'), the loss modulus (G''), yield and flow points. FTIR (Fourier-transform infrared spectroscopy) was then performed to confirm the hydrogels formation.

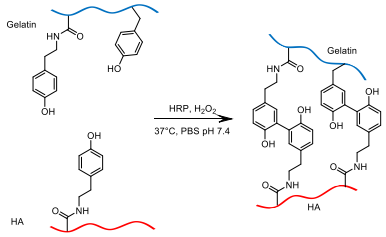

Figure 1: horseradish peroxidase phenol coupling between hyaluronic acid and gelatin

Comparing these results, the most suitable hydrogels for meniscal regeneration were determined to mimic the outer and inner zones of the tissue: a viability test was finally performed with mesenchymal stem cells on them to investigate their interaction and cytocompatibility.

References:

[1] H. Vignes, G. Conzatti, G. Hua, N. Benkirane-Jessel, 2022, Organoids, 1, 116 - 134.
[2] E. Makris, P. Hadidi, K. Athanasiou, 2011, Biomaterials, vol. 32, 7411 – 7431.
[3] E. Stocco, A. Porzionato, E. De Rose, S. Barbon, R. De Caro, V. Macchi, 2022, Journal of Tissue Engineering, Vol. 13, 1 – 14.

Acknowledgment: Iniziativa "PNC0000003 - "ANTHEM: AdvaNced Technologies for Human-centrEd Medicine". CUP BICOCCA B53C2200667000; Ministero della Salute, RF-2021-12371959 Tackling immunomodulatory properties of stromal cells to improve therapeutic strategies in lung cancer. MUR PRIN 2022, 2022MY7AZT Dynamic multifunctional hydrogels for glioblastoma therapy (DINGO).

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Chemo-enzymatic approaches for recovery and valorization of stilbenoids from agri-food waste

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Food loss and waste (FLW) currently represent one of the most pressing public and economic challenges, since negatively impact food security and nutrition and significantly contribute to greenhouse gas emissions.[1] Agri-food industries produce significant amounts of FLW, especially from fruit and vegetable processing,[2] including peels, seeds, leaves, and stems which are known for their high content of bioactive molecules. The development of extraction and processing procedures of these high value natural products for different industrial sectors (i.e., nutraceutical, cosmetic and pharmaceutical industries) is a valid solution to the social and environmental issue represented by agri-food waste.

Resveratrol, a stilbenoid found in grapes, is a natural phytoalexin.[3] It has been intensively studied for its variety of biological activities, together with its metabolites. However, these biological investigations have to deal with the scarce quantity and difficult isolation of pure compounds present in the natural matrices.

In this context, we focused our attention on the development of sustainable chemical processes ("green" extractive chemical approaches and/or enzymatic bioconversions) for the recovery, valorization and production of high value-added molecules starting from vine-wine supply chain. The proposed strategy aims to the search and chemical characterization of active antimicrobial and antioxidant stilbenoids in a "circular economy" approach,[4] allowing at the same time a stable and consistent source of supply.

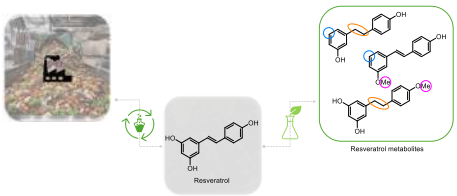

Figure 1: From agri-food waste to high value-added bioactive molecules

References:

[1] https://www.fao.org/policy-support/policy-themes/food-loss-food-waste/en/
[2] A. Mir-Cerdà, O. Nuñez, M. Granados, S. Sentellas, J. Saurina, Trends in analytical chemistry, 2023, 161, 116994.
[3] L. M. Mattio et al. Scientific Reports. 2019, 9, 19525.
[4] T.L. Chen, et al., Science of the Total Environment, 2020, 716 -136998.

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ORG-PO-030

Covalent functionalization of reduced graphene oxide improving its dispersibility in P3HT to obtain composite Hole Transporting Materials for Perovskite Solar Cells

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Enhance the efficiency and device's reproducibility of perovskite solar cells (PSC) is a largely pursued goal. Improving the long-term stability of hole transporting materials (HTM) is a key strategy to bring PSC closer to their practical application.

We synthesized and characterized reduce graphene oxide (RGO) derivatives with the aim of increasing the stability and homogeneity of their dispersion within a poly(3-hexylthiophene) (P3HT) HTM. In principle, RGO and P3HT have the potential to establish π–π stacking interactions between their individual delocalized π electrons clouds, which can make their composites highly stable, but unfortunately this does not often occur due to the stronger tendency of pristine nanostructures to self-aggregate compromising the homogeneity of their dispersion within a polymer matrix.

Goal of chemical functionalization of RGO is therefore to promote interactions with P3HT, by choosing appropriate functional groups, while avoid an excessive disruption of the RGO native electronic structure.

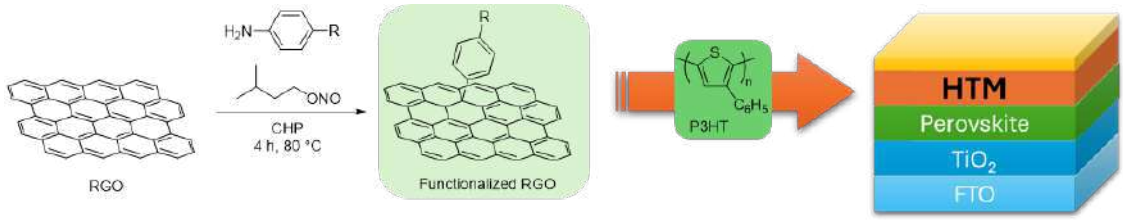

Figure 1: Schematic illustration of functionalization reaction of RGO to obtain derivatives to be used as fillers in P3HT-based composite HTM.

References:

[1] T. Gatti, F. Lamberti, P. Topolovsek, M. Abdu-Aguye, R. Sorrentino, L. Perino, M. Salerno, L. Girardi, C. Marega, G. A. Rizzi, M. A. Loi, A. Petrozza, E. Menna, Solar RRL 2018, 2, 1800013.

[2] T. Gatti, S. Casaluci, M. Prato, M. Salerno, F. Di Stasio, A. Ansaldo, E. Menna, A. Di Carlo, F. Bonaccorso, Adv. Funct. Mater. 2016, 26, 7443-7453.

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ORG-PO-031

Pirfenidone-Containing Dual Conjugates Targeting $\alpha_V\beta_6$ Integrin as New Potential Antifibrotic Agents

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Idiopathic Pulmonary Fibrosis (IPF) is a rare, chronic, and fibrotic lung disease, characterized by a median survival after diagnosis around 3-5 years. Pirfenidone is one of the two drugs approved for the treatment of IPF, although *i)* its mechanism of action is not completely clear; *ii)* it just slows down the disease progression; *iii)* it causes several off-target side-effects.[1] Thus, research in finding new drugs against IPF is widely active, and several biological targets are currently under investigation as new markers. The $\alpha_V\beta_6$ integrin is one of these targets, as it is overexpressed in IPF being involved in activation of the principal pro-fibrotic mediator, TGFβ, and it may be exploited both for the selective delivery of an antifibrotic drug, and as therapeutic target.

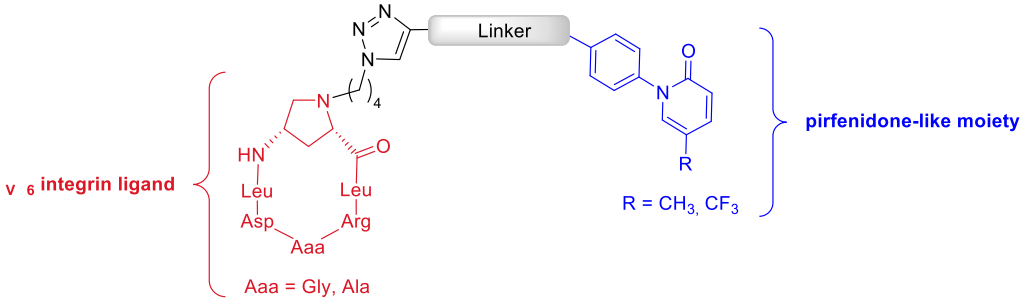

Figure 1: Generic representation of covalent conjugates embedding an $\alpha_V\beta_6$ integrin-targeting ligand and a pirfenidone-like moiety.

Based on this evidence and on the promising results of our previous work on integrin-based conjugates as antifibrotic agents,[2] the aim of this project is the construction of new covalent conjugates embedding an $\alpha_V\beta_6$ integrin-targeting ligand and a pirfenidone unit. Three covalent conjugates (Figure 1) were designed and synthesized, constituted by a pirfenidone-like moiety (depicted in blue), which is linked to the integrin-targeting aminoproline-based cyclopeptide (depicted in red) by means of a robust triazole-based linker (depicted in black). The synthesized compounds will be tested towards activated fibroblasts, also with the aim of better elucidating the mechanism of action of pirfenidone, paving the way to the development of potential targeted antifibrotic drugs.

References:

[1] B. Ballester, J. Milara, J. Cortijo et al., Int. J. Mol. Sci. 2019, 20, 593.
[2] K. Bugatti, E. Andreucci, N. Monaco, et al., ACS Omega 2022, 7, 17658−17669.

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ORG-PO-032

Synthesis and Characterization of New Mono- and Bis-Alkylated Iminosugars to Study Their *Endo*-Cavity Complexation with Water-Soluble Prismarene Hosts as pH-Responsive Pharmacological Chaperones

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Gaucher disease (GD), the most prevalent lysosomal storage disorder, arises from a genetic anomaly in the *GBA* gene, causing misfolding of acid-β-glucosidase (GCase) enzyme. The mutation in GCase perturbs its trafficking to the lysosomes leading to substrate accumulation which in turn determines severe systemic symptoms. A promising therapeutic approach is the Pharmacological Chaperone (PC) Therapy[1], which utilizes enzyme inhibitors, such as iminosugars, as folding templates to restore GCase trafficking and thus endogenous enzyme activity. The affinity of the PC to the enzyme should be higher in the endoplasmic reticulum (pH = 7) and lower in the lysosome (pH = 4.5) to allow the natural substrate entering the catalytic site, thus maximizing the therapeutic efficacy. Aim of this study is to develop innovative PCs for GD based on smart host-guest systems responsive to the physiological pH fluctuation (Figure 1). In this context, the synthesis of mono and bis-alkylated-iminosugars with piperidine and pyrrolidine skeletons was carried out, starting from cost-effective carbohydrates. The alkylation was carried out either on the nitrogen atom, on the alpha carbon neighbouring the nitrogen atom, or on both positions (bis-alkylated) to guarantee the affinity with GCase. The *endo*-cavity complexation of these bioactive compounds with water-soluble prismarenes[2] will be studied at different pH values by NMR or Fluorescence titration experiments.

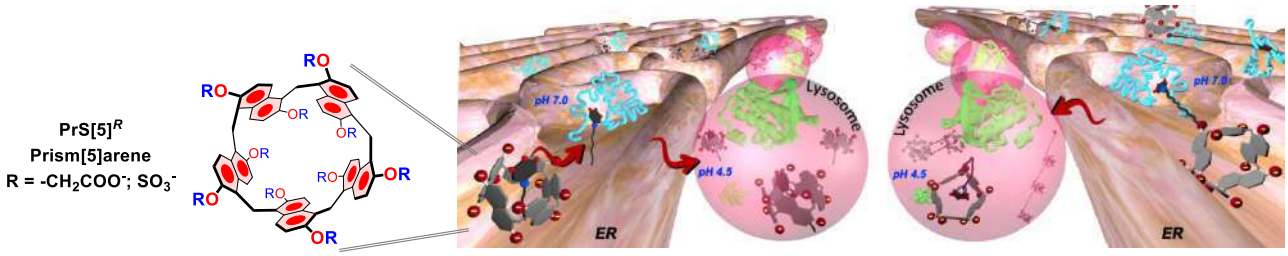

Figure 1: Schematic representation elucidating the rationale behind pH-responsive PCs.

References:

[1] M. Martínez-Bailén, F. Clemente, C. Matassini, F. Cardona, Pharmaceuticals 2022, 15, 823.
[2] P. Della Sala, R. Del Regno, C. Talotta, A. Capobianco, N. Hickey, S. Geremia, M. De Rosa, A. Spinella, A. Soriente, P. Neri, C. Gaeta, J. Am. Chem. Soc., 2020, 142, 1752-1756.

Acknowledgement: Fondo per il Programma Nazionale della Ricerca (PNR) e Progetti di Ricerca di Rilevante Interesse Nazionale (PRIN), finanziato dall'Unione europea – NextGenerationEU. Project: New stimuli-responsive pharmacological chaperones based on prismarenes (PH- PRISM). Codice CUP: B53D23015340006.

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ORG-PO-033

Application of quinoxaline emitters, through luminescent downshift (LDS), in photovoltaic devices.

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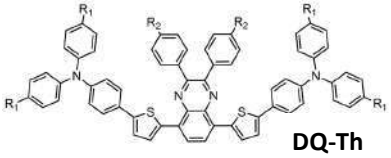
The aim of moving towards a sustainable global economy and a future without fossil fuels has driven researchers to seek new methods for producing and storing energy. Harnessing solar energy to generate power through photovoltaic technology is an economical, stable, and clean method. However, currently available photovoltaic panels are black or blue and therefore not suitable for all environments. In this work, we report the synthesis of new organic fluorophores with LDS properties, which once dispersed in PMMA can be used as Luminescent Solar Concentrator (LSC), colored optical devices that can be used in alternative contexts to traditional photovoltaics. With this in mind, a series of quinoxaline emitters was designed for maximum absorption wavelength between 500 and 600 nm.[1] The emitters were expeditiously prepared following a direct arylation protocol and extensively characterized by spectroscopic analyses and computational studies. They present high light harvesting ability in the green region of the visible spectrum and good emission properties, which were fully retained in the solid state when embedded into a PMMA matrix. Devices constructed with these materials could thus be used in greenhouses because they are transparent in the radiation used by plants and they can convert the remaining visible radiation into electrical energy. The tailored properties of these materials allowed us to prepare LSC devices with promising efficiencies, η_{dev} up to 0.43%. More broadly, this study highlights the use of organic emitters as a convenient strategy in the development of green-light selective LSC devices for their integration into agrivoltaic technologies.



DQ-Th

References:
[1] G. Goti, G. Reginato, *et.al Eur JOC* **2024**, e202400112, *accepted article.*

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ORG-PO-034

Prismarene macrocycles as chirality sensors

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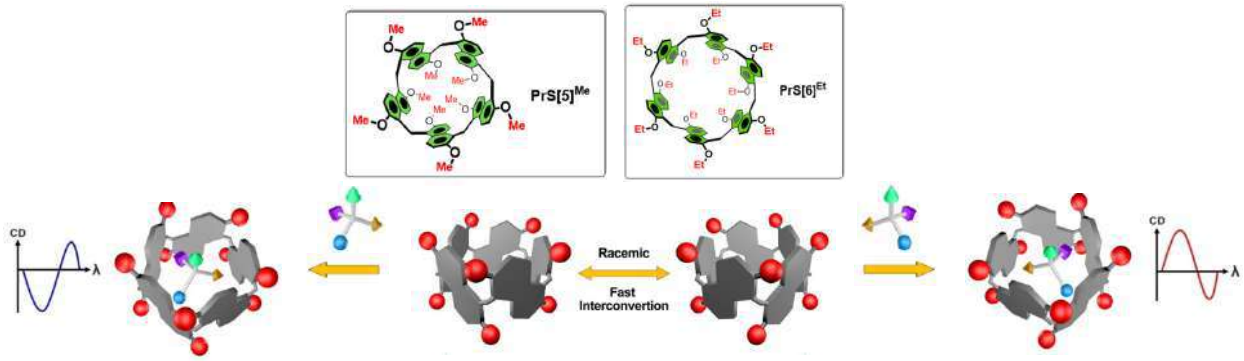
Chiral recognition is gaining significance across multiple fields such as biochemistry, clinical and medicinal chemistry, natural product chemistry, and environmental chemistry. Identifying the structure and enantiomeric composition of chiral molecules is crucial for their detection and comprehension of their behaviour in both the environment and living organisms. One of the most promising methods for chirality sensing and detection is the use of stereodynamic chiroptical probes.[1] These probes consist of achiral or racemic compounds which adopt a preferred chiral conformation when interacting with a chiral analyte, thereby generating a CD signal from which the absolute configuration and/or enantiomeric excess of the analyte can be determined.[2] Some of us recently introduced prismarenes,[3] a novel class of macrocycles able to form inclusion complexes with cationic guests. These macrocycles can assume enantiomeric chiral conformations and it has been shown that inclusion of chiral enantiopure guests induces formation a preferred host enantiomer, as evidenced by characteristic CD spectrum features.[4] The presence of numerous aromatic chromophores on the macrocycles facilitates the detection of UV and CD silent chiral compounds, termed "cryptochiral", due to their ability to produce easily detectable CD signals. We report herein the study of the chiral induction in the host-guest complexes between different chiral compounds and prismarenes PrS[5]^{Me} and PrS[6]^{Et} using CD spectroscopy, eventually applying this approach to determine the enantiomeric composition of scalemic mixtures.



References:
[1] J. S. S. K. Formen, J. R. Howard, E. V. Anslyn, C. Wolf, Angew. Chem. Int. Ed. 2024, e202400767.
[2] S. Vergura, P. Scafato, S. Belviso, S. Superchi, S. Chem. Eur. J. 2019, 25, 5682–5690.
[3] P. Della Sala, R. Del Regno, C. Talotta, A. Capobianco, N. Hickey, S. Geremia, M. De Rosa, A. Spinella, A. Soriente, P. Neri, C. Gaeta, J. Am. Chem. Soc., 2020, *142*, 1752-1756
[4] X. Liang, *et al*. Chem. Commun. 2022, 58, 13584-13587.

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ORG-PO-035

Applications of carbon nitride-perovskite composite materials as heterogeneous photocatalysts in C-C bond formation and oxidation processes

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Grafitic carbon nitride-based materials (general formula: g-C_3N_4) are commonly used as photocatalyst (PCs) working via *single-electron transfer* (SET) in several applications, ranging from fuels production to synthesis due to their ease of preparation, low cost and light absorption in the visible light range.[1] Heterojunction design can improve the redox properties of g-C_3N_4 (in particular, the carrier lifetime) and metal halide perovskites (MHPs) resulted to be effective semiconductors to be coupled to g-C_3N_4 in composites.[2] Herein, we devised and prepared the g-C_3N_4/$Cs_2AgBiCl_6$ and g-C_3N_4/$CsPbCl_3$ composite systems, considering the good energy alignment between the two semiconductors and the efficient photocatalytic activity of $Cs_2AgBiCl_6$ and $CsPbCl_3$.[3,4] In this work, we have tested the prepared composites (including the parent derivatives) in the role of heterogeneous photocatalysts for synthetic purposes under visible light irradiation. Specifically, we have tested their competency in the 1,2-difunctionalization of olefins via *Atom-Transfer Radical Addition* (ATRA; see Figure 1, left part)[5]. Moreover, we have placed our attention on different kind of benzylic oxidation processes (see Figure 1, right part).

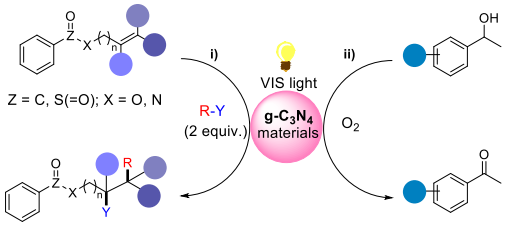

Fig.1 Carbon Nitride-perovskite composites as heterogeneous photocatalysts under visible light irradiation in synthetic applications for: i) ATRA processes between olefins and alkyl halides (left part) and ii) benzylic oxidation (right part).

Acknowledgements Financial support through the HORIZON-EIC-2021-PATHFINDEROPEN-01 project CATART (GA 101046836) entitled "Reaction robot with intimate photocatalytic and separation functions in a 3-D network driven by artificial intelligence" is gratefully acknowledged.

References:

[1] X. Wang, K. Maeda, A. Thomas, K. Takanabe, G. Xin, J.M. Carlsson, K. Domen, M. Antonietti, *Nat. Mater.,***2009**, *8*, 76–80.
[2] L. Romani, L. Malavasi, *ACS Omega*, **2020**, *5*, 25511–25519.
[3] K. Guo, P. Lin, D. Wu, Z. Shi, X. Chen, Y. Han, Y. Tian, *Chem. Eur. J.,* **2023**, *29*, e202300400.
[4] M. Aktary, M. Kamruzzaman, R. Afrose, *RSC Adv.,***2022**, *12*, 23704–23717.
[5] A. Hamadamin, V. Benazzi, C. Campalani, L. Quattri, D. Ravelli, F. Hussain, A. Perosa, M. Selva, S. Protti, *ChemCatChem* **2023**, *15*, e202300708.

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ORG-PO-036

Design and synthesis of new BRD9 inhibitors as potential anticancer agents

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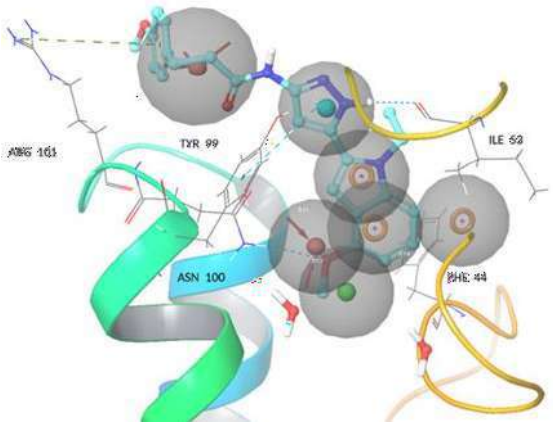
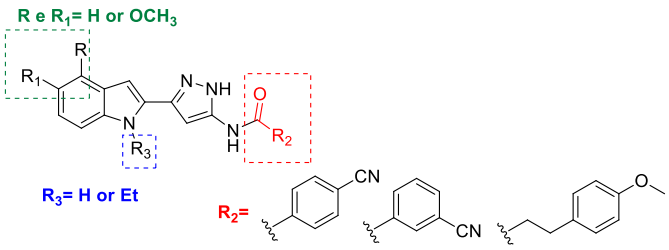
Bromodomains (BDs) are protein modules of ~110 amino acids that recognize acetylated lysine, particularly in histones, and thereby they have important roles in the regulation of gene expression. Following the most recent structure-based classification, the human BRDs are grouped into eight families that span all 61 domains.[1] Bromodomain-containing protein 9 (BRD9), an epigenetic reader, has received increasing attention in the scientific community for its role in gene regulation and its overexpression in many human tumours highlighting it as an attractive target for cancer therapy.[2,3]

The identification of selective BRD9 inhibitors could disclose new epigenetic chemical probes useful to elucidate its biological function, as well as for discovering new anti-cancer drugs.

Following a multidisciplinary protocol that involves virtual combinatorial screening, chemical synthesis and preliminary pharmacological assay, we afforded to the identification of a new chemotype of BRD-9 inhibitors, endowed with an indolyl 2-pyrazole scaffold.

These outcomes pave the way toward a medicinal chemistry optimization campaign of the disclosed hits in order to obtain new BRD-9 inhibitors endowed with high affinity and selectivity.





References:

[1] P. Filippakopoulos *et al.* Cell 2012, **149**.

[2] L. Scotto, G. Narayan, S. V. Nandula, S. Subramaniyam, A. M. Kaufmann, J. D. Wright, B Pothuri, M. Mansukhani, A. Schneider, H. Arias-Pulido, V. V. Murty, Molecular Cancer 2008, **7,** 58.

[3] J. U. Kang, S. H. Koo, K. C. Kwon, J. W. Park, J. M. Kim, Cancer Genetics and Cytogenetics 2008, **182**, 1-11.

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ORG-PO-037

A novel approach to the stereoselective total synthesis of four stereoisomers of the fungal phytotoxin ascaulitoxin aglycone.

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Agriculture faces a significant challenge in safeguarding crops against weed competition while minimizing their spread. To this end, natural biopesticides like phytotoxins offer promising traits, having low persistence in the environment and highly targeted modes of action, thus minimizing pest resistance issues and environmental impact. Ascaulitoxin and its aglycone (**AscA**), derived from the *Ascochyta Caulina* fungus[1], stand out as potent phytotoxins with potential for controlling weeds[2]. The absolute configuration of natural **AscA** was unknown and its relative configuration uncertain. Therefore, aim of this work was the total synthesis of stereoisomers of ascaulitoxin aglycone to both determine its absolute configuration and provide quantities necessary for large-scale applications and structure-activity relationship studies. **AscA** can display up to 16 possible stereoisomers, but initially, we assumed an (*S*) absolute configuration of the terminal amino acid moieties, thus limiting the search to four of them. Therefore, this report details the approach to the diastereo- and enantioselective synthesis of four ascaulitoxin aglycone stereoisomers. The synthesis of *anti* isomers of the central amino and hydroxy groups was carried out by an asymmetric dihydroxylation-Mitsunobu azidation sequence, while the *syn* isomers were obtained through direct asymmetric aminohydroxylation. Both methods originate from the same olefin, readily prepared from commercially available Boc-L-allylglycine through self-metathesis. Furthermore, the phytotoxic activity of the synthetic intermediates of ascaulitoxin aglycone diastereomers was tested on host and non-host weed plants.

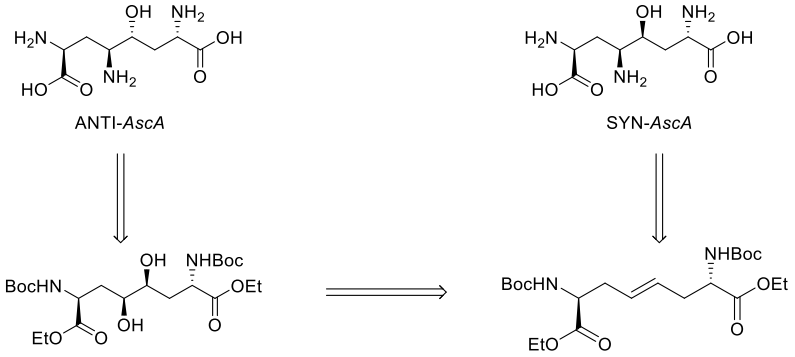

Figure 1: Retrosynthetic approach for the synthesis of the *anti* and *syn* stereoisomers of AscA

References:
[1] A. Evidente *et al*, Phytochemistry, 1998, 48, 1131-1137.
[2] S.O. Duke *et al*, Pesticide biochemistry and physiology, 2011, 100, 41-50.
Work carried out within the Agritech National Research Center funded by Next-GenerationUE plan (PNRR – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1032 17/06/2022, CN00000022.

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ORG-PO-038

New molecular cages for chiroptical sensing

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Metal complexes of tris(2-pyridylmethyl)amine (**TPMA**) ligands have gained interest in sensing applications due to the seminal contributions of Canary[1,2] and Anslyn.[3] Recently, these complexes have been exploited by our research group as building blocks for the synthesis of novel molecular cages.[4] These architectures are obtained through imine bond formation from the self-assembly of a modified **TPMA**-based metal complex bearing three aldehyde groups and diamine linkers.[4,5]

The present work illustrates the synthesis of new **TPMA**-complexes and the corresponding novel molecular cages. Furthermore, the synthesis of new chiral hydrolytically stable cages, exploiting a method recently published by our research group,[6] is described. The goal of this project is to obtain new chiroptical properties like, for example, an amplification of circular dichroism (CD) and circularly polarized luminescence (CPL) signals. In order to achieve these aims, chiral cages could be employed together with fluorophore guest molecule appropriately functionalised. Otherwise, the fluorophore could be embedded in the chiral cage structure as in the case of the 9,9-dihexylfluorene unit (Figure 1).

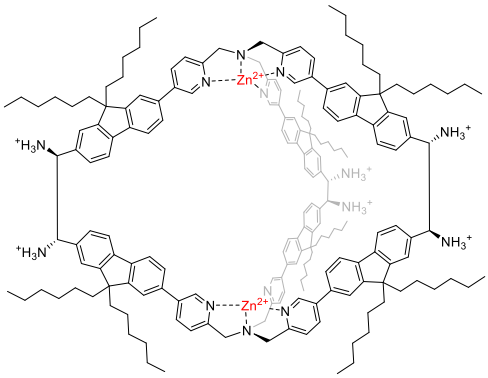

Figure 1: New hydrolytically stable **TPMA**-based molecular cage bearing six 9,9-dihexylfluorene units.

References:

[1] J. W. Canary, C. S. Allen, J. M. Castagnetto, Y. Wang, J. Am. Chem. Soc. 1995, 117, 8484-8485.
[2] S. Zahn, J. W. Canary, Science 2000, 288, 1404-1407.
[3] L. A. Joyce, J. W. Canary, E. V. Anslyn, Chem.-Eur. J. 2012, 18, 8064-8069.
[4] C. Bravin, E. Badetti, G. Licini, C. Zonta, Coord. Chem. Rev. 2021, 427, 213558.
[5] C. Bravin, E. Badetti, F. A. Scaramuzzo, G. Licini, C. Zonta, J. Am. Chem. Soc. 2017, 139, 6456-6460.
[6] F. Begato, R. Penasa, K. Wurst, G. Licini, C. Zonta, Angew. Chem. Int. Ed. 2023, 62, e20230449.

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Metal-free synthesis of selenoglycosylated eumelanin monomers

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Eumelanins are dark insoluble pigments,[1] arising by oxidative polymerization of 5,6-dihydroxyindole (DHI) and DHICA 5,6-diacetoxy-indole-2-carboxylic acid, involved in important biological functions (*e.g.,* photoprotection, homeostasis). Due to their natural origin and peculiar physical-chemical properties, eumelanin can play a key role in biomedical applications and bioelectronics[2]. In a previous study, the first water-soluble eumelanin monomer 3-thiogalactoside-DHI (S-GAL-DHI) allowed noteworthy insights in structural investigations of DHI melanin[3]. In the view of the emerging interest of soluble glycosylated eumelanin in materials science and in glycobiology, the synthesis of new glycosylated melanins involving diverse saccharide precursors represents a field of research of high relevance. In this work, a series of 3-selenoglycosylated eumelanin derivatives (figure 1) were prepared through a practical and efficient approach exploiting a metal free, simple, and scalable synthetic route. The strategy is feasible for installing both mono- and disaccharide units for the first time on both O-protected eumelanin precursors and relies on the exploit of easily accessible glycosyl diselenides[4] as selenium source.

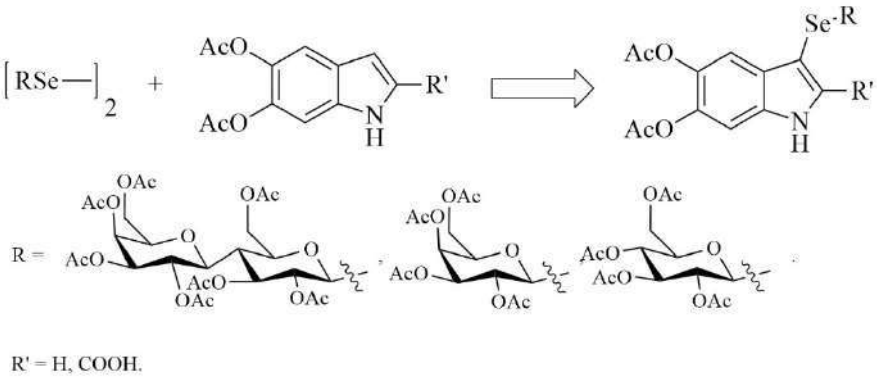

Figure 1: Synthesis of 3-selenoglycosilated eumelanin monomers.

References:

[1] M. D'Ischia, A. Napolitano, A. Pezzella, P. Meredith, T. Sarna, *Angewandte Chemie - International Edition* 2009, *48*, 3914

[2] P. Meredith, T. Sarna, *Pigment Cell Research* 2006, *19* (6), 572–594.

[3] A. Pezzella, A. Iadonisi, S. Valerio, L. Panzella, A. Napolitano, M. Adinolfi, M. d'Ischia, Polymer. *J. Am. Chem. Soc.* 2009, *131* (42), 15270–15275.

[4] A. Iadonisi, S. Traboni, D. Capasso, E. Bedini, S. Cuomo, S. D. Gaetano, G. Vessella, *Org. Chem. Front.* 2021, *8* (8), 1823–1829.

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ORG-PO-040

π-Conjugated Functionalized Wood towards Sustainable Optoelectronics

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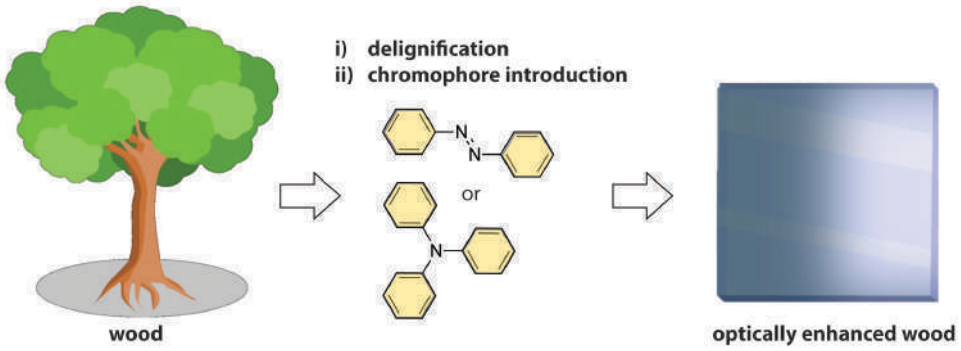
Highly transparent materials are pivotal for the development of energy saving budling.[1] Among these materials, transparent wood (TW) offers exceptional optical properties, UV blocking and low thermal conductivity,[2] in combination with a rapid fabrication process and impressive mechanical strength, reducing building energy consumption and construction industry's environmental impact. Transparent wood is made in a two-step process. First, delignification using an oxidant solution of hydrogen peroxide and sodium hydroxide in combination with heat, resulting in bleached wood that has empty channels (lumens) deprived of chromophore molecules.[3] The second step involves the filling of these channels with of thermo- or photocurable polymer resins.

In this work, we introduce a novel approach to enhance the optical and optoelectronic properties of these materials. Lumen filling is done utilizing three methods: 1) chromophore adsorption followed by polymer infiltration, 2) covalent chromophore anchoring to the lumen wall followed by polymer infiltration, and 3) synthesis of monomers inclusive of pendant chromophores for a single-step infiltration and polymerization. Two types of class of compounds were investigated: light-responsive azobenzene and electron-rich arylamine derivatives. The resulting wood-optoelectronic materials were characterized through UV-vis and IR spectroscopy, X-ray diffraction (XRD), SEM, TEM, moreover tensile strength and fracture mechanics tests were carried out to complete the mechanical investigation of the new material.



References:
[1] T. Li, M. Zhu, Z. Yang, J. Song, J. Dai, W. Luo, G. Pastel, B. Yang, L. Hu, **2016**, *Adv. Energy Mater*., 6, 1601122
[2] Y. Li, M.Cheng, E. Jungstedt, B. Xu, L. Sun, L. Berglund, **2019**, *ACS Sustain. Chem. Eng.*, 7, 6061–6067.
[3] A.N.S. Rao , G.B. Nagarajappa , S. Nair , A.M. Chathoth , K.K. Pandey, **2019**, *Compos. Sci. Technol.*, 182, 107719.

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Engineering of giant unilamellar vesicles via development of light-switchable amphiphiles

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Nowadays the responsiveness of supramolecular entities toward applied stimuli is fuelling a compelling area of research. Being inspired by the reactivity of living cells to encountered inputs, the interest of researchers has rapidly spread towards the development of systems able to accomplish complex and specific tasks upon a controllable stimulus.[1] Mirroring the features of living cells might potentially be the key to shaping new future technologies, widening from groundbreaking strategies for **pollution remediation** to novel **therapeutic tools** in the frame of drug delivery.[2]

In this work, a library of artificial **azobenzene-based amphiphiles** was designed and synthetized, further to their incorporation in the bilayer of giant unilamellar vesicles (GUVs). Given the photo-triggered *E-Z* isomerization of the azobenzene moiety, unconventional behaviours were highlighted on the supramolecular scale via microscopy experiments. Remarkable shape and size alteration were confirmed upon light exposure in our engineered GUVs, as well as the **opening of pores** through the bilayer. All the observed phenomena were readily reverted by interrupting the irradiation.[3] In light of the positive results attained, novel amphiphilic molecules were developed further on by integrating the **photo-switch** feature with **fluorescence**.

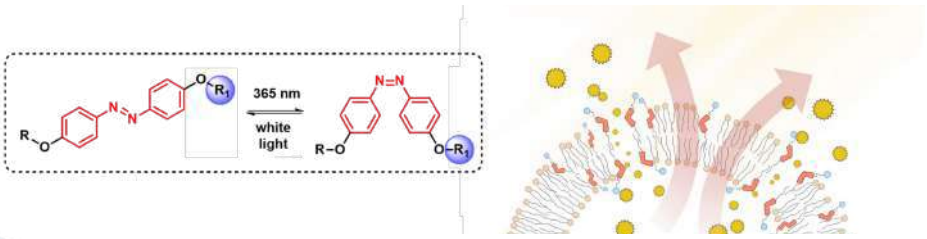

Figure 1: on the left, E-Z isomerization of the light-responsive amphiphiles; on the right, representation of the cargo release for the engineered GUVs

References:
[1] C. Z. J. Ren, P. Solís Muñana, J. Dupont, S. S. Zhou, J. L. Y. Chen, Angew. Chem. Int., 2019, 58, 15254.
[2] Y. Elani, Angew. Chem. Int., 2021, 60, 5602.
[3] P. Albanese, S. Cataldini, C. Z. J. Ren, N. Valletti, J. Brunetti, J. L. Y. Chen, F. Rossi, Pharmaceutics, 2022, 14, 2777.

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Hydrochars as soil amendments for heavy metals removal from soil

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In the last years, mankind faced problems associated to depletion of non-renewable resources and the rise of demand for raw materials; lignocellulosic biomass and circular economy principles can help to solve this issue. Biomass is a renewable and carbon neutral resource, that can also be exploited starting from its waste form; according to circular economy waste biomass valorisation is a better option than waste disposal. Biochars are carbonaceous materials that can be derived from waste lignocellulosic biomass. They are often employed in several fields, such as electrochemistry, water, soil purification, and as catalytic support[1,2]. Biochars are usually obtained from pyrolysis, which requires deep drying, which is energy-intensive, particularly for biomass with high-moisture content. A more sustainable thermochemical process is hydrothermal carbonization (HTC), which operates in water-rich environment under autogenous pressure generated from water and at moderate temperature conditions, about 200-260°C[3]. The final solid product is called hydrochar, a particular class of biochars, that retains volatile organic matter and functional groups that are crucial for adsorption. This study investigates the effectiveness of hydrochars from different biomass waste sources in the adsorption of lead, zinc, and cadmium from soil, both as single metals and simultaneously.

Figure 1: Waste biomass valorisation into hydrochar for heavy metals adsorption from soil

References:
[1] F. Valentini, E. Cerza, F. Campana, A. Marrocchi, L. Vaccaro, *Bioresour. Technol.*, **2023**, *390*, 129847-129856
[2] F. Ferlin, F. Valentini, D. Sciosci, M. Calamante, E. Petricci, L. Vaccaro, *ACS Sustainable Chem. Eng.*, **2021**, *9*, 12196-12204
[3] J. Huang, Y. Feng, X. Xie, P. Wu, M. Wang, B. Wang, Q. Zhang, S. Zhang, Z. Liu, *Biochar*, **2023**, *5*, 12
This work has been funded by the European Union – NextGenerationEU.

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Unlocking the Potential of Lignin: Integrating Extraction and Depolymerization Strategies for Sustainable Biomass Valorization

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Lignin, the second most abundant natural polymer, holds immense value in the biorefinery sector, offering diverse opportunities for innovation and sustainability across industries. However, the complex and irregular structure of this biopolymer presents challenges in achieving specific target molecules. Firstly, the focus is on obtaining unaltered lignin, known as "lignin first," which closely resembles its natural composition. Protective agents like aldehydes and ketones have been explored to mitigate lignin denaturation during extraction processes[1]. Additionally, lignin depolymerization often relies on harsh catalytic methods with limited selectivity. However, recent advancements in photocatalysis with earth-abundant metal offer a promising avenue for gentler lignin depolymerization.

This study integrates those approaches to enhance lignin's suitability as a natural feedstock for obtaining target aromatic molecules such as aryl aldehydes, carboxylic acids, and formates. Therefore, formaldehyde is chosen as a protective agent to stabilize α,γ-diols, such as β-1 and β-O-4, during the 1,4-dioxane extraction process, facilitating acetal formation. Subsequently, acetals are removed to recover formaldehyde and restore vicinal diol functionalities. Indeed, the presence of α,γ-diol is essential for the vanadium(II) aminotriphenolate complex in order to catalyse aerobic oxidative cleavage of C-C bonds under ambient conditions and visible light [2,3]. In summary, this study provides a comprehensive perspective on biomass utilization, focusing on enhancing lignin as a platform for aromatic derivatives.

References

[1] W. Lan, M.T., Amiri, C.M. Hunston, J.S. Luterbacher. *Angew. Chem. Int. Ed.*, **2018**, *57*, 1356–1360.
[2] a H. Liu, H. Li, N. Luo, F. Wang. *ACS Catat.* **2020**, *10*, 632-643; b.TA. hanetchaiyakup, K.F. Chin., M. Đokic, T. Leetiong, D.J. Lin, M. Mathiew, X. Zhao, H. Zhi Xiong Heng, D.J. Xiong Toh, X-W Liu, . Bamalingam, and H.S. Soo. Chem. Catal., *3*, **2023**, 100530.
[3] a.E. Amadio, J. González-Fabra, D. Carraro, W. Denis, B. Gjoka, C. Zonta, K. Bartik, F. Cavani, S. Solmi, C. Bo, G. Licini. *Adv. Synth. Catal.* **2018**, *360*, 3286–3296. b. R. Carpentier, W. Denis, F. Sanz Azcona, D. Carraro, G. Grauwels, M. Orlandi, C. Zonta, G. Licini, K. Bartik. *ACS Sustainable Chem. Eng.*, **2023**, *11*, 8633 - 8641.

Acknowledgements.
The project has been carried out in the frame MICS (Made in Italy – Circular and Sustainable) Extended Partnership. We thank the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3 – D.D. 1551.11-10-2022, PE00000004) (ED and WB fellowships) and Progetto PON "Ricerca e Innovazione" 2014-2020 Azione IV.5 – Dottorati su tematiche green (FAS fellowship) for financial support.

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Buckwald-Hartwig goes greener. An effective heterogeneous protocol to access the synthesis of Csp2 – N bond under microwave irradiation.

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Buchwald-Hartwig coupling is a powerful tool allowing the formation of Csp^2-N bonds. Compared to traditional synthetic strategies,[1] offers the advantages of being a one-step reaction, using relatively mild reaction conditions and having greater tolerance to functional groups. This versatile method has a strong impact in both academic and industrial sectors: agrochemicals, natural products, sensors, ligands, polymers, and e Active Pharmaceutical Ingredients (API) heavily rely on this type of bond.[2] Despite its applicability, improving energy efficiency and environmental friendliness remains an ongoing endeavour. To address these challenges, the use of recoverable, low-energy-consuming, biomass-derived 2-MeTHF,[3] presents a promising solution. Herein, a comparison between traditional and microwave heating is reported in combination with Pd/C as a recoverable catalyst. To the best of our knowledge, there are few examples of applying this technology in this field. The synergy between microwave technology, heterogeneous catalysts, and recoverable reaction media enhances the accessibility of diversely functionalised arylamines, key intermediates in API synthesis.

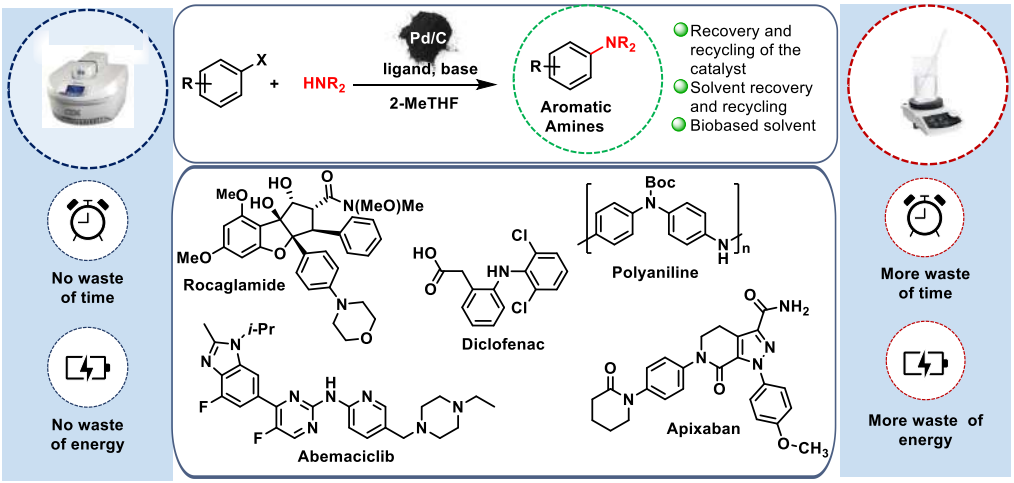

Figure 1: Buchwald-Hartwig reaction and some of its applications.

References:

[1] a) M. B., Smith, J. March, Org. Proc. Res. Dev. 2001, 5, 6, 669, 5th edn., Wiley-Interscience, New York; b) J. F Bunnett, R. E. Zahler, Chem. Rev. 1951, 49, 237–412; c) C. Sambiagio, S. P. Marsden, A. J. Blacker, P. C. McGowan, Chem. Soc. Rev. 2014, 43, 3525– 3550.
[2] P. Ruiz-Castillo, S. L. Buchwald, Chem. Rev., 2016, 116, 19, 12564–12649.
[3] V. Pace, P. Hoyos, L. Castoldi, P. Domínguez de María, A.R. Alcántara, ChemSusChem 2012, 5, 1369-1379.

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ORG-PO-045

Halloysite/Pyrazole[3,4-d]pyrimidine nanomaterials for potential local treatment of prostate cancer

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Prostate cancer is the second most common tumor and the fifth cause of cancer death in men. Recent studies showed that different types of human tumors, as for example prostate cancer, present an overexpression of a protein kinase, c-Src, which downregulation could be a useful strategy for their treatment. Over the years several c-Src inhibitors have been developed that possess in their structure some heterocyclic rings, such as pyrazolo[3,4-d]pyrimidine derivatives. However, these molecules present a very poor aqueous solubility that requires high dosage to be efficient worsening the patience compliance. Halloysite, a clay mineral belonging to kaolin group with a typical hollow tubular structure, because of its biocompatibility and low cost represents a valuable carrier system for the local delivery of such drugs.[1,2] Herein, we report the design of halloysite based nanomaterials covalently or supramolecular modified with some pyrazolo[3,4-d]pyrimidine derivatives ad hoc synthetized. The obtained nanomaterials were thoroughly investigated from a physico-chemical point of view to assess the successful modification and their morphology was imaged by transmission electron microscopy. Furthermore, their antiproliferative activity was also assessed by *in vitro* studies on RT112, UMUC3 and PC3 cell lines as model of bladder and prostate cancer cells.

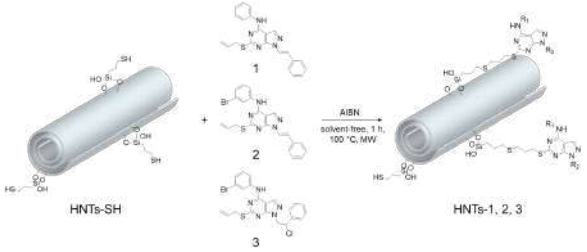

Figure 1. Halloysite/Pyrazole[3,4-d]pyrimidine nanomaterials.

References:

[1] M. Massaro, G. Barone, V. Barra, P. Cancemi, A. Di Leonardo, G. Grossi, F. Lo Celso, S. Schenone, C. Viseras Iborra, S. Riela, Int. J. Pharm. 2021, 599, 151, 120281.
[2] M. Notarbartolo, M. Massaro, R. de Melo Barbosa, C. Emili, L. F. Liotta, P. Poma, F. M. Raymo, R. Sànchez-Espejo, R. Vago, C. Viseras-Iborra, S. Riela Coll. Surf. B 2022, 220.

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Study of methods, enviromentally sustainable abatement of organic fraction responsible for Chemical Oxygen Demand in wastewater of industrial plants

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This research aims to conduct a comprehensive large-scale analysis, focusing on exploring advanced and sustainable methods to reduce the presence of the organic component associated with Chemical Oxygen Demand (COD) in industrial effluents. The main objective is the identification, evaluation, and implementation of innovative protocols, with particular emphasis on the application of the Fenton reaction as an Advanced Oxidation Process (AOP)[1].

The Fenton reaction, based on the generation of highly reactive free radicals through the interaction between hydrogen peroxide and iron, emerges as a promising perspective for wastewater treatment, also mediated by other metals such as copper, cobalt, and manganese. This approach is particularly important in the context of treatment using activated sludge, a traditional methodology that employs microorganisms to simulate purification processes observed in nature in water bodies. However, an intrinsic limitation of this approach lies in its inefficacy in treating toxic pollutants, as microorganisms may not completely degrade them[2].

In the presence of toxic pollutants challenging the efficacy of activated sludge treatments, advanced oxidation processes such as the Fenton reaction emerge as an alternative and complementary solution. These processes, characterized by their ability to generate highly reactive free radicals, offer a more robust and efficient oxidation mechanism. Therefore, the integration of innovative approaches in industrial wastewater management aims to overcome the limitations of conventional treatments, more effectively addressing the presence of recalcitrant contaminants[3].

A distinctive aspect of this research lies in the synthesis of metallic catalysts employed in the Fenton reaction, obtained through the recovery of metallic waste from various industrial sources. This synergy between the power of the Fenton reaction and the recycling of waste materials highlights a sustainable approach that not only aims to reduce COD but also seeks to transform waste into valuable resources through the production of metallic catalysts[4].

The studied reaction conditions include the concentration of hydrogen peroxide (0-0.2 mol/L), pH (1-8), quantity of metallic waste (0-15 mg/mL), temperature (25-80 °C), and reaction time (0-24 hours). Decolorization tests using methylene blue and methyl orange were conducted, showing complete decolorization and dye removal at room temperature after 5 hours. Subsequently, decolorization tests were carried out on industrial wastewater samples, also showing complete decolorization at short reaction times.

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Halloysite/heteroaryl ethylene nanomaterials for potential biomedical applications

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Biomedical science has long been looking for innovative systems for diagnostic and therapeutic applications. In the last years, particular interest has been given to heteroaryl ethylene molecules, which have both anti-tumor and antibacterial activity, as well as excellent pH-sensitive fluorescent properties, useful in the diagnostic field.[1,2] However these molecules show a very low aqueous water solubility and short lifetime that hamper their use. Halloysite nanotubes (HNTs), a phyllosilicate clay mineral, represent appealing nanomaterial because of their high biocompatibility, low cost and the peculiar capability to cross cellular membrane, localizing themselves in the perinuclear area, that together the presence of an empty lumen, make them excellent systems for the loading and delivery of different biologically active species.[3,4]

Herein we report the synthesis and characterization on HNTs based nanomaterial loaded with 2,6-Bis{(E)-2-[4-(Dimethylamino)phenyl]vinyl}-1-methylpyridinium iodide (HNTs/PB_4). Furthermore, the luminescent properties of HNTs/PB_4 were also studied by fluorescent spectroscopy both in solution and in solid state. The data obtained show the potentiality of the obtained nanomaterial for future application in biomedical field.

References:

[1] V. Barresi, C. Bonaccorso, G. Consiglio, L. Goracci, N. Musso, G. Musumarra, C. Satriano, C.G. Fortuna, Mol Biosyst 2013, 9, 2426 – 2429.
[2] D. Bongiorno, N. Musso, P.G. Bonacci, D.A. Bivona, M. Massimino, S. Stracquadaino, C. Bonaccorso, C.G. Fortuna, S. Stefani, Antibiotics 2021, 10,1034.
[3] A.P. Falanga, M. Massaro, N. Borbone, M. Notarbartolo, G. Piccialli, L.F. Liotta, R. Sanchez-Espejo, C. Viseras-Iborra, F.M. Raymo, G. Oliviero, S. Riela, J Colloid Interface Sci 2024, 663, 9 – 20.
[4] M. Massaro, M. Notarbartolo, F.M. Raymo, G. Cavallaro, G. Lazzara, M.M.A. Mazza, C. Viseras-Iborra, S. Riela, ACS Appl. Nano Mater. 2022, 5, 10, 13729 – 13736.

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Direct enantioselective photocatalytic α-functionalization of aldehydes with nitrogen-lactam radicals

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Lactams can be considered some of the most significant heterocycles in medicinal chemistry and drug discovery. They are a privileged structure common to a large variety of natural products and drugs, to which they lend a potential therapeutic effect for the treatment of different disorders, spanning from cancer, diabetes, and infectious diseases.[1] Typically, lactam rings are introduced in organic molecules by ring-closure reactions, while no example of direct introduction is reported.

In this context we report the development of a photocatalytic strategy that enables the direct stereoselective introduction of lactam rings, via nitrogen radicals. In the last decades, light emerged as one of the most powerful synthetic tools to assist the organic synthesis, enabling challenging transformations under mild conditions, via radical intermediates. Its combination with organocatalysis allowed us to point out a stereoselective version of the reaction, that opened the door to the synthesis of chiral molecules of synthetic interest.

To the best of our knowledge, no example of nitrogen lactam radical is reported in the literature, therefore we first studied the development of a *N*-aminopyridinium salt as radical precursor.[2] Inspired by a work of MacMillan and coworkers, we tested the reactivity of the radical with the nucleophilic enamine of aldehydes, obtaining good results in the α-functionalization of a wide range of substrates (**Figure 1**).[3] The scope of lactam rings and of the substrates was studied, obtaining the desired products in moderate to good yield and with good enantiomeric excess. In the end, the strategy was exploited for the synthesis of an orphan drug, Levetiracetam, to demonstrate the synthetic applicability of the method.

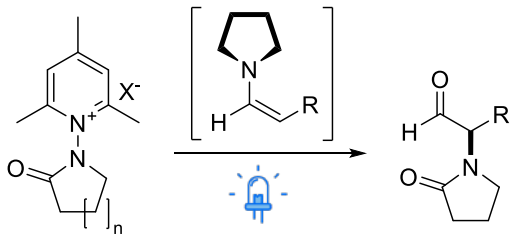

Figure 1: Stereoselective, photocatalytic α-functionalization of aldehydes with *N*- lactam radicals

[1] F. Saldìvar-Gonzalez, E. Lenci, A. Trabocchi, and J. L. Medina-Franco; *RSC Adv.*, **2019**, *9*, 27105-27116
[2] T. W. Greulich, C. G. Daniliuc, A. Studer, *Org Lett*, **2015**, *17*, 254–257
[3] G. Cecere, C. M. König, J. L. Alleva, D. W. C. MacMillan, *JACS*, **2013**, *135*, 11521–11524

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ORG-PO-049

Para-aminomethyl calixarenes as ligands for biologically relevant G-quadruplexes

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G-quadruplexes (G4s) are DNA and RNA four-stranded secondary structures generated by the stacking of guanine tetrads. Due to their presence in key regions of the human genome, such as telomeres and gene promoters, and their association with cancer and neurodegenerative diseases, several classes of ligands have been developed to study and modulate their biological functions.[1]

Here, we present a small library of calix[n]arenes, which were synthetized as potential new ligands for G4s (Fig. 1). The upper rim of these compounds was decorated with various amines to promote their association with the negatively charged surfaces of their targets, while their aromatic scaffold was expected to provide hydrophobic and stacking interactions. Also, we tuned the size and conformational mobility of the tested compounds through a different valency of the macrocycles (n = 4, 6, 8) and the functionalization of their lower rim (free vs methylated phenolic OHs).

The binding features of these compounds were assessed via Förster Resonance Energy Transfer (FRET)-melting assays, using the human telomeric G4 as a substrate. In this assays, the target DNA sequence was labelled with a FRET couple of fluorophores, and ligand-induced variations of its melting temperature were monitored through fluorescence measurements.[2] This approach enabled the automated screening of the tested ligands, evidencing the ability of some of them to affect the stability of their target. Then, the interaction between the tested G4 and the most promising calixarenes was further characterized via CD spectroscopy.

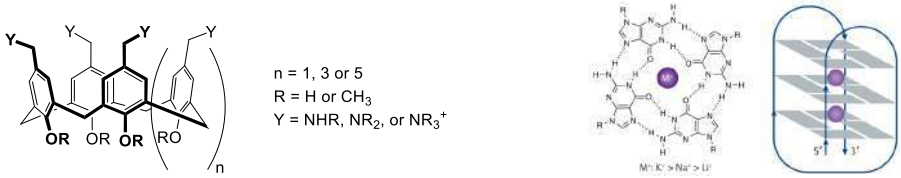

Figure 1: general structure of the tested calix[n]arene ligands (left) and a possible G4 topology (right).

Funder: Project funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.1 - Call for tender No. 104 of 02.02.2022 of Italian Ministry of University and Research funded by the European Union – NextGenerationEU. Award Number: Project code 2022N9E847, Concession Decree No. 1064 of 18.07.2023 adopted by the Italian Ministry of the University and Research, CUP D53D23010430006, Multifunctional compounds for a multitarget approach against neurodegenerative disorders - MULTIFUN

References:

[1] D. Rhodes and H. J. Lipps, *Nucleic Acids Res.*, 2015, 43 (18), 8627 – 8637.
[2] A. De Rache and J. L. Mergny, *Biochimie* 2015, 115, 194 – 202.

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Design and synthesis of chimeric antitumoral compounds Nutlin-DCA

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Chimeric compounds are used in cancer research for the treatment of distal pathways that integrate several concurrent signals responsible for tumour growth. Their structure comprises of two or more pharmacophores connected through suitable chemical linker. This dual or multi-functional drugs have the ability to interact with different biological targets for a more pronounced therapeutic effect upon administration.

In this work we designed and built novel multifunctional molecules DCA and (-)-Nutlin-3, focusing on two important pathways linked to the predominant survival and proliferative aggressiveness of malignant cells: the Warbug effect and the suppression of "the genome guardian", p53.

Dichloroacetic acid and in particular dichloroacetate (DCA) showed to unlock cancer cells from anti-apoptosis state due to Warburg effect, via inhibition of mitochondria pyruvate dehydrogenate kinase (PDK) restoring oxidative phosphorylation metabolism.

The substitute *cis*-imidazolines, also known as Nutlins are potent antitumoral compounds studied in several types of cancer in clinical trials for their ability to restore the protective function of p53, by blockage of its antagonist oncoprotein MDM2.

Chimeric compounds derived from the connection of dichloroacetic acid (DCA) and the cis-imidazoline (-)-Nutlin-3 through suitable biodegradable linkers, could simultaneously inhibit mitochondrial pyruvate dehydrogenase kinase (PDK) and restore p53 function, inducing cell cycle arrest to impede tumor development and harboring normal cells.

Hence the final intent of this work is the selection of new multitargeting drugs with enhanced antitumoral efficacy given by a synergistic activity

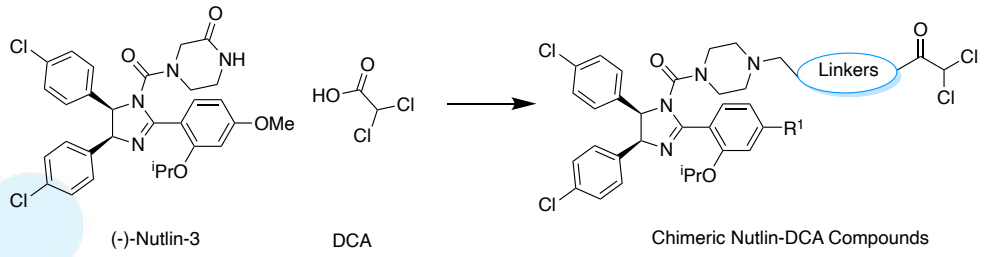

Figure 1: Schematic preparation of chimeric Nutlin-DCA compounds.

References:

[1] A. Fantinati, S. Bianco, V. Cristofori, et al. Chemistry Select, 2017, 2(27), 8504 – 8508.
[1] C. Trapella, R. Voltan, E. Melloni, V Tisato, C. Celeghini et al. J. Med. Chem. 2016, 59, 147-156

ORG-PO-051

Carbon-doped Ionic Liquid Gels for simultaneous removal of emerging pollutants from water

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Contamination of water bodies is a pressing issue of present-day society, exacerbated by their wide structural variety. It is therefore necessary to develop systems able to remove multiple pollutants simultaneously. In this context, we prepared and characterized supramolecular hybrid ionic liquid gels of 1,3:2,4-dibenzylidene-D-sorbitol (DBS), doped with carbon materials such as graphite, carbon nanotubes, graphene and graphene oxide. We employed these gels as sorbents for the simultaneous removal of pollutants of different classes, such as dyes and emerging pollutants like drugs and bisphenol A.

We firstly characterized the gels in terms of thermal stability, rheology and self-healing ability. Then, we tested them as sorbents for pollutants in aqueous mixtures, observing high removal efficiency and high recyclability, especially in the case of the graphite-doped gel, which achieved adsorption capacities as high as 117 mg/g and 66 mg/g for rhodamine B and bisphenol A in mixture, with a distinct preference towards cationic contaminants.

Acknowledgement: We thank MUR for funding, SiciliAn MicronanOTecH Research And Innovation CEnter "SAMOTHRACE" (MUR, PNRR-M4C2, ECS_00000022), spoke 3 - Università degli Studi di Palermo "S2-COMMs - Micro and Nanotechnologies for Smart & Sustainable Communities". The funding source had no role in analysis, design, interpretation of results and report writing.

References:

[1] T. O. Ajiboye, O. A. Oyewo, D. C. Onwudiwe, Chemosphere 2021, 262, 128379.

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ORG-PO-052

QM/MM investigation and rate constant evaluation of long-range electron transfer pathways in Bacteriorhodopsin and Bacteriorhodopsin-sensitized TiO_2 hybrid systems

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Bacteriorhodopsin (bR) is a protein present in the purple membrane of *Halobacterium salinarum*. Due to its favourable chemical and photochemical properties, it has been used in photocatalysis, photoelectrochemistry, and bioelectronics fields as a sensitizer for TiO_2.[1,2] It has been widely employed to improve the efficiency of solar energy conversion in technological devices such as photovoltaic and photoelectrochemical cells. Nevertheless, the mechanism of the Electron Transfer (ET) from the Retinal Protonated Schiff Base (RPSB) to the surface of the protein is not yet fully understood. In this work, Quantum Mechanics/Molecular Mechanics (QM/MM) methods were applied to investigate the most probable long–range ET pathways in the isolated bR and four different bR/TiO_2 hybrid systems. The goal of this work is to acquire knowledge about the intramolecular ET mechanism that leads the electron to be injected into the semiconductor conduction band. The bR/TiO_2 hybrid systems were previously generated in our laboratory.[3] Mulliken Population Analysis (MPA) and Spin Density (SD) values were computed to investigate the active redox amino acids involved in the long–range ET. Marcus's equation for ET rate constant (K_{ET}, eq. 1) was also solved for the isolated bR and the four bR/TiO_2 hybrid systems, involving the RPSB and the amino acids identified based on the SD delocalization map.

$$K_{ET} = \sqrt{\frac{4\pi^3}{h^2 \lambda RT}} \boldsymbol{H}_{\boldsymbol{AB}}^2 exp\left\{-\frac{(\Delta G^\circ + \lambda)^2}{4\lambda RT}\right\}, \qquad (1)$$

The electron coupling, $\mathbf{H_{AB}}$, was unraveled from the off-diagonal terms of the Hamiltonian corresponding to the donor D and the acceptor A of the ET reaction and treated through the Green's function ($H_{D,A}\mathbf{g}H_{A,D}$) under perturbation theory principles.[4] The driving force ($\mathbf{\Delta G^o}$) and the reorganization energy ($\boldsymbol{\lambda}$) were also computed. Since the models are treated in the gas phase, $\boldsymbol{\lambda}$ was estimated to be the internal nuclear rearrangement and calculated as half contribution from donor rearrangement and half from the acceptor.[5]

Such understanding would drive the design of novel punctual mutations for bR to produce potentially more efficient bR–variants/TiO_2 hybrid models with enhanced ET properties.

References:

[1] C. Espinoza-Araya, R. Starbird, E. Senthil Prasad, V. Renugopalakrishnan, B. D. Bruce, C. C. VillarrealBiochim. Biophys. Acta, 2023, 1864(4), 148985.
[2] K. E. Johnson, S. Gakhar, S. H. Risbud, M. L. Longo, Langmuir, 2018, 34, 7488.
[3] M. Avelar, C. Coppola, A. d'Ettorre, A. Ienco, M. L. Parisi, R. Basosi, A. Santucci, M. Olivucci, A. Sinicropi, 2024, to be submitted.
[4] C. Roldán-Piñero, C. Romero-Muñiz, I. Díez-Pérez, G. J. Vilhena, R. Pérez, J. C. Cuevas, L. A. Zotti, J. Phys. Chem. Lett., 2023, 14(49), 11242.
[5] C. Lee, B. Mertz, J. Chem. Theory Comput., 2016, 12(4), 1639.

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PharmaCore: automatic 3D structure-based pharmacophores development and its applications in drug discovery and repositioning

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In the last few years, the development and application of 3D structure-based pharmacophores in routine virtual screening procedures led to an improvement in the quality of the results, creating a robust selective method.[1-3] However, the development of the procedure is highly time-consuming, and the time/benefit ratio was still very unfavourable. Prompted by these findings, we generated PharmaCore[4]: a completely automated workflow that can create 3D structure-based pharmacophores for any protein that meets specific requirements. In brief, this method is based on available experimental protein-ligand complexes, guaranteeing that the pharmacophoric hypotheses are developed, considering each molecule's binding orientation. The reliability of this method was recently extensively tested by us on well-known systems returning predictions that are in line with the biological data. Here we show the development of pharmacophore hypotheses for all the bromodomain for which more than 4 protein-ligand complexes with biological data were available (477 structures for 16 bromodomains) and for tankyrase 2 (60 structures). A retrospective study was also carried out using know inhibitors (AM879 for bromodomains and Pur1-3 for tankyrase) and the results were in line with what reported, with interesting new targets discovered for AM879. Moreover, considered the importance of the target, the same evaluation was performed considering the pharmacophores developed for SARS-CoV-2 M^{Pro} (1084 structures). PharmaCore, therefore, provides highly reliable pharmacophores that can be used for drug discovery or target identification. A web application and further details are available at www.computorgchemunisa.org/pharmacore.

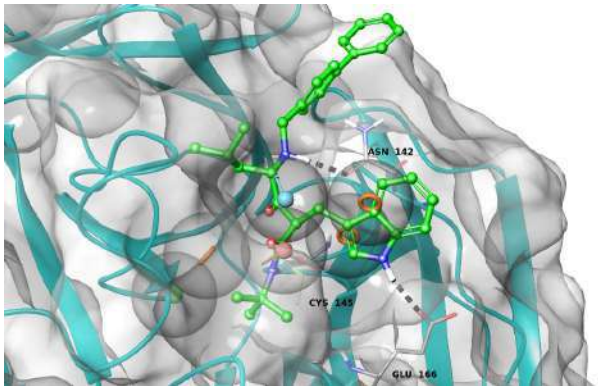

Figure 1. Example of virtual screening using a 3D structure-based pharmacophore.

References:

[1] M.Pierri, E. Gazzillo, M. G. Chini, M. G. Ferraro, M. Piccolo, F. Maione, C. Irace, G. Bifulco, I. Bruno, S. Terracciano, G. Lauro, Bioorg. Chem. 2022, 118, 105480.

[2] E. Gazzillo, M. Pierri, E. Colarusso, M. G. Chini, M. G. Ferraro, M. Piccolo, C. Irace, I. Bruno, G. Bifulco, S. Terracciano, G. Lauro, Bioorg. Chem. 2023, 139, 106677.

[3] E. Gazzillo, S. Terracciano, D. Ruggiero, M. Potenza, M. G. Chini, G. Lauro, K. Fischer, R. K. Hofstetter, A. Giordano, O. Werz, I. Bruno, G. Bifulco, Molecules 2022, 27, 3866.

[4] S. De Vita; E. Colarusso; M.G. Chini; G. Bifulco; G. Lauro, J. Chem. Inf. Model. 2024 (submitted).

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ORG-PO-054

Innovative molecular platforms for G-quadruplex stabilization

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G-quadruplexes (G4s) have received considerable attention in recent years, due to evidence of their occurrence in living cells. [1]Formed by stacks of guanine quartets, G4s belong to the wide class of non-canonical nucleic acid structures. Putative G4 forming sequences are distributed in genomic regions relevant for a number of pathologies, spanning from cancer to viral infections, where they can act as regulators of genetic information transfer.[2] In this context, G4-targeting is regarded as a novel potential therapeutic approach for the treatment of associated diseases.[3] Taking inspiration from the recent literature on G4 ligands[4] and relying on the scaffold hopping strategy,[5] we selected three different heterocyclic frameworks, potentially able to bind G4s by stacking the external G-tetrads. We functionalized these scaffolds with proper polar or positively charged flexible groups for binding to G4 loops/grooves, and/or with alkylating warheads for more selective covalent targeting. To investigate the G4 binding properties of the new molecules, *in vitro* biophysical studies were performed employing both telomeric and oncogene promoter G4-forming sequences. Interestingly, the investigated compounds showed potent G4-stabilizing properties and a certain preference for G4 over duplex DNA. Under preliminary *in vitro* studies, some ligands proved to inhibit cancer cells proliferation, not affecting healthy cells used as control.

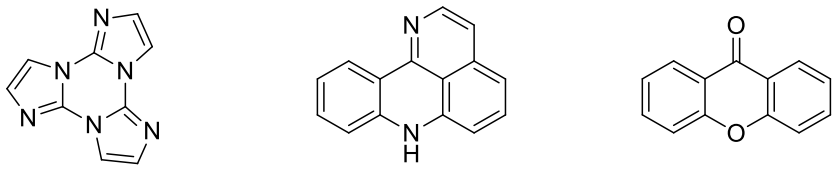

Figure 1: Heterocyclic scaffolds.

References:

[1] S. Burge, G. N. Parkinson, P. Hazel, A. K. Todd, S. Neidle, *Nucleic Acids Res.* **2006**, 34, 5402–5415.
[2] R. Hänsel-Hertsch, M. Di Antonio, S. Balasubramanian, *Nat. Rev. Mol. Cell Biol.* **2017**, 18, 279–284.
[3] A. R. Duarte, E. Cadoni, A.S. Ressurreição, R. Moreira, A. Paulo *ChemMedChem*, **2018**, 13, 869-893.
[4] M. P. O'Hagan, J. C. Morales, M. C. Galan, *Eur. J. Org. Chem.* **2019**, 4995–5017.
[5] H. Sun,1, G. Tawa, A. Wallqvist *Drug Discov Today*. **2012** 17(7-8), 310–324.

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Minisci Chemistry Applied on First Total Synthesis of Caerulomycin K

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Caerulomycins, natural pyridine-based alkaloids, have been previously synthesized starting with highly pre-functionalized starting materials or requiring many functional group interconverions.[1–3] In this work,[4] we exploit recent C-H activation methodologies of N-heterocycles for the first total synthesis of Caerulomycin K, a diversely tri-functionalized pyridine readily assembled in three steps. Starting from mono-functionalized pyridines, the first strategy looked at a double C-H activation by means of phosphonium chemistry.[5] However, this strategy revealed unsuccessful. A better alternative was represented by a radical approach, achieved *via* Minisci chemistry. Firstly, an ortho-arylation on 4-chloro pyridine occurred, followed by an ortho-alkylation using trioxane.[6] In conclusion, a one pot S_NAr, trioxane deprotection and oxime formation occurred to obtain the desired final product. Compared to already reported Caerulomycin syntheses, this novel approach requires only three step and a mono-functionalized starting material.

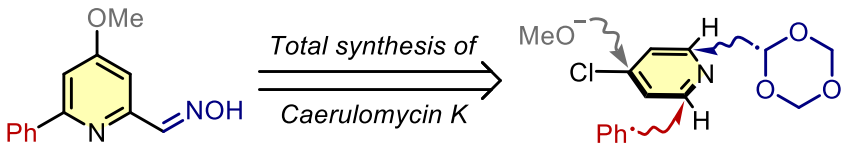

Figure 1: The first total synthesis of Caerulomycin K has been reported exploiting Minisci-type chemistry. Compared to previously reported Caerulomycin syntheses, this novel approach does not require highly pre-functionalized starting materials

References:

[1] F. Mongin, F. Trécourt, B. Gervais, O. Mongin, O.; G. Quéguiner, J. Org. Chem. 2002, 67, 3272–3276.
[2] F. Trécourt, B. Gervais, O. Mongin,C. Le Gal, F. Mongin, G. Quéguiner, J. Org. Chem. 1998, 63, 2892–2897.
[3] T. Sammakia, E.L. Stangeland, M.C. Whitcomb, Org. Lett. 2002, 4, 2385–2388.
[4] A. Dimasi, M. Failla, A. Montoli, A. Citarella, P. Ronchi, D. Passarella, V. Fasano, RSC Adv. 2024, 14, 5542-5546.
[5] M.C. Hilton, R.D. Dolewski, A. McNally, J. Am. Chem. Soc. 2016, 138, 13806–13809.
[6] R.S.J Proctor, R.J. Phipps, Angew. Chem. Int. Ed. 2019, 58, 13666–13699.

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Synthesis and test of a bipyridine-derived bifunctional photocatalyst to carry out Ni-mediated C-O cross couplings

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Base metal-mediated cross couplings represent one of the fields in which photocatalysis can unfold its potential. In this area, for example, it has been shown that it is possible to carry out Ni-catalytic C-O and C-N cross couplings with Ni under irradiation with visible light in the presence of several types of photocatalysts.[1] In these reactions it would be highly desirable to lower the loading of Ni, considering in particular its toxicity. As a possible strategy to achieve this goal, our group envisaged the use of bifunctional photocatalysts featuring a covalent linkage between the photoactive moiety and the nickel complex. Although in visible light photocatalysis the bifunctional approach has been exploited much less than in other subareas of catalysis,[2] there are some examples in which this approach has been used to increase the catalytic performance in terms of stereoselectivity[3] and activity.[4]

Our research group synthesized and tested a bifunctional ligand for C-O cross coupling reactions between aryl bromides and aliphatic alcohols, created by linking a bipyridine moiety to a donor-acceptor cyanoarene dye similar to **4CzIPN** (**1**). By comparison of the bifunctional photocatalyst with a reference dual catalytic system involving **2** as dye, it is possible to observe the beneficial effect given from the proximity of the Ni metal centre to the light absorbing moiety.

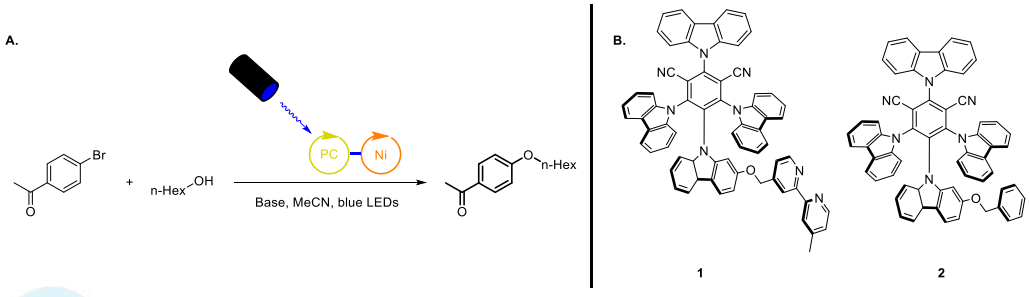

Figure 1: A. C-O coupling model reaction; B. Photocatalysts tested in this work.

References:

[1] D. MacMillan *et al.*, Nature 2015, 524, 330-334; L. Dolcini, L. Pignataro *et al.*, ChemCatChem 2022, 14, e202200990.
[2] Y. Wei *et al.*, Chem. Eur. J. 2023, 29, e202301157.
[3] T. Bach *et al.*, Angew. Chem. Int. Ed. 2021, 60, 2684-2688.
[4] J. Aléman *et al.*, ACS Catal. 2018, 8, 5928-5940; P. G. Cozzi *et al.*, Dalton Trans. 2020, 49, 14497-14505.

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ORG-PO-057

Synthesis of natural and nature-inspired ferulic acid derivatives as antimicrobial agents

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Plant secondary metabolites play a pivotal role in defense mechanisms both as antimicrobial compounds and as substrates for cell wall reinforcement. Their accumulation is often observed after pathogen infections and wounding. Cinnamoylamides are phytoalexins containing a cinnamic acid unit coupled with biogenic amines[1] and are involved in dimerization reactions under biotic or abiotic stress conditions triggered by oxygen radical species. Dimers are often endowed with higher antimicrobial activity, as reported for the ferulic acid dimer poacic acid and for hordatines[2]. To deepen the investigation of their biological activity, high amounts of the compounds are needed, but their recovery from the natural matrices is often laborious and low yielding. The development of efficient synthetic strategies could overcome this limitation, finally opening the possibility to enrich this collection of compounds with new analogues.

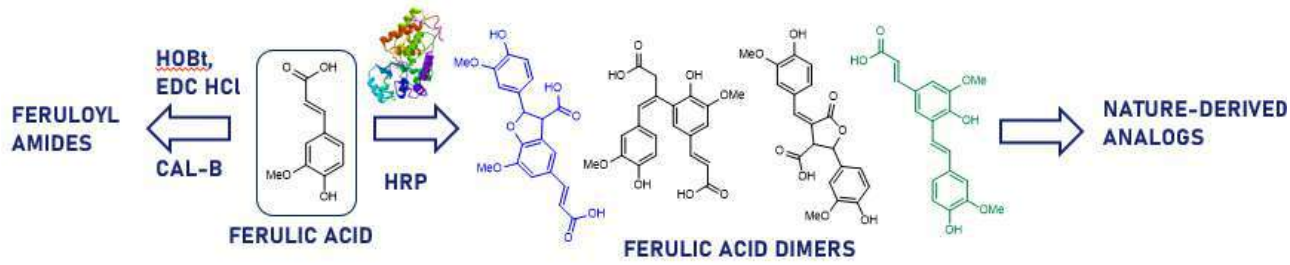

Figure 1: Ferulic acid derivatization pathway. In blue the hordatine precursor, in green poacic acid

A small library of feruloyl-amides was obtained by chemical condensations and enzymatic amidations using the lipase B from *Candida antartica* (CaL-B) in the green solvent *tert*-amyl alcohol. In parallel, to obtain ferulic acid dimers, radical reactions were performed employing the horse radish peroxidase (HRP) in presence of H_2O_2. Starting from the carboxylic intermediates shown in Figure 1, a series of natural and nature-derived analogues was synthesized. Preliminary results about their antibacterial and antifungal activities suggest the possible application of new synthetized natural compounds for a wide range of different sectors.

References:

[1] N. Morimoto, et al., Bioscience, Biotechnology and Biochemistry, 2018, 82, 407 – 416.
[2] J. S. Piotrowski, et al., PNAS, 2015, E1490 – E1497.

This investigation is partially supported by National Recovery and Resilience Plan (NRRP), Mission4 Component 2 Investment 1.3 -Call for tender No. 341 of 15/03/2022 of Italian Ministry of University and Research funded by the European Union–NextGenerationEU, in the frame of the project: Research and innovation network on food and nutrition Sustainability, Safety and Security (ONFOODS).

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ORG-PO-058

Novel organic molecule designed to optimize next-generation photovoltaic components

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Recently, energy generation has become a crucial scientific and technological issue. Given the increased global demand for energy, there is an urgent need to find new strategies to get energy from renewable sources.[1] In this field, among the new generation of photovoltaic systems, dye-sensitized solar cells (DSSCs) are devices that stand out for their simplicity of fabrication and peculiarities of functioning. For these reasons, those devices have recently received considerable attention with the focus on optimizing their components to improve efficiency.[2]

The same aim can be found in this work in which we present a novel organic photosensitizer (DYAD) designed to improve light-harvesting efficiency (LHE) containing an antenna moiety to enable the well-known Förster Resonance Energy Transfer (FRET) effect, often used to increase the LHE.[3] The novelty of the compound lies in its structure containing a dye with the classical D-π-A sequence used in DSSCs and a covalently bonded antenna (donor). To achieve this purpose, two compounds were designed in order to have complementary spectroscopy properties and they were prepared to be joined together by a "click" reaction as a late-stage connection. Moreover, a model dye was synthetized to verify the increased properties and the FRET effect.

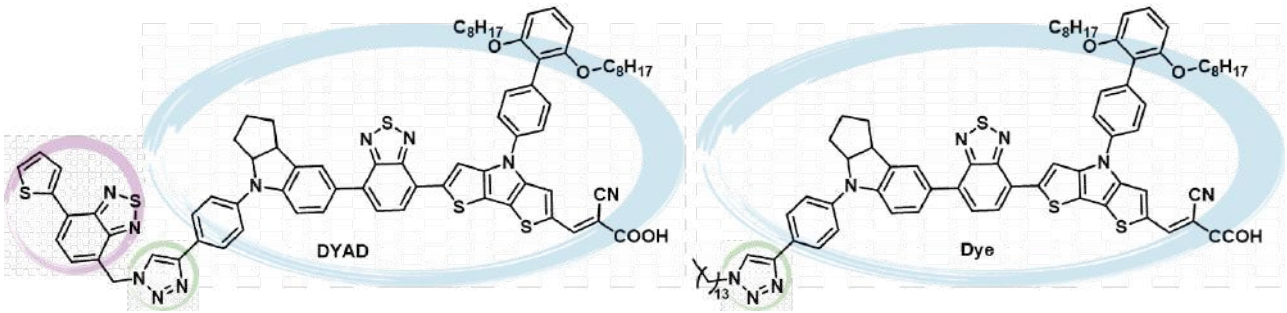

Figure1: structure of the new DYAD and the model dye

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References:

[1] D. Gayen, R. Chatterjee, S. Roy, *Int. J. Environ. Sci. Technol*., **2024**, *21*, 5285–5310.
[2] M. Kokkonen *et al. J. Mater. Chem. A*, **2021**, *9*, 10527-10545. S. Rahman, A. Haleem, M. Siddiq, M. K. Hussain, S. Qamar, S. Hameedd, M. Waris, *RSC Adv*., **2023**, *13*, 19508-19529.
[3] M.T. Efa, J.-C. Huang, T. Imae, *Nanomaterials* **2022**, *12*, 4085.

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Proximity Effects on the Reactivity of Nonheme Fe(IV)=O complex in C-H Oxidation

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Precise control of substrate positioning and orientation (its proximity to the reactive unit) is often invoked to rationalize the superior enzymatic reaction rates and selectivities when compared to synthetic models. Artificial nonheme Fe(IV)=O complexes react with C(sp^3)-H bonds via a biomimetic Hydrogen Atom Transfer/Hydroxyl Rebound mechanism,[1] but rates, site-selectivity and even hydroxyl rebound efficiency (ligand rebound versus substrate radical diffusion) are smaller than in oxygenases.[2,3] Herein, we quantitatively analyze how substrate binding modulates nonheme Fe(IV)=O reactivity by comparing rates and outcomes of C-H oxidation by a pair of Fe(IV)=O complexes that share the same first coordination sphere but only one contains a crown ether receptor that recognizes the substrate (Figure 1). Substrate binding makes the reaction intramolecular, exhibiting Michaelis-Menten kinetics and increased reaction rates. In addition, C-H oxidation occurs with high site selectivity for remote sites. Analysis of Effective Molarity reveals that the system operates at its maximal theoretical capability for the oxidation of these remote sites. Remarkably, substrate positioning also affects Hydroxyl Rebound, whose efficiency increases only on the sites placed in proximity by recognition. Overall, these observations provide evidence that control of substrate positioning via weak interactions is an effective tool to modulate the reactivity of oxygenases and its models.

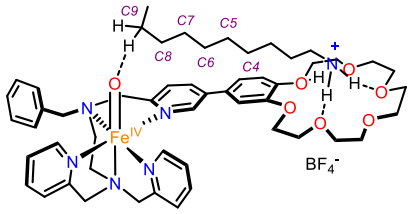

Figure 1: representation of a supramolecularly guided C-H oxidation by a Fe(IV)=O complex. Crown ether receptor interact with primary ammonium function of oxidable substrate.

References:

[1] A. J. Jasniewski, L. J. Que, *Chem. Rev.* **2018**, *118*, 2554–2592.

[2] S. D. Wong, M. Srnec, M. L. Matthews, L. V. Liu, Y. Kwak, K. Park, C. B. Bell, E. E. Alp, J. Zhao, Y. Yoda, et al., *Nature* **2013**, *499*, 320–323.

[3] K. Bin Cho, H. Hirao, S. Shaik, W. Nam, *Chem. Soc. Rev.* **2016**, *45*, 1197–1210.

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First Total Synthesis of Caerulomycin K: From Phosphonium Chemistry to Multiple Minisci C-H Functionalizations

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Caerulomycins, natural alkaloids with antineoplastic and antibiotic properties, have been previously synthesized starting with highly pre-functionalized building blocks or requiring many functional group manipulations.[1–3] In this work,[4] we report the first total synthesis of caerulomycin K, a diversely tri-functionalized pyridine readily assembled in three steps exploiting the recent advancements in the C-H activation of N-heterocycles. Starting from mono-functionalized pyridines, we attempted as first strategy a double C-H activation by means of phosphonium chemistry.[5] We succeeded in the mono-functionalization of *para*-position, whereas a poor conversion of the second *ortho*-C-P bond formation prompted the search for a better approach. This was achieved by sequential Minisci *ortho*-arylation and *ortho*-alkylation,[6] with the latter converted in one pot into the desired oxime. Compared to previously reported caerulomycin syntheses, this innovative strategy involves shorter synthetic route and does not demand highly pre-functionalized starting materials.

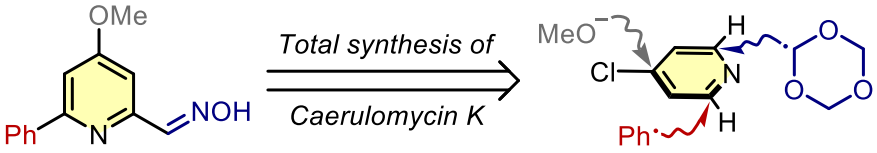

Figure 1: first total synthesis of caerulomycin K *via* Minisci-type chemistry.

References:
[1] F. Mongin, F. Trécourt, B. Gervais, O. Mongin, O.; G. Quéguiner, *J. Org. Chem.* **2002**, *67*, 3272–3276.
[2] F. Trécourt, B. Gervais, O. Mongin,C. Le Gal, F. Mongin, G. Quéguiner, *J. Org. Chem.* **1998**, *63*, 2892–2897.
[3] T. Sammakia, E.L. Stangeland, M.C. Whitcomb, *Org. Lett.* **2002**, *4*, 2385–2388.
[4] A. Dimasi, M. Failla, A. Montoli, A. Citarella, P. Ronchi, D. Passarella, V. Fasano, *RSC Adv.* **2024**, *14*, 5542-5546.
[5] M.C. Hilton, R.D. Dolewski, A. McNally, *J. Am. Chem. Soc.* **2016**, *138*, 13806–13809.
[6] R.S.J Proctor, R.J. Phipps, *Angew. Chem. Int. Ed.* **2019**, *58*, 13666–13699.

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ORG-PO-061

Investigation analysis of the phytochemical composition of *Laurus nobilis* L. leaves essential oil: a study of the antioxidant and anti-inflammatory properties using a combination of *in vitro* and *in silico* methods.

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This study centres on the field of natural product chemistry, specifically aiming to analyse and describe the structure of secondary metabolites obtained from plants. These secondary metabolites have been evaluated as potential "new drugs" because of their fascinating pharmacological effects shown in both laboratory and animal experiments[1]. The features of this substance encompass anti-inflammatory, antioxidant, anticancer, antiviral, and antibacterial actions.

The perennial Mediterranean shrub *Laurus nobilis* L., also referred to as bay laurel, has an extensive historical background of customary utilisation in culinary practices and traditional medicine owing to its beneficial effects on health. These features are currently being scientifically clarified through a range of biological activities.

Specimens of *L. nobilis* were gathered from three distinct areas in central-southern Italy. The leaves underwent hydro-distillation, and essential oils (EOs) were examined using gas chromatography (GC/FID) to quantification volatile chemicals and gas chromatography/mass spectroscopy (GC/MS) to identify them. The multivariate analysis of the principal components examines the relationships between various chemical substances and their respective antioxidant and anti-inflammatory effects.

The antioxidant activity was assessed using various methods (DPPH, ABTS, FRAP assay) *in vitro*. Additionally, the ability to reduce inflammation was evaluated by measuring its inhibition of specific enzymes involved in the production of eicosanoids through three metabolic pathways: cyclooxygenase (COX), 5-lipoxygenase (5-LO), and cytochrome P450 (CYP450)[2].

In more detail here, the simultaneous targeting of several enzymes, specifically COXs and Soluble Epoxide Hydrolase (sEH) of the EOs, in a more detailed manner. Moreover, the *in silico* investigations were used to explain the biological activities in inflammatory events that were observed for the primary secondary metabolites of the various types of *L. nobilis* essential oils at the molecular level.

References:

[1] D.J. Newman, G.M. Cragg, J. Nat. Prod. 2020, 83, 3, 770–803.
[2] C. Sun, X. Zhang, C. Morisseau, S.H. Hwang, , Z. Zhang, , B.D. Hammock, J. Med. Chem. 2021, 64, 1, 184–215.

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Light-induced *N*-Lactam radicals generation under continuous flow conditions

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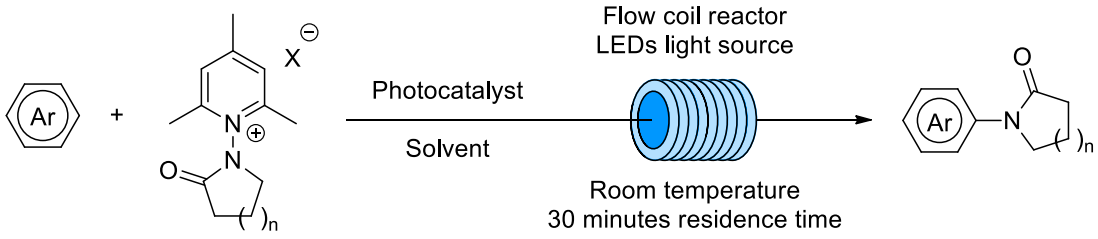
Nitrogen-containing structures are widespread in both natural and synthetic organic compounds, including pharmaceutical products. Finding novel synthetic approaches for forming C-N bonds in a mild, sustainable, and potentially stereoselective way is a subject that captivates synthetic organic chemists.
Over the past twenty years, photoredox catalysis[1] and flow chemistry[2] emerged as powerful methods for generating radical species in such conditions. The possibility to use light as traceless reagent plays a pivotal role in the development of green synthetic strategies, and flow setups can further enhance the performances of light-induced reactions. Additionally, the characteristics of flow reactors offers advantages in terms of both process scalability and safety, making flow chemistry an indispensable tool for organic chemists.

Among the various nitrogen radical species, amidyl radicals[3] have interesting properties for synthetic purposes. The light-induced generation of *N*-lactam radicals, which are not know in literature, and their reactivity with aromatic substrates under flow conditions are the focus of this work (scheme 1).



Scheme 1: General reaction scheme for the reaction under study.

The *N*-radical precursor was synthesized by taking inspiration from the literature.[4] Different indole derivatives were successfully tested. The reaction proceeds in mild conditions, and the use of an organic photocatalyst makes this approach interesting since the use of expensive and polluting metal-based catalysts is avoided. The development of a flow setup permitted to achieve better results compared to a conventional batch reactor, significantly reducing the time required to complete the reaction.

References:

[1] M.H. Shaw, J. Twilton, D.W.C. MacMillan; *J. Org. Chem.* **2016,** *81*, 6898-6926
[2] M.B. Plutschack, B. Pieber, K. Gilmore, P.H. Seeberger; *Chem. Rev.* **2017**, *117*, 11796−11893
[3] J. Davies, S.P. Morcillo, J.J. Douglas, D. Leonori; *Chem. Eur. J.* **2018,** *24*, 12154–12163
[4] WO2021/013712A1; T.W. Greulich, C.G. Daniliuc, A. Studer; *Org. Lett*. **2015**, *17*, 254−257

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Oxazolidinone-Derived *N*-Centered Radicals: Unlocking Bioactive Compounds by Photoredox Catalysis

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The recent advancements in radical chemistry have paved the way for new opportunities in synthesis, solving challenges that more conventional methodologies have historically encountered. Traditional approaches used to build C-N bonds often rely on high temperatures and pre-functionalized coupling partners, such as Cu-catalyzed Ullman type coupling or Pd-catalyzed Buchwald-Hartwig amination.[1] However, in the last few years, some of these issues have been solved by the use of *N*-centered radicals generated by photoredox catalysis. These radicals have proven effective for building C-N bonds under mild reaction conditions. The use of *N*-centered radicals, when combined with flow chemistry, have proven to be effective also for large-scale productions, overcoming issues related to limited light penetration associated to batch processes.[2]

In this context, we focused our attention on the development of novel synthetic methodologies for the synthesis of products of pharmaceutical interest such as Linezolid and Eperezolid[3] (**Figure 1a**), involving the use of *N*-oxazolidinone radicals generated by photocatalytic approach. An easy protocol for the generation of *N*-oxazolidinone radicals have been developed (**Figure 1b**), which were successfully employed in amidation reactions of various aromatic substrates performed under traditional batch and continuous flow conditions. These initial investigations mark a significant step toward devising efficient and sustainable methods for the synthesis of APIs.

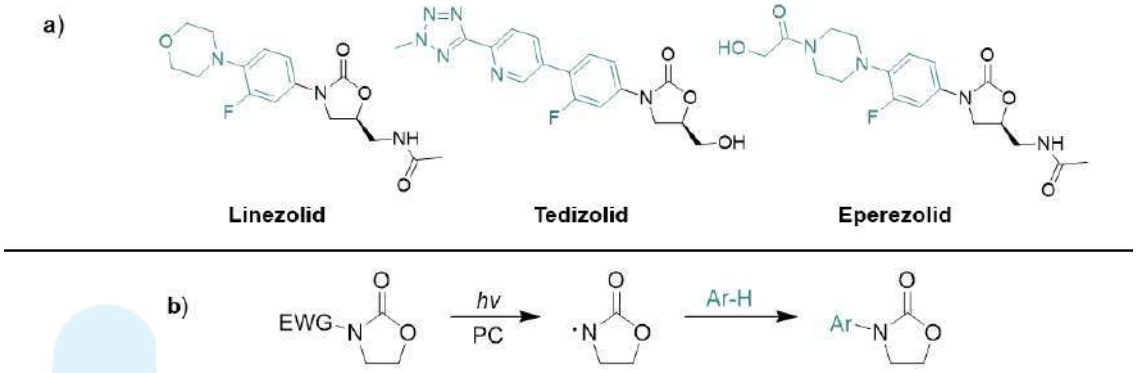

Figure 1: **a)** Exemplary chemical structures of the APIs and **b)** Synthetic approach

References:

[1] C. Pratley, S. Fenner, J. A. Murphy, *Chem. Rev.* **2022**, *122*, 8181 – 8260.
[2] J. D. Williams, C. O. Kappe, *Curr Opin Green Sustain Chem* **2020**, *25*, Article 100351.
[3] M. F. Chellat, L. Raguž, R. Riedl, *Angew. Chem. Int. Ed.* **2016**, *55*, 6600-6626.

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ORG-PO-064

Thermodynamic studies on Pb(II) complexes with polydentate linear and macrocyclic ligands

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Although Pb is known to be a highly toxic element at concentrations above 0.1 ppm, the existence of Pb radioisotopes makes it of great interest for biomedical applications. ^{212}Pb decay chain includes ^{212}Bi, which decays mainly through the emission of β^--particles and secondarily by emitting α-particles. In order to exploit the properties of the ^{212}Pb/^{212}Bi pair in therapy, it is necessary to identify polydentate ligands that form with both the radioactive cations complexes with high thermodynamic stability and kinetic inertness. Unfortunately, the literature often focuses exclusively on the stability properties of the complexes formed with the parent radiometal (^{212}Pb), as in case of $[Pb(DOTAm)]^{2+}$ (DOTAm = DOTA tetraamide, Figure 1) which presents several problems such as instability in basic environment and the tendency of primary amides to hydrolysis. In addition, the $[Bi(DOTAm)]^{3+}$ complex is not stable enough to prevent dissociation of the complex once ^{212}Pb has decayed to ^{212}Bi.[1] This work aims to evaluate the stability constants and the kinetic inertness of the Pb(II) complexes of a series of macrocyclic and linear polydentate chelators such as DOTA, DOTAm, DOTP and DTPA (Figure 1 and Table 1). Among them neither the macrocyclic DOTA, DOTAm and DOTP nor the linear DTPA are able to form stable and inert complexes with Bi^{3+}/Pb^{2+} pair.

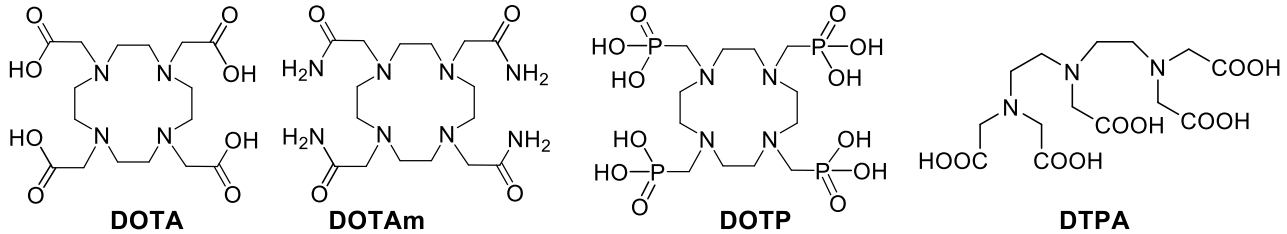

Figure 1. Chemical structures of the ligands used in this study

Table 1. Conditional stability, selectivity, dissociation half-life of Pb(II)-complexes with ligands shown above

	Conditional Stability at pH=7.4 ($\log K_{PbL}^{Cond}$)	Selectivity of the ligand for Pb^{2+} over Ca^{2+}, Zn^{2+} and Cu^{2+} ($\log K_{Pb}^{sel}$)	Diss. half-life at pH=7.4 and 25°C, $\log t_{1/2}$ (h)
DOTA	18.50	6.35	6.16
DOTAM	15.25	5.21	–
DOTP	12.41	0.10	2.21
DTPA	15.18	0.21	–

References:
[1] K. V. Kokov et al. *Pharmaceutics* 2022, 14, 189

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Synthesis, biological evaluation and metabolic profile of BAR502/fibrate conjugates

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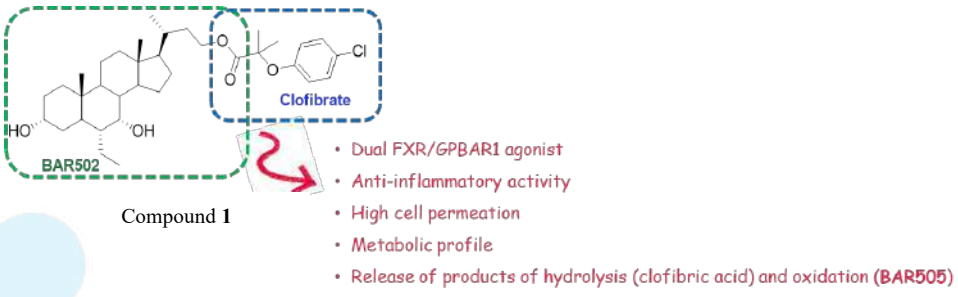
NASH is a hepatic manifestation of metabolic syndrome characterized by accumulation of fat, inflammation, and fibrosis in the liver. If untreated, it could irreversibly progress to liver cancer or liver cirrhosis.[1] New potential therapeutic agents were developed and introduced in the market but at present, there are no approved drugs and satisfying pharmacological treatment. Therefore, there is an urgent need to discover new biological active lead structures useful for the pharmacological treatment of this disease. One of the best approaches in the fight against NASH remains the combination of different agents, that target multiple pathways involved in this pathology.[2]

In this poster, we propose the development of hybrid compounds, obtained by conjugation, through high-yield condensation reaction, of **BAR502**[3,4] with three different fibrates.[4] The aim was to evaluate the ability of these hybrid derivatives to be hydrolyzed in physiologic fluids releasing two active chemical entities, with synergistic action in treating NASH. Within the library of hybrids, compound **1**, obtained by conjugation of **BAR502** with clofibric acid, showed an interesting activity, maintaining a similar **BAR502** dual behaviour towards FXR and GPBAR1 receptors. Compound **1** showed also anti-inflammatory activity, reducing the expression of IL-1β, IL-6 and CXCL2, and was able to reduce the expression of all markers of adipocyte differentiation in 3T3.L1 cells. Furthermore, we have proved by LC-MS analysis that compound **1** is hydrolyzed in mice releasing clofibric acid and **BAR505**, the oxidized metabolite of **BAR502**, endowed with retained dual FXR/GPBAR1 activity. In addition, compound **1** showed a high cell permeability in HepG2 cells and a better ability to release clofibric acid compared to clofibrate. These data suggested that compound **1** could be considered a promising pro-drug, achieving higher plasmatic concentrations of clofibric acid and **BAR505**.



Compound **1**

References:

[1] R. J. Wong, et *al*. *Gastroenterology* **2015**, 148, 547−555.
[2] F. A. Romero, et *al J. Med. Chem.* **2020**, 63, 10, 5031–5073.
[3] A. Carino, et *al*. *Nutrients* **2019**, 11, 1132.
[4] A. Carino, et *al Sci. Rep.* **2017**, 16, 42801.
[5] J. Laurin, *Hepatology* **1996**, *23*, 1464–1467.

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ORG-PO-066

Hydrophilic emissive NDIs and DNA: a tale of love and hate

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Naphthalenediimides (NDIs) are versatile fluorophores developed throughout the last century.[1] The first synthetic report on substituted NDIs dates to 1937 and useful synthetic strategies to modify the chemical structure and photophysical properties have been published in the early 2000s. [2,3] NDIs have been investigated for several applications spanning from supramolecular chemistry, catalysis through anion−π interactions, organic electronics and chemical biology. [1] NDIs in biological chemistry have been mainly used for targeting biomolecules as well as for cell imaging. [4,5] NDIs have been proposed as DNA intercalators: their small size and flat morphology allow the allocation between base pairs in DNA duplexes (Figure 1).[4]

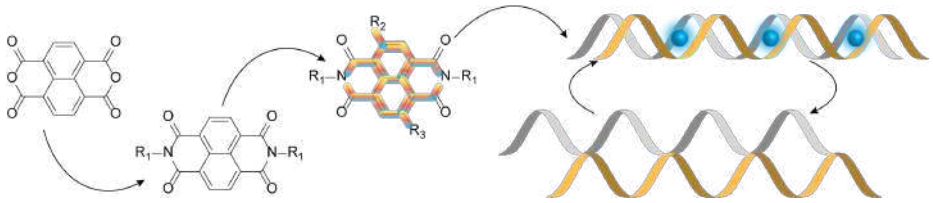

Figure 1: NDI interactions with DNA.

Here, we present the synthesis of a small library of substituted NDIs and preliminary evaluations as emissive probes for nucleic acids visualization. NDI's ability to intercalate in different DNA duplexes was monitored by fluorescence and related to their molecular variations on the core, as well as, on the imide edges to point out the best candidate for the visualization of nucleic acids.

References:

[1] S.V. Bhosale, M. Al Kobaisi, R.W. Jadhav, P.P. Morajkar, Chem. Soc. Rev. 2021, 50, 9845–9998.
[2] H. Vollmann, H. Becker, M. Corell, H.N. Streeck, H. Liebigs, Ann. Chem. 1937, 531, 1–159.
[3] A. Fin, I. Petkova, D.A. Doval, N Sakai, E. Vauthey, S. Matile, Org. Biomol. Chem. 2011, 9, 8246–8252.
[4] E.J. Gabbay, R. DeStefano, C.S. Baxter, Biochem. Biophys. Res. Commun. 1973, 51, 1083–1089.
[5] D.A. Doval, A. Fin, M. Takahashi-Umebayashi, H. Riezman, A. Roux, N Sakai, S. Matile, Org. Biomol. Chem. 2012, 10, 6087–6093.

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Effect of dopants on Spiro-OMeTAD in perovskite solar cells: device preparation, characterization and sustainability aspects

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The deployment of renewable energy sources is a critical strategic lever for decarbonizing the energy sector and mitigating the effects of climate change[1]. Solar PV and wind power are the main tools for reducing emissions from the electricity sector, and the IEA predicts that the growing competitiveness of solar PV could lead its installed capacity to surpass that of wind power before 2025 and coal before 2040[2].

Perovskite solar cells are emerging as a promising photovoltaic technology due to their outstanding power conversion efficiency (PCE) and low material costs. Since the first report of a solid-state solar cell with a PCE of 9.7% in 2012, progress has led to a certified PCE (NREL) of 26.1%. A prevalent material for the hole transport layer (HTM) is Spiro-OMeTAD, often doped with metal salts of bis(trifluoromethyl-sulfonyl)imide ($M(TFSI)_n$). These dopants play a crucial role in generating radically active cationic species within the HTM[3].

In the first part of the work, carried out at Uppsala University in Professor Gerrit Boschloo's research group, perovskite solar cells were prepared and the effect of metal cations (M= Li, Zn, Mg, Cu) on the doping of Spiro-OMeTAD was analyzed by a combination of techniques, including Electron Paramagnetic Resonance (EPR), UV-Visible and photoluminescence, complemented by analysis of fabricated photovoltaic devices.

In the second part, carried out in the R²ES research group of the University of Siena, DFT (Density Functional Theory) calculations were performed on the Spiro-OMeTAD radical cation in different environments, which confirmed the good hole-transport capacity of the above-mentioned material due to the broad delocalization of the spin density over the entire molecule in all cases considered. Moreover, calculations of $(Spiro\text{-}OMeTAD)^{\bullet+}$ on $CH_3NH_3PbI_3$ surface's paramagnetic properties are ongoing.

The study also delved into the criticality of raw materials and hazardous chemicals for the advancement of renewable and sustainable technologies, focusing particularly on perovskite solar cells. Several raw materials used in these cells were evaluated for their criticality and potential risks, considering their roles as electrode materials, components of electron-carrying layers, photoactive materials, and p-dopants. Some of these materials, such as indium, magnesium, and lithium, were identified as critical due to factors such as availability, import/export dynamics, price, widespread industrial use, and recycling challenges. However, it was noted that alternatives to these materials are readily available. In future research, the use of alternative materials that don't pose human health risks or supply chain issues will be explored.

References:

[1] Sinsel, S. R.; Riemke, R. L.; Hoffmann, V. H. *Renew. Energy* **2020**, *145*, 2271–2285.
[2] Quandt, A.; Mokgosi, I.; Warmbier, R. Elsevier Ltd, **2019**, 249-276.
[3] Seo, J. Y.; Akin, S.; Zalibera, M.; Preciado, M. A. R.; Kim, H. S.; Zakeeruddin, S. M.; Milić, J. V.; Grätzel, M.. *Adv. Funct. Mater.* **2021**, *31* (45).

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Sustainable cross-coupling protocol: Miyaura borylation and one-pot Suzuki-Miyaura reaction in Deep Eutectic Solvents (DES)

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Deep Eutectic Solvents (DESs) represent a sustainable alternative to common organic solvents complying with green chemistry requirements.[1] In this work, DESs have been employed for the first time for a Miyaura borylation and Suzuki-Miyaura cross-coupling one-pot protocol.[2]

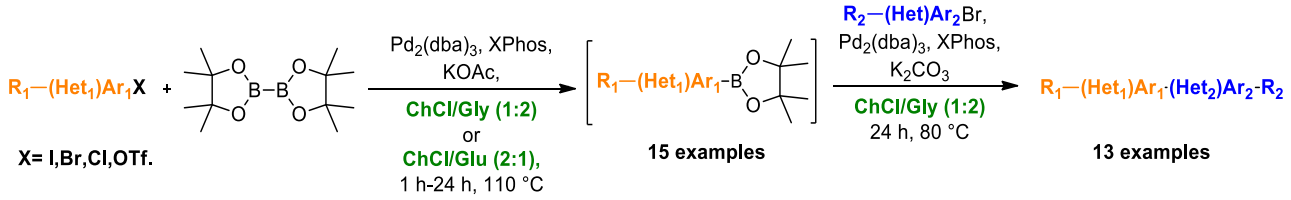

Figure 1: Generic scheme of Miyaura borylation and one-pot Suzuki-Miyaura cross-coupling in DES.

Starting from a precedent work on direct arylations in DES,[3] the protocol was optimized for borylation and coupling of (hetero)aromatic iodides, bromides, chlorides, and triflates in choline chloride/glycerol (1:2) and choline chloride/glucose (2:1) DESs. Robust and efficient conditions were found for electron-poor and electron-rich (hetero)aryl substrates. The boronic esters were isolated and characterized or directly exploited for cross-coupling in a one-pot fashion. The optimized protocol was successfully applied for preparing conjugated organic compounds with potential application in optoelectronics. The protocol sustainability was assessed through green metrics and compared with the literature when possible.

References:

[1] A.P. Abbott, G. Capper, D.L. Davies, R.K. Rashed, V. Tambyrajah, Chem. Commun. 2003, 70-71.
[2] V. Pelliccioli, G. Dilauro, S. Grecchi, S. Arnaboldi, C. Graiff, F.M. Perna, P. Vitale, E. Licandro, A. Aliprandi, S. Cauteruccio, V. Capriati, European J. Org. Chem. 2020, 45, 6981–6988.
[3] F. D'Amico, C. Papucci, D.Franchi, G. Reginato, M. Calamante, L. Zani, A. Dessì, A. Mordini ACS Sustainable Chem. Eng. 2022, 10, 9, 3037-3047.

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ORG-PO-069

Synthesis and characterization of Palladium containing polymeric colloidal nanoparticles for heterogenized catalysis

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Sustainability is an important concern for the development of new organic materials. Synthetic procedures should become simpler, more efficient and less resource-intensive. Furthermore, waste must be avoided as much as possible. Hence, the combination of heterogeneous catalysis and micellar approaches can have a major impact on this field. Micellar catalysis helps in getting rid of organic solvents replacing them with water and in creating nanometric environments having enhanced reagent local concentrations to assure higher reaction rate and selectivity[1]. Easy recovery, reuse, and lack of toxic ligands make heterogeneous catalysts preferable with respect to homogeneous ones, although several challenges have yet to be faced: heterogeneous catalysts have lower activity, selectivity, and stability with respect to homogeneous ones, beside suffering from metal leaching phenomena. Undoubtedly the need for high surface area, reactant compatibility and homogeneous active sites distribution are the starting point for further studies[2]. Having all these challenges in mind, we developed a new heterogenized catalyst having π-conjugated organic colloidal nanostructures obtained through micellar polymerization as active sites support. They are designed to be intrinsically stable, water-dispersible and to embed the Pd catalyst involved into their own synthesis so that they could be directly reused as heterogenized catalyst in further micellar cross-coupling reactions. As a proof of concept, we synthetised a first-generation heterogeneous catalyst through deposition of Pd metal nanoparticles (Pd-NPs) on reprecipitated Poly(9,9-dioctyl)fluorene (PFO) nanospheres, then we tested its catalytic activity in in-water micellar Suzuki-Miyaura reactions. The efficiency of such catalyst was compared to that of the benchmark heterogeneous palladium catalyst Pd/C (Evonik hydrogenation catalyst). The initial findings show higher conversion associated to the use of the polymer-supported Pd catalyst. Furthermore, recycling of the catalyst is also possible thanks to the development of a straightforward workup procedure. The second-generation heterogenized catalyst requires the synthesis of conjugated polymer nanoparticles (CPNPs) by direct miniemulsion Suzuki polymerization. Literature examples of CPNPs synthesis always contemplate a purification step, to get rid of surfactants[3]. However, in this case, their entanglement within the colloidal structure is a crucial advantage: they constitute a template in which the polymeric nano-object can grow having a controlled morphology, and they make it suitable for its final application as catalyst. The synthesis produces dispersed spherical Pd-embedding polymer-surfactant semi-interpenetrated networks (sIPN). Such dispersion was then used as heterogenized catalyst showing the highest conversion rate. Encouraged by preliminary results both catalyst generalities are currently under investigation as well as the fine tuning of the structure of the polymeric support. The final big picture foresees the study and understanding of how the presence of

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Towards the total synthesis of gnetin c

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Dihydrobenzofurans and 2,3-dihydrobenzofurans are known for their important biological properties like anticancer, anti-inflammatory and antioxidant [1]. Many of them are naturally produced by the dimerization of polyphenols as resveratrol, one of the most important stilbenes. Among them, gnetin C (figure 1) is particularly interesting as it is currently in III phase of clinical studies of prostate antitumor compound [2]. Up to now no synthesis of gnetin C has been performed.

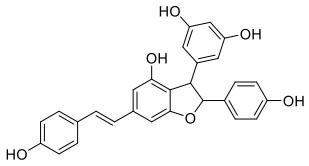
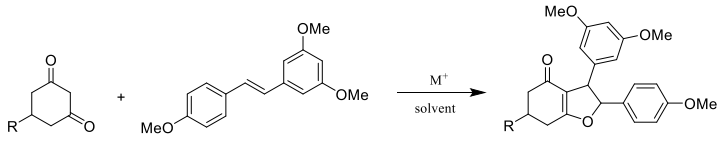


Figure 1. Structure of gnetin C

To this challenging end we are investigating a strategy to synthesize it. A preliminary attempt has been conducted using a 1,3-dicarbonyl compound and an internal olefin in a [3+2] addition promoted by an oxidating agent (scheme 1), in order to obtain the dihydrofuran [3], which has been aromatized to the corresponding dihydrobenzofuran.[4,5]. A regioisomeric mixture has been obtained deriving from different reactivity of the two possible sites of attack to the olefin (Scheme 1).



1. R = Me;
2. R = (p-OMe-Ph)$CHCH_2$

Scheme 1. 1,3-dicarbonyl addition to a protected resveratrol

References:

[1] S. Moussouni et al. Tetrahedron Letters, 2011, 52, 1165 – 1168.

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Electrochemical di-oxygenation of quinolines

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Electrochemical methods for the synthesis and transformation of organic compounds have recently received increased interest by both academic and industrial research[1]. Electrochemistry represents a mild and green way to obtain useful molecules, avoiding the stoichiometric use of harsh and often hazardous or waste-generating oxidating and reducing agents, that can limit large-scale applications. Moreover, the highly selective nature of this method allows to avoid the sometimes tedious protection/deprotection steps. The renaissance of organic electrochemistry has been accompanied by an increased attention to flow electrochemistry, that, thanks to the small interelectrode gap, reduces the resistance and improves the mass transport of the substrates from the bulk to the electrode surface, with the advantage of reducing the reaction time[2].

Di-oxygenation of olefins is generally achieved with several methods including the use of transition metals, for example Sharpless reaction[3]. In very recent years, electrochemical approach has emerged as an alternative method to perform di-oxygenation not only of olefins, but also of heterocycles, like indoles and thiophenes[4].

In this context, we envisioned the possibility to perform the di-oxygenation of activated quinolines. Dihydroquinolines, that can be pre-formed by classic chemical activation, are subjected to electrochemical transformation, opening new frontiers in the synthesis of highly functionalized tetrahydroquinolines. Alternatively, the one-pot procedure will be attempted.

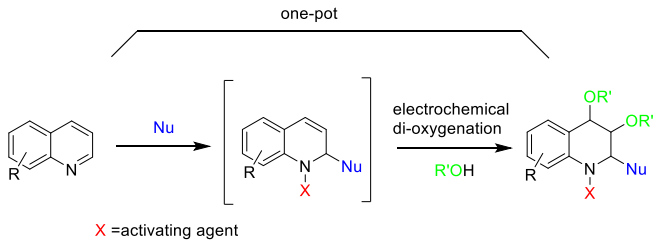

Figure 1: One-pot or two-step electrochemical di-oxygenation of quinolines

References:

[1] C. Schotten, T. P. Nicholls, R. A. Bourne, N. Kapur, B. N. Nguyen, C. E. Willans, Green Chem. 2020, 22, 3358–3375
[2] T. Noel, Y. Cao, G. Laudadio, *Acc. Chem. Res.* 2019, 52, 10, 2858–2869
[3] S. G. Hentges, K. B. Sharpless, J. Am. Chem. Soc. 1980, 102, 4263- 4265.
[4] a) S. Zhang, L. Li, P. Wu, P. Gong, R. Liu, K. Xu, Adv. Synth. Catal. 2019, 361, 485–489. b) C. Y. Cai, H. C. Xu, Nat Commun 2018, 9. c) J. Wu, Y. Dou, R. Guillot, C. Kouklovsky, G. Vincent, J. Am. Chem. Soc. 2019, 141, 2832−2837.

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Synthesis of trifluoroborates derivates for the preparation of theranostics in Boron Neutron Capture Therapy

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Boron Neutron Capture Therapy (BNCT) is a binary therapeutic treatment based on the nuclear fission reaction of ^{10}B. When irradiated with neutrons, ^{10}B produces the isotope ^{11}B in an excited state, which spontaneously decays generating a high-energy α particles and recoiling a ^{7}Li ion. [1] The required neutron beam is nowadays generated by proton accelerators containing a lithium or beryllium target and a beam shaper to produce epithermal neutrons. [2] These neutrons have enough penetrating power to reach cancer tissues where they become thermalized reaching the right energy for the capture by ^{10}B nuclei. [3]

In perspective, this therapy will be used in addition to conventional cancer treatments such as radiotherapy or surgery and is mainly focused to treat tumours that are resistant to other types of therapy, such as glioblastoma multiforme (GBM), but also metastatic melanoma, head and neck tumours and malignant mesothelioma.[4]

Agents containing boron atoms, such as carboranes (clusters of ten boron atoms and two carbon atoms), boronic acids or trifluoroborate groups, are under investigation in order to deliver enough boron atoms to tumour cells. It was decided to synthesise compounds containing either a carborane or a trifluoroborate group because the last one has a dual function: it allows boron to be delivered to cancer cells and the replacement one of the fluorine atoms of the trifluoroborate group with the ^{18}F isotope, allows its detection by PET, so generating a potential theranostic compound. Finally, it was planned to conjugate the boron-containing agent to structures that would further enhance its concentration in cancer cells exploiting known features of these cells such as overexpression of specific transporters. The strategy followed for the conjugation of the boron containing moiety and the tumour recognizing structures exploits the copper-catalysed Huisgen reaction.

References:

[1] S. Wang, Z. Zhang, L. Miao and Y. Li, *Front Oncol*, 2022, 12.

[2] H. Kumada, T. Sakae and H. Sakurai, *EPJ Techniques and Instrumentation* 2023, 10, 1–15.

[3] N. Hu, M. Suzuki, S. Masunaga, G. Kashino, Y. Kinashi, Y.-W. Chen, Y. Liu, K. Uehara, T. Mitsumoto, H. Tanaka and K. Ono, *J Radiat Res*, DOI:10.1093/jrr/rrad056.

[4] A. Monti Hughes and N. Hu, *Cancers (Basel)*, 2023, 15.

ORG-PO-073

Innovative macrocyclic friction reducer additives for lubricant oils

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Friction is the force that hinders the movement between sliding or rolling surfaces, and it is caused mainly by microscopic contact points between mechanical parts, that can cause adhesion and deformation. About 25% of the energy provided by an engine is lost due to friction; therefore, lubricants are crucial to reduce the energy waste and to ensure the optimal functioning of the machine.

To maximize the lubricating properties of an oil, friction reducing additives are needed. The typical structure of a friction reducer (FR) consists of a polar head, that allows the additive adsorption on metal surfaces in the engine, and long alkyl chains to ensure the solubility in oil and the formation of a protective multilayer matrix. The most common functional groups that can be found in friction reducers are carboxylic acids, amides, imides, amines, and phosphoric or phosphonic acid derivatives. These functionalities lead to the formation of absorbed layers anchoring the additive to the metal surface, while the hydrocarbon tails align to each other and favour the layers formation thanks to van der Waals forces.[1]

Macrocycles can be suitable candidates for the synthesis of FRs, thanks to their synthetic versatility and stability. Moreover, their scaffold can provide preorganization of the matrix layers, facilitating the film formation. To investigate and exploit these properties, we synthesized various resorcinarene- and calixarene-based additives with different polar functionalities.[2] The products that showed the best solubility and stability in oil formulations were tested to evaluate their tribological properties.

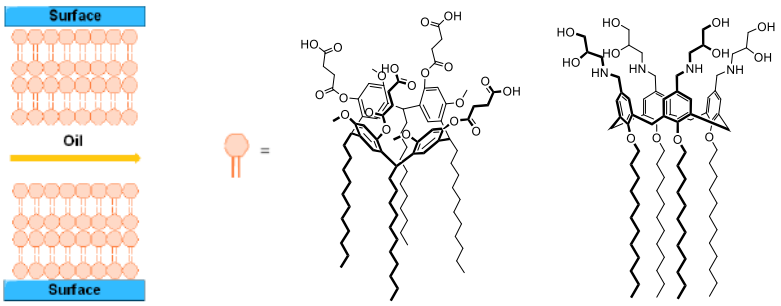

Figure 1: left: multilayer matrix structure; right: examples of macrocyclic FRs.

References:

[1] S. Basu, Friction modifiers, Springer: Berlin, Heidelberg, 2014.
[2] F. Cyriac, X.Y. Tee, S.K. Poornachary et al., Friction, 2021, 9, 380 – 400.

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ORG-PO-074

Development of new sterically hindered chiral phosphoric acids: synthesis and catalytic applications

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In the broad field of stereoselective synthesis, Chiral Phosphoric Acids (CPAs) have recently found widespread application in several and crucial chemical transformations, considered powerful tools for the synthesis of pharmaceuticals and natural products. Due to the important applications of chiral phosphoric acids in organic synthesis, in the last few years the design and the synthesis of new chiral phosphoric acids have attracted much attention.[1] A new class of chiral phosphoric acids, with a two-carbon-atom-spacer between the aromatic rings bearing the acidic functional group and a decahydroquinoxaline scaffold derived from the *trans*-1,2-diaminocyclohexane through a diastereoselective pinacol-type coupling reaction, has been developed. Decahydroquinoxaline-based chiral phosphoric acids have been successfully applied in the model stereoselective Friedel-Crafts addition of indoles to *N*-tosylimines with good to excellent yields and enantioselectivities (**Figure 1**).[2]

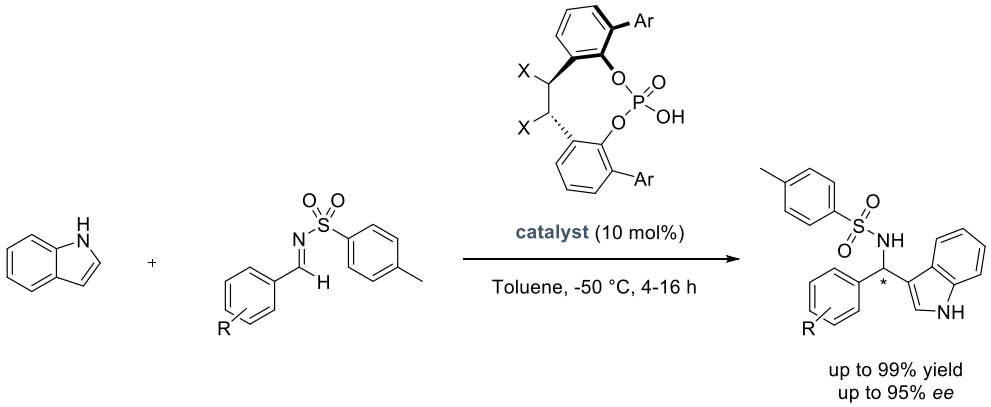

Figure 1: Stereoselective Friedel-Crafts addition of indoles to *N*-tosylimines catalyzed by decahydroquinoxaline-based CPAs

[1] D. Parmar, E. Sugiono, S. Raja, M. Rueping, *Chem. Rev.*, **2014**, *114*, 9047−9153
[2] Q. Kang, Z. A. Zhao, S. L. You, *J. Am. Chem. Soc.*, **2007**, *129*, 1484–1485

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ORG-PO-075

Hydroxyapatite: an inexpensive and sustainable carrier for enzyme immobilization

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High efficiency and selectivity, mild operational conditions and low toxicity are some of the main features that make enzymes efficient catalysts and important tools in making chemical processes greener[1]. However, to render the process economically viable, enzymes should be recovered and reused and sometimes their operational stability should be improved[2]. A common strategy to tackle these problems is the immobilization of the enzyme on a solid support[3]. Hydroxyapatite (HAP) is a biocompatible inorganic material which is suitable for this task thanks to its structural stability, non-toxicity, large surface area and ease of surface modification. Moreover, it can be obtained from waste such as ashes from waste-to-energy plants, the fish supply chain, the avian supply chain, etc., in agreement with circular economy principles.

γ-Glutamyl transferases from both *Bacillus subtilis* (BsGGT) and *Escherichia coli* (EcGGT) were chosen as model enzymes to study the immobilization process on HAP. HAP was synthesised according to a literature-reported wet procedure of coprecipitation of calcium nitrate and ammonium phosphate under basic conditions. Enzyme immobilization was carried out through adsorption, simply by mixing an enzyme solution and a hydroxyapatite suspension under controlled conditions (pH, temperature). Different particle sizes and experimental set-up were investigated and, after assessing that the enzyme did not desorb under reaction conditions, the supported GGTs were tested as biocatalysts in the γ-glutamylation of L-methionine. Moreover, the enzyme reusability was tested in five consecutive reaction cycles and its storage stability was verified.

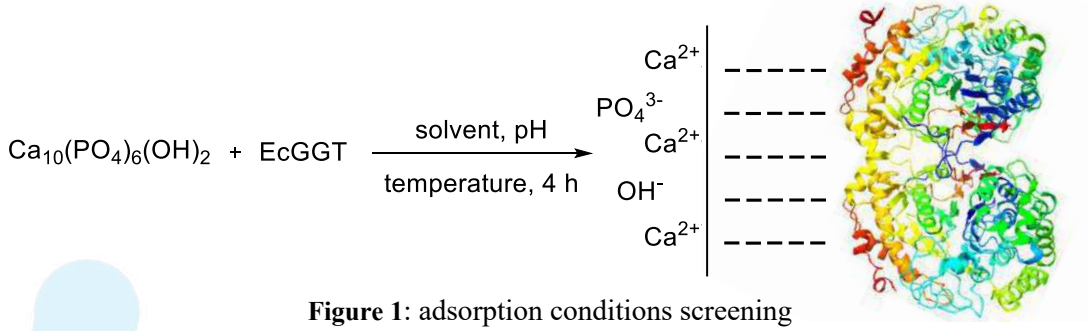

Figure 1: adsorption conditions screening

References:
[1] Y. Q. Almulaiky, N. M. Khalil, R. M. El-Shishtawy, T. Altalhi, Y. Algamal, M. Aldhahri, S. A. Al-Harbi, E. S. Allehyani, M. Bilal, M. M. Mohammed, *Int. J. Biol. Macromol.* **2021**, *167*, 299 – 308.
[2] Y. Ueda, M. Sakaguchi, K. Hirayama, R. Miyajima, A. Kimizuka, *Agric. Biol. Chem.* **1990**, *54*, 163 – 169.
[3] W. Xie, X. Zhang, *Food Chem.* **2017**, *227*, 397 – 403.

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C1 to Cn Hydroxyalkylation enabled by Photoredox Catalysis

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The introduction of a single hydroxyl group can dramatically influence the drug−receptor binding affinity through the formation of an extensive hydrogen bond network.[1] Moreover, the -OH group can serve as a handle for further derivatizations. In the polar domain, hydroxyalkylations can be accomplished via different reaction pathways. However, retrosynthetically, the possibility to obtain γ-hydroxy substituted derivatives is precluded from polar mechanisms due to a polarity mismatch. α-hydroxyalkyl radicals have emerged as suitable intermediates to promote radical hydroxyalkylations.[2] Despite extensive research into the chemistry of ketyl radicals, we hypothesised that a more direct approach to access these intermediates was feasible using readily available feedstocks. Naturally occurring and readily available α-hydroxy carboxylic acids (AHAs) can be utilized as a platform for visible light-mediated oxidative CO_2-extrusion furnishing α-hydroxy radicals which proved to be versatile C1 to Cn hydroxyalkylating agents. In particular, we developed a photoredox-based γ-hydroxyalkylation via the coupling of α-hydroxy radicals with various SOMOphiles. Furthermore, flow technology facilitates the scaling of this photochemical methodology.[3,4]

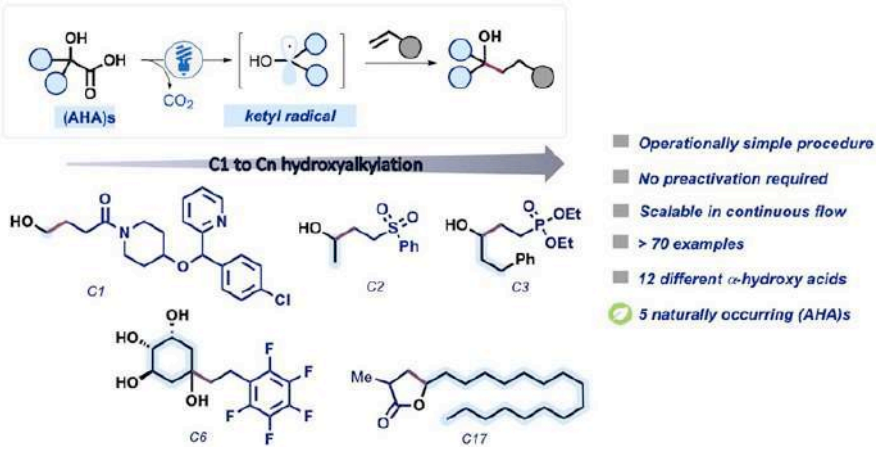

Figure 1: Photoredox hydroxyalkylation leveraging ketyl radicals generated from AHAs.

References:

[1] J. Cramer, C. P. Sager, B. Ernst, J. Med. Chem., 2019, 62, 8915-8930.
[2] Á. Péter, S. Agasti, O. Knowles, E. Pye, D. J. Procter, Chem. Soc. Rev. 2021, 50, 5349-5365.
[3] S. D. A. Zondag, D. Mazzarella, T. Noël, Annu. Rev. Chem. Biomol. Eng., 2023, 14, 283-300.
[4] M. Colella, Y. Gelato, M. Andresini, E. Graziano, G. Vilé, L. Degennaro, R. Luisi. Eur. J. Org. Chem. 2023, 26, e202300413.

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Sustainable approaches for Sonogashira coupling reactions in water and under air atmosphere

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Metal-catalysed cross-coupling reactions hold a pivotal role in organic chemistry, enabling the construction of carbon-carbon bonds. Among them, the Sonogashira coupling stands out as a transformative tool for synthesizing substituted and/or conjugated alkynes. Recently, noteworthy advances have been achieved from the standpoint of health, safety and environmental concerns, leading to the development of Cu-free methodologies. However, some challenges still persist.[1]

Within this context, our project aims to address the worldwide demand for sustainable and straightforward chemical processes, focusing on reducing the catalyst loading and ensuring mild reaction conditions. Experiments are initially conducted via homogeneous catalysis using water in the presence of surfactants to enhance the dispersibility of organic substrates in aqueous environments.[2] Synthetic procedures are easy, mild and reproducible. Additionally, the use of low amounts of commercially available and cost-effective palladium acetate addresses the challenges associated with low metals availabilities and their high costs. Simultaneously, the project explores the assembly of bio-based core-shell nanocapsules loaded with various palladium(II) sources by originally modifying the solvent evaporation encapsulation technology. In an aqueous environment, the bio-polymer selected for the external shell of our capsules, ethylcellulose, reorganizes its chains to orient the hydrophilic components towards the bulk aqueous medium, thereby creating a central hydrophobic cavity where the catalytic species localize.[3] These innovative nanoreactors exhibit remarkable catalytic activity, operating directly in heterogeneous aqueous environments with minimal metal loadings and without additional organic cosolvents. The synergy between surfactants and our synthetic nanocapsules is essential, creating nano-confined spaces which offer enhanced control and increase local reactant concentrations at the interface of EC structures due to the hydrophobic effect.

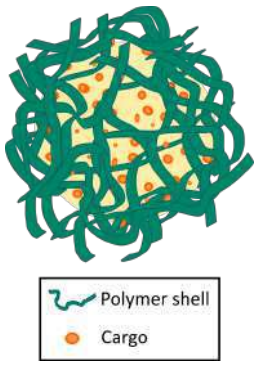

Figure 1: cartoon of EC nanocapsules produced with our methodology.

Overall, the methodologies here presented are completely aligned with the Green Chemistry principles, representing a significant step towards more environmentally-friendly and efficient chemical processes in the field of metal-catalysed cross-coupling reactions.

References:

[1] S. Handa, J. D. Smith, Y. Zhang, B. S. Takale, F. Gallou, B.H. Lipshutz, Org. Lett. 2018, 20 (3), 542-545.
[2] S. Mattiello, M. Rooney, A. Sanzone, P. Brazzo, M. Sassi, L. Beverina, Org. Lett. 2017, 19 (3), 654-657.
[3] P. Ahmadi, A. Jahanban-Esfahlan, A. Ahmadi, M. Tabibiazar, M. Mohammadifar, Food Rev. Int. 2022, 38 (4), 685-732.

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Synthesis of a new family of surfactants based on 2,2'-biindole scaffold and their application in micellar Suzuki-Miyaura reactions

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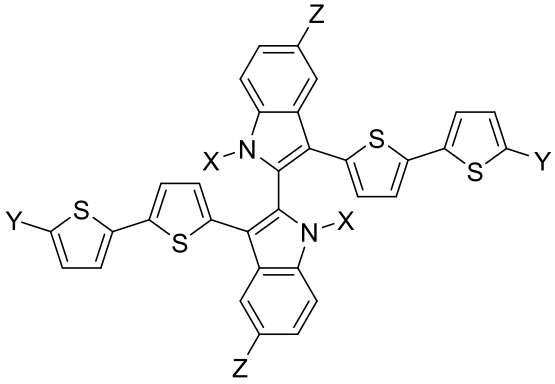
The research for replacing classical organic solvents (which are unhealthy VOCs) with greener media represents an increasingly urgent scientific challenge. Water represents a safe and sustainable alternative, with the obvious problem that lipophilic organic reagents typically do not dissolve in it. Surfactants are amphiphilic molecules characterized by a hydrophilic and hydrophobic domain and give great opportunities to perform reactions in aqueous medium[1] making the process clean, fast and efficient with consequent remarkable overall benefits for sustainability.[2]

A family of conjugated 2,2'-biindole derivatives **1a-c** functionalised in position 3,3' with bithienyl units and bearing hydroxylic groups in different positions of the heteroaromatic scaffold was synthesized as precursors for an innovative class of surfactants.



1a X = CH_2CH_2OH; Y, Z = H
1b X = Pr; Y = H; Z = CH_2OH;
1c X = Pr; Y = CH_2OH; Z = H

Figure 1: The family of the 2,2'-biindole derivatives

The hydroxy groups of compounds **1a-c** were functionalised with PEG derivatives of different length and, taking advantage of the design of the 2,2'-biindole scaffolds, which allows to introduce the hydrophilic chains in different position, a wide series of amphiphilic molecules was prepared. Their aqueous solutions were successfully employed as non-conventional media in Suzuki-Miyaura coupling reactions. The different catalytic performances of the surfactants as a function of their structural features are discussed.

References:

[1] F. Gallou, B.H. Lipshutz, Topics in Organometallic Chemistry, 2019, 65, 199-216.
[2] L. Beverina *et al.* Green Chem., 2019, 21, 4400-4405.

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ORG-PO-079

Regio- and stereoselective arylation of *L*-proline

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The five-membered pyrrolidine ring and its derivatives are heterocyclic scaffolds widely used in medicinal chemistry and drug design.[1] Among this vast class of compounds, *L*-proline is of particular interest, and is often employed for the synthesis and optimization of lead compounds.[2] Among the many derivatizations that can occur to the *L*-proline scaffold, the stereoselective functionalisation of position 5 proves particularly challenging.

We are currently exploring this problem in an effort to obtain novel glycomimetic ligands for the *N*-terminal domain of the bacterial lectin BC2L-C from *Burkholderia cenocepacia*[3]. The desired ligands (general formula **1**) consist of N-fucosyl amides carrying a functionalized proline residue either in the *cis* or *trans* configuration. For the synthesis of compounds with *cis* configuration, we are pursuing classical synthetic pathways for the preparation of *cis*-5-arylproline **2** starting from *L*-pyroglutamic acid **4**.[4] The preparation of *trans* diastereomers is significantly more challenging. For these, we are examining a photoredox-mediated hydrogen atom transfer (HAT) process described by MacMillan *et al* as a single example starting from proline **5**.[5]

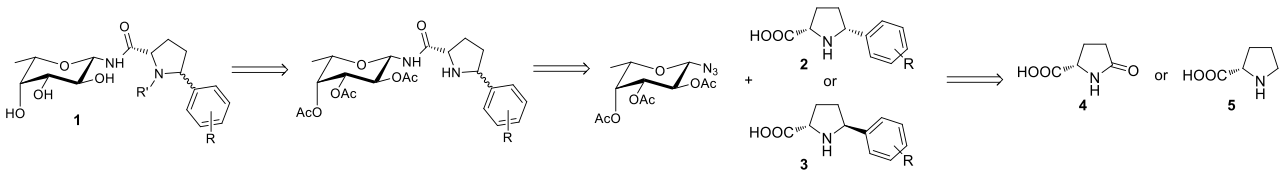

Figure 1: Synthetic strategy for glycomimetic fucosides with arylated *L*-proline

Acknowledgement
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References:
[1] G. Li Petri, M. V. Raimondi, V. Spanò *et al*, Topics in Current Chemistry, 2021, 379, 34
[2] J. Bojarska, M. Remko, M. Breza *et al*, Pharmaceuticals 2020, 13, 338
[3] S. Mazzotta, G. Antonini, F. Vasile *et al*, Molecules 2023, 28, 1494
[4] A. Turočkin, W. Raven, P. Selig, Eur. J. Org. Chem 2017, 296-305
[5] M. H. Shaw, V. W. Shurtleff, J. A. Terrett *et al*, Science 2016, 352, 6291, 1304-1308

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ORG-PO-080

Selenium-containing glycoconjugates as antioxidants

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Selenium (Se) is recognized as a trace element essential for human health; low Se levels are actually associated with several diseases.[1] Many natural occurring Se compounds show redox and biologically capacities, thus stimulating synthesis of new molecules with the aim to spread antioxidant effects in biological systems.[2] Most of these bioactive Se-containing molecules showed a strong therapeutic and biological relevance.[3]

In the framework aimed at discovering new efficacious antioxidants, the synthesis of new seleno-glycoconjugates, consisting of monosaccharaides containing selenium bound to polyphenols, is of our interest with the aim to overcome the poor (poly)phenol bioavailability and to provide a synergistic antioxidant effect at once.

The results herein reported open new and long- term perspectives in the seleno-sugars like antioxidants in biological medium.[4]

References:

[1] C. A. Collins, F. H. Fry, A. L. Holme, A. Yiakouvaki, A. Al-qenaei, C. Jacob, OBC. 2005, 1541–1546.
[2] C.W. Nogueira, J.B.T. Rocha, Arch Toxicol. 2011, 1313-1359.
[3] A. Dominiak, A. Wilkaniec, P. Wroczy|ski, A. Adamczyk, Curr. Neuropharmacol. 2016, 282–299.
[4] L. Serpico, M. De Nisco, F. Cermola, M. Manfra, S. Pedatella, Molecules. 2021, 2541.

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ORG-PO-081

Wittig Reaction in Deep Eutectic Solvents: Expanding the DES Toolbox in Synthesis

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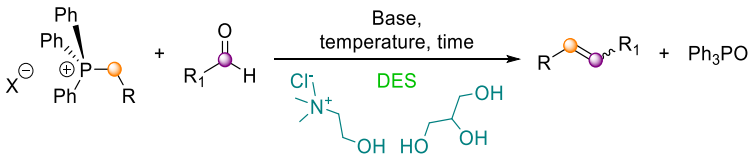
The Wittig reaction[1] is a reliable strategy that allows the chemo-, regio- and stereoselective preparation of alkenes from carbonyls and it is widely used both in academia and on industrial scale.[2] This transformation requires the use of a phosphorus ylide that can react with a carbonylic compound via an oxaphosphetane intermediate. Traditionally the Wittig olefination is carried out in dry and aprotic solvents, under homogeneous conditions, using an organometallic base to generate a phosphonium ylide.[3] In order to improve the sustainability of the reaction, in recent years many variations of the Wittig reaction have been studied, including catalytic versions and processes carried out in an aqueous environment.[4] However, many organic molecules are not soluble in water or may undergo undesired chemical transformations in a protic environment.

In this context, owing to our interest in the development of sustainable synthetic strategies,[5] we decided to investigate Deep Eutectic Solvents (DESs) as green reaction media to promote the Wittig olefination. It emerged that it is possible to carry out Wittig reactions using weak bases, at room temperature and in air. The procedure allowed us to synthesize alkenes with good to quantitative yields, starting from a wide range of non-enolizable aldehydes. In addition, experimental attempts to separate the alkenes from the phosphine oxide byproduct and from the excess of reagents without the use of chromatographic columns will be presented.



Scheme 1: Wittig olefination in Deep Eutectic Solvents.

References:

[1] G. Wittig, G. Geissler, Justus Liebigs Ann. Chem. 1953, 580, 44 – 57.

[2] H. Pommer, Angew. Chem. Int. Ed. Engl. 1977, 16, 423 – 429.

[3] B. E. Maryanoff, A. B. Reitz, Chem. Rev. 1989, 89, 863 – 927.

[4] a) C. J. O'Brien, J. L. Tellez, Z. S. Nixon, L. J. Kang, A. L. Carter, S. R. Kunkel, K. C. Przeworski, G. A. Chass, Angew. Chem. Int. Ed. 2009, 48, 6836 –6839; b) J. McNulty, P. Das, Eur. J. Org. Chem. 2009, 4031–4035.

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ORG-PO-082

Study of the effect of ionic liquid on the aggregation of Nickel-tetra-(4-sulfonatophenyl) porphyrin by Density Functional Theory and UV-Vis absorption for Aqueous Organic Redox flow batteries applications

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Aqueous Organic Redox flow batteries (AORFBs) offer several advantages over other types of batteries in energy storage such as scalability, safety, long cycle life and cost-effectiveness, making them an exciting frontier to explore[1]. For this scope, the family compound of porphyrins was considered thanks to their well-defined redox processes. In fact, porphyrins go through four electron reactions which can be exploited to develop the redox couple. Particularly, as water-soluble electroactive species for AORFB application, the tetra-(4-sulfonatophenyl) porphyrins (H_2TPPS) and nickel-tetra-(4-sulfonatophenyl) porphyrin (Ni-TPPS) were prepared and tested. The disadvantage related to these compounds is their tendency to aggregate, so a preliminary Density Functional Theory (DFT) study on H_2TPPS and NiTPPS was performed. It revealed that the introduction of a metal atom inside the porphyrinic core can twist the molecular skeleton resulting in saddle structure that can reduce the normal tendency of porphyrins to aggregate (Fig.1a). This result was confirmed by a UV absorption study (Fig.1b). Efficient redox reactions within the electrolyte are essential for AORFB performance[1]. Improving the kinetics of charge transfer and minimizing energy losses during cycling are key objectives to enhance the overall system efficiency. One of the challenges related with these concepts concerns that the redox processes of electroactive species must occur within the stability potential window of water[2]. Ionic liquids (ILs) are fascinating compounds that for electrochemical applications, show good ionic conductivity, wide electrochemical potential window and high thermal stability[3]. For these reasons, different ILs were considered to be investigated for use as supporting electrolyte to improve stability and electrochemistry. Among the different ILs electrochemically characterized, 1-butylpyridinium tetrafluoroborate ([$Bupy^+$][BF_4^-]) showed the largest water potential stability (-1.3 an +1.5 V) and was chosen as candidate to test the electroactive species.

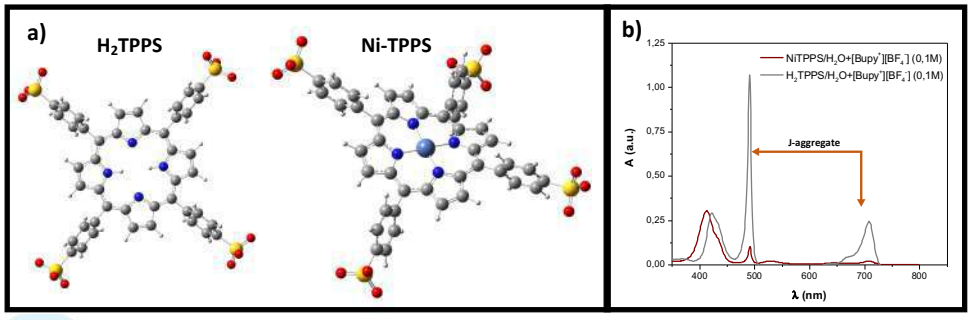

Figure 1 a) DFT calculation of the molecular structure of H_2TPPS (left) and NiTPPS (right); b) UV-Visible aggregation study on H_2TPPS and NiTPPS revealing the highest formation of J-aggregates at 490 and 700 nm for H_2TPPS.

References:

[1] P. Arévalo-Cid, P. Dias, P. Mendes, P. Azevedo, Sustaineable Energy Fuels 2021, 5, 5366–5419.

[2] J. Montero, W. da Silva Freitas, B. Mecheri, M. Forchetta, P. Galloni, S. Licoccia, A. D'Epifanio, ChemElectroChem, 2023, 10.

[3] A. A. J. Torriero, Molecules, 2022, 27, 21, 7428.

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ORG-PO-083

o-Propargylphenols: A Gateway to Divergent Synthesis of 2-Substituted Benzofurans and Chromenes

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Oxygen-containing molecules represent an indispensable class of heterocyclic compounds, due to their physicochemical properties. In particular, two of the most studied scaffolds are benzofurans and chromenes, widely present in natural compounds (flavonoids, alkaloids, etc.) and synthetic drugs (antiarrhythmic, dermatological and anticancer therapy).[1]

Due to their importance, chromene and benzofuran core have gained enormous attention in the development of different synthetic pathways, involving a plethora of methods and types of reactions.[2] In this context, Divergent Synthetic Strategy emerges as a promising tool, in order to obtain a variety of products under different reaction conditions, starting from similar simple and affordable substrates.[3]

Herein, we report our recent results in the development of a divergent regioselective synthesis of benzofuran and 4*H*-chromene nuclei. Specifically, we describe the reactivity of substituted *o*-propargylphenols under two different reaction conditions, both supported by microwave heating: using a catalytic amount of base we were able to selectively obtain substituted benzofuran, while in the presence of a metal catalyst, the reactivity shifted to the formation of chromenes. We also investigated the limitations and the mechanism of our approach.

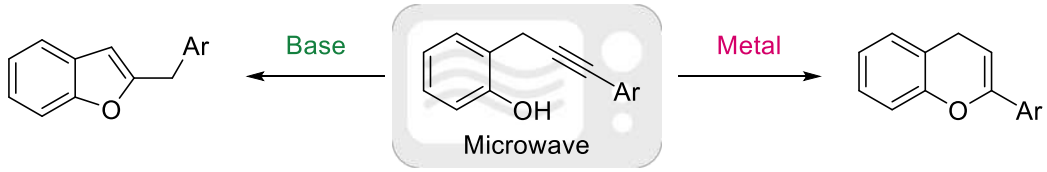

Figure 1: Divergent synthesis of benzofurans and chromenes.

References:
[1] a) R. M. Okasha, F. F. Alblewi, T. H. Afifi, A. Naqvi, A. M. Fouda, A. M. Al Dies, A. M. El-Agrody, Molecules 2017, 22, 479; b) R. J. Nevagi, S. N. Dighe, S. N. Dighe, Eur. J. Med. Chem. 2015, 97, 561-581.
[2] a) L. Chiummiento, R. D'Orsi, M. Funicello, P. Lupattelli, Molecules 2020, 25, 2327; b) Z. Wen, K.-C. Yang, J.-F. Deng, L. Chen, Adv. Synth. Catal. 2023, 365, 1290.
[3] S. H. Hou, F. F. Zhou, Y. H. Sun, Q. Z. Li, Molecules 2023, 28, 6193.

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ORG-PO-084

Synthesis of enantioenriched carbocycle-fused uracils as SARS-Cov-2 RdRp inhibitors

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During a previous work,[1] we developed a new asymmetric methodology to access chiral enantioenriched (5*S*,6*R*)-5-hydroxy-6-nitro-5,6,7,8-tetrahydroquinazoline-2,4(1*H*,3*H*)-diones[2] of type **3** through an organocatalyzed [4+2] cycloaddition between remotely enolizable uracil carbaldehyde **1** and nitroolefins **2** (Figure 1). Using this strategy, a "first generation" set of compounds were synthetised and tested in preliminary *in-vitro* assays assessing a "hit compound",[3] showing a low micromolar activity as inhibitor of SARS-CoV-2 viral protein RNA dependent RNA polymerase (RdRp).

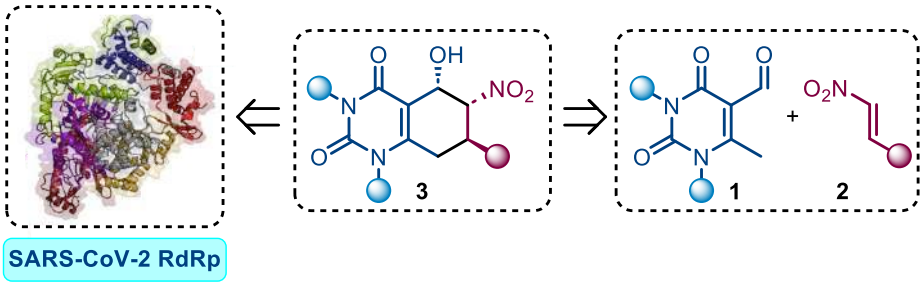

Figure 1

Molecular docking studies were then performed[3] to identify probing interactions between the "hit compound" and the crystal structure of viral RdRp: based on these observations, a "second generation" set of molecules was designed and here presented. Structural modifications involved the nitrogen appendages within pronucleophiles **1** (blue dots in Figure 1) and differently functionalized substituents within dienophiles **2** (purple dots). The design and synthesis of properly functionalized starting materials **1** and **2**, and their use in a series of asymmetric [4+2] cycloaddition reactions will be described, along with the isolated chiral products **3** which were accessed in good yields, complete diastereocontrol and good enantioselectivity.

References:
[1] E. Marcantonio, F. Zanardi, *Adv. Synth. Catal.* **2021**, *363*, 2625–2633.
[2] C. Curti, E. Marcantonio, A. Sartori, L. Battistini, F. Zanardi, *TargetsHeterocycl.Syst.* **2022**, *26*, 509–532.
[3] F. Zanardi, A. Contini, K. Vermeire, *unpublished results*.
[4] S. H. Hillen, *Current Opinion in Virology* **2021**, *48*, 82-90.

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Structure-based design and synthesis of novel HUR inhibitors.

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Human antigen R (HUR) is a master post-transcriptional regulator mainly involved in messenger RNA (mRNA) translation and turnover. HUR over-expression and cytoplasmic accumulation is well correlated to several diseases, including cancer, inflammation, cardiovascular, muscle, kidney, and liver diseases, making HUR an attractive therapeutic target.[1] Reported HUR targeting strategies include the use of small interfering RNAs (siRNAs) and small molecule inhibitors.[2] Regarding the latter, although several compounds have been reported,[2] they still face major issues, such as limited solubility and bioavailability, as well as off-target effects against other RNA-binding proteins (RBPs). Therefore, targeting HUR remains a major challenge in biomedical research.

Based on the screening of a large, small molecule library, a hit compound has been identified as a potential HUR inhibitor with promising biochemical properties. Docking studies performed on this hit showed more insights about its interactions with HUR, giving us more room for SAR elucidation and structural optimization for analogues endowed with better affinity and pharmacokinetic profile.

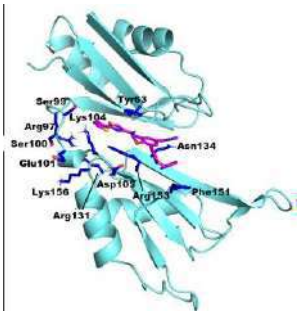

Figure 1: Molecular docking of the Hit compound and HUR

Our attempts towards the rational design and synthesis of novel HUR inhibitors aimed at improving their pharmacokinetic profile will be presented together with their preliminary biochemical evaluation.

References:

[1] Zucal C, D'Agostino V, Loffredo R, et al. *Curr Drug Targets* **2015**, *16*, 499-515.
[2] Assoni G, La Pietra V, Digilio R, et al. *Adv Drug Deliv Rev*. **2022**, *181*, 114088.

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ORG-PO-086

A novel family of photo-sensitizers: Ir-based complexes featuring radical-stabilizing ligands.

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In the last decades, light mediated processes have emerged as a new way to access novel and unparalleled transformations due to the implementation of photocatalyst in light mediated protocols, which allows for functional group tolerance and selectivity.[1] Between all photocatalyst, Iridium organometallic complexes stands out due to their unique photophysical features,[2] allowing challenging transformations and achieving high molecular complexity through streamlined protocols. Recently, our research group reported that the tedious formation of an open-shell intermediate can benefit form the presence of stochiometric amounts of naphthalene thanks to the stabilization of the transient triplet states through radical-π dispersion interactions.[3] Herein we report the first class of iridium-based photocatalysts featuring pendant radical-stabilizing groups aimed to enhance the EnT-based transformations via generation and stabilization of the biradical species trough the pendant naphthyl or binaphthyl moieties.

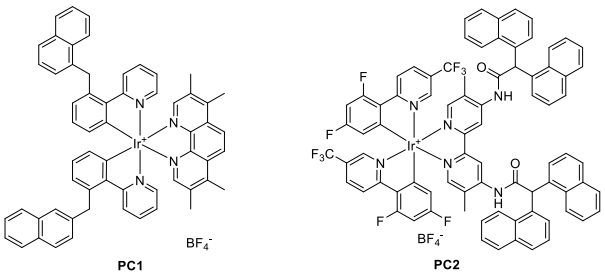

Figure 1: Iridium photosensitizers bearing naphthyl-radical stabilizing moieties.

Different degree of substitution with naphthyl pendants were explored, isolating a family of 8 new photosensitisers. Their catalytic activity was studied in isomerization, cyclization and dearomatization reactions. The results showed diradical stabilization thus achieving high reaction yields, typically only attainable in the presence of stochiometric amounts of naphthalene.

References:

[1] M. Akita, P. Ceroni, R. J. Stephenson, G. Masson, *J. Org. Chem.,* 2023, 88, 6281 – 6283.
[2] R. Bevernaeigie, S. A. M. Wehlin, B. Elias, L. Troian-Gautier *ChemPhotoChem* 2021, 5, 217 – 234.
[3] A. Cerveri, G. Scarica, S. Sparascio, M. Hoch, M. Chiminelli, M. Tegoni, S. Protti, G. Maestri *Chemistry A European J,* 2024, Volume, e202304010.

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ORG-PO-087

Sustainable synthetic methods for decoration of BN modules

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Borazine, a heterocyclic analogue of benzene, is isoelectronic and isostructural with benzene. For this reason, borazine is sometimes referred to as "inorganic benzene". Owing to the substitution of B−N bonds, the electron donation of nitrogen to boron centers contributes to the strong polar character of the B–N bonds, which makes borazine and its derivatives good UV emitters and peculiar reactivities. Based on its properties, borazine and its derivatives have wide applications including, optoelectronic organic materials, self-assembly, H_2 storage, and ceramics since it was reported in 1926.

This work aims to explore more borazine derivatives about the C–H functionalization of borazine and expand the applications of borazine derivatives. In this work, the C–H functionalization of tri-substituted and hexa-substituted borazines between heterocycles and aromatics has been explored, which enables to diversify the variety of borazine derivatives and enlarges the scope of their application.

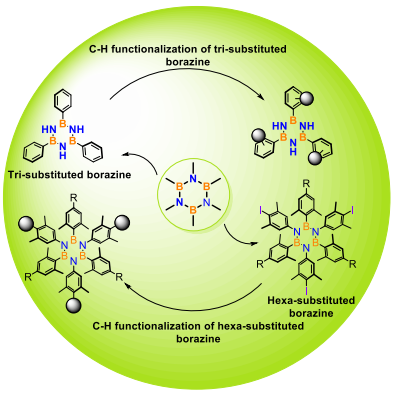

Figure 1: C–H functionalization of tri-substituted and hexa-substituted borazines.

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References:

[1] D. Marchionni, S. Basak, A. N. Khodadadi, A. Marrocchi, L. Vaccaro, Adv. Funct. Mater. 2023, 33, 2303635.
[2] D. Marchionni, A. N. Khodadadi, E. Cela, F. Huang, L. Vaccaro. Adv. Synth. Catal. 2024, 366, 494–501.
[3] D. Bonifazi, F. Fasano, M. M. Lorenzo-Garcia, D. Marinelli, H. Oubaha, J. Tasseroul, Chem. Commun., 2015, 51, 15222–15236.

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Harnessing light energy: photoresponsive surfactants for enhanced micellar catalysis

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In the context of green chemistry, minimizing waste and energy consumption is crucial in chemical processes. Organic solvents, known for their toxicity and hazards, pose a significant waste issue, prompting the search for non-toxic alternatives like water for organic reactions. Despite the hydrophobic nature of many organic compounds in aqueous environments, self-assembling surfactants enable "micellar catalysis", overcoming this challenge by hosting reagents in their lipophilic pockets, offering conditions for high-yield, efficient, and sustainable reactions, if appropriately chosen.[1]

The chemical nature of surfactant-formed interphases significantly influences products distribution in competitive reactions. Within the micelle, an interfacial dipole induces selectivity between the hydrophilic and hydrophobic portions of the surfactant.

Introducing selectivity in surfactant-enhanced reactions requires controlling the non-covalent interaction between surfactant and substrates, considering: 1) regioselectivity in competitive transformations induced by the preferential orientation of reaction intermediates due to interface dipoles at the hydrophilic/lipophilic interphase; 2) product selectivity induced by specific surfactant/substrate interactions; and 3) product selectivity due to compartmentalization effects between the water and oil phases.

To enhance selectivity, we propose a novel surfactant design with a photochromic compound, specifically a spiropyran. The photochromic residue is incorporated at the boundary between the hydrophilic and the lipophilic portion of the amphiphilic molecule, which consists respectively of a PEG moiety and an alkyl chain. Responsive to UV light, it switches between a neutral-low polarity and a zwitterionic-high polarity state. This tuning ability, rooted in the concept of photostatic equilibrium, determines the relative population of open (polar) and closed (nonpolar) forms of the photochromic molecules.[2] Adjusting irradiation conditions in terms of intensity, pulse duration and temperature, tunes the interfacial dipole and the Hydrophilic-Lipophilic Balance (HLB) of the surfactants used. This innovation holds promise for improving reaction selectivity in surfactant-enhanced processes.

References:

[1] B.H. Lipshutz, S. Ghorai, Green Chem 2014, 16, 3660 – 3679.
[2] L. Kortekaas, W.R. Browne, Chem Soc Rev 2019, 48, 3406 – 3424.

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Unveiling the Potential of Indolizines: New Chemotypes able to Modulate the Protein Quality Control System in cancer pathology

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BAG3, or Bcl-2-associated athanogene 3, is a multifunctional protein involved in critical cellular processes such as protein quality control and cell proliferation and survival. As part of the BAG protein family, it interacts with the molecular chaperone Hsp70, working as a co-chaperone to regulate protein folding, functioning, and degradation. BAG3-HSP70 interaction is crucial for maintaining cellular homeostasis under stress conditions like those experienced by malignant cells. Interestingly, both BAG3 and Hsp70 are overexpressed in different types of cancer, where they are connected to tumor progression and resistance to chemotherapy.[1] For this reason, targeting BAG3 and HSP70 represents a promising approach in cancer therapy.

Continuing our research in the field of protein quality control system regulation using small molecules, we decided to investigate the indolizine scaffold as a new promising moiety for the design of new Hsp70-BAG3 modulators, taking advantage of innovative MCRs procedures for the synthesis.

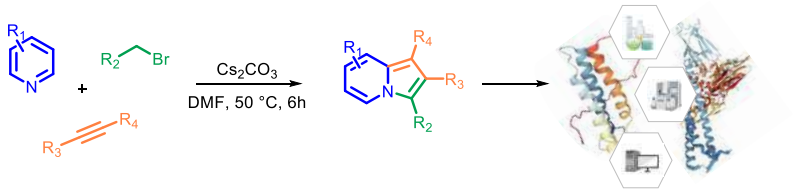

Figure 1: Synthetic approach and application to BAG3-HSP70 modulators identification.

We investigated several experimental conditions for the synthesis of indolizines through the 1,3-dipolar cycloadditions of pyridine, bromide derivatives, and alkynes, and finally, we succeeded in optimizing the procedure using the caesium carbonate as base in DMF as solvent.[2] Hence, we designed and synthesized a first set of compounds that have been tested against the targets of interest using an SPR-based assay. The results obtained allowed us to identify a compound with an interesting binding profile, being able to bind both BAG3 and HSP70 that can be considered as a starting point for further optimization process.

References:

[1] H. Sondermann, C. Scheufler, C. Schneider, J. Höhfeld, *Science* **2001**, *291 (5508),* 1553-1557.
[2] X. Zhang, G. Lu, Z. Xu, C. Cai, *ACS Sustainable Chemistry & Engineering* **2017**, *5 (10),* 9279-9285.

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ORG-PO-090

A Morita-Baylis-Hillman Adduct Derivative as an Electrophilic Agent in the Formation of Unnatural Photoisomerizable RNA Bases

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RNA-based drugs increasingly appear to represent the therapy of the future and the search for methodologies to control gene expression by external stimuli is one of the open challenges in the years to come.[1] Here, we lay the foundations for building photomodulable RNA systems through the use of chromogenic molecules and unnatural nitrogenous bases. An acetylated Morita-Baylis-Hillman adduct[2,3] (compound **1**) was tested in the functionalization reaction of the four RNA bases and two unnatural nitrogenous bases (5-aminomethyl uracil, **5-AMU**, and 5-methylaminomethyl uracil, **5-MAMU**) revealing a high selectivity towards the latter. The obtained conjugation products (compounds **2** and **3**) were investigated from a photophysical and photochemical point of view with experimental and computational methods. The investigation revealed the efficient abitilty of monoadduct **2**, containening only one generated cinnamic structure, to act as light-driven molecular switch, while diadduct **3** under light irradiation lead to photoinduced reactions such as a 2+2 cycloaddition. The results of this study push us to apply this chemical strategy to the creation of photomodulable RNA systems.[4]

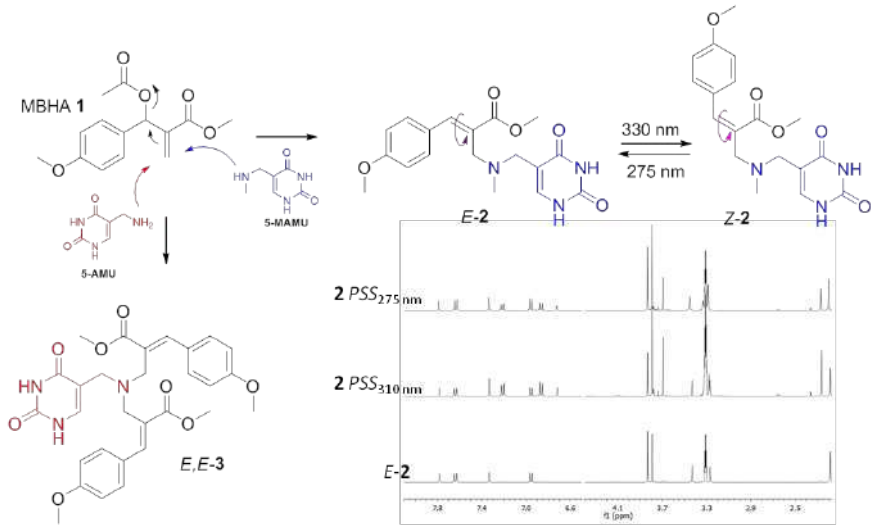

Figure 1: Reaction of MBHA derivative **1** with the unnatural nitrogen bases **5-AMU** and **5-MAMU** and photointerconversion of the monoadduct **2** monitored by ^{1}H NMR.

References:

[1] H. Zhou, D. S. Chen, C. J. Hu, X. Hong, J. Shi, Y. Xiao, Adv. Sci. 2023, 10, 2303597.
[2] C. R. Mateus, W. P. Almeida, F. Coelho, Tetrahedron Lett. 2000, 41, 2533–2536.

ORG-PO-091

MS-based investigation of chickpea seeds grown under different water conditions

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Due to the higher cost of living and climate change, nowadays, legumes represent one of the most important sources of human food after cereals.[1] Particularly, chickpea (*Cicer arietinum L.*) is considered one of the most popular legumes crops worldwide. To date comprehensive studies on agronomic and genetic influences on chickpea protein composition are lacking. This work reports a comparative proteomic analysis via shotgun approach and label-free quantification (LFQ) of two chickpea samples of the Italian genotype Pascià, grown under two different water conditions, namely rain fed and irrigated.[2,3] Proteomic analysis allowed the identification of about 1100 different proteins. Most of them are common to the two samples (about 78%), whereas 9% of the total and 12% appear exclusively revealed in the rain fed and the irrigated sample, respectively. This comparison revealed a similar qualitative distribution of protein composition in both samples, although some differences have been detected. As expected, in both samples the most abundant components belong to the storage protein family (i.e., legumins, vicilins, and albumins), although the rainfed sample globally contains a little higher content of both legumins and vicilins, and also shows a little higher ratio between vicilins and legumin (V/L ratio). Moreover, a label-free quantification (LFQ) analysis allowed the identification of twenty-three differential abundant proteins (DAPs) that resulted significantly more abundant in the rain fed sample. Most of them are storage proteins or components belonging to the family of the late embryogenesis abundant proteins (LEA), a group of proteins that are upregulated during dehydration stress and show a high abundance during the later stages of seed development, giving the seeds the ability to tolerate drought. Taking into account that legumins and vicilins belong to the cupin superfamily, a group of proteins already identified as legumes allergens,[4] these results, although preliminary, suggest that a balanced water regime might promote a reduction in allergenic potential in chickpea. In the future, this investigation will be extended to another chickpea genotype, to study the impact of different water regimes and nitrogen supply on the qualitative and quantitative protein composition.

References:

[1] R. Ghelfi, A. Palmieri, Ital. J. Agron., 2017, 225-232.
[2] Y. Zhang, B.R. Fonslow, B. Shan, M.C. Baek, J.R. Yates 3rd, Chem. Rev. 2013, 2343-2394.
[3] M.A. De Santis, A. Satriani, F. De Santis, Z. Flagella, Agriculture 2022, 2026-2039.
[4] S.Bar-El Dadon, C. Pascual, D. Eshel, P. Teper-Bamnolker, M.D. Paloma Ibáñez, R. Reifen, Food Chem. 2013, 13-18.

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Development of nanomaterials based on halloysite/NDIs derivatives as theranostic agents

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Cancer theranostics represent a valuable tool for successful treatment and ease patient care. To achieve efficient medical care, nanoparticle-based therapeutics are commonly used for different biological purposes. Natural inorganic carriers such as halloysite nanotubes (HNTs) are attracting considerable attentions thanks to their capability to penetrate cellular membranes and localizing itself in the perinuclear region.[1] Recently, the modifications of HNTs with different biological active species allowed to synthetize valuable carrier systems, capable of selective detection of cancer cells.[2] In last years, naphthalene diimides, have emerged as versatile compounds able to span the whole visible spectrum upon simple structural modifications and they can be used for fluorescence tissue imaging. Furthermore, they can generate singlet oxygen acting as photosensitizers for photodynamic therapy.[3] Herein we report synthesis of HNTs modified on the external surface with different NDIs derivative to develop new nanomaterials that can be used as theranostic agents. The obtained nanomaterials were characterized by different physical-chemical techniques, their morphology was examined by TEM and the photophysical properties were investigated both in dispersion and solid state. The generation of singlet oxygen by these nanomaterials was also evaluated by recording the absorbance value of 1,3-diphenylisobenzofuran, a singlet oxygen scavenger, after its irradiation with a 650 nm laser. Finally, as proof of concept, the HNTs-NDI nanomaterials were used as carrier for the loading of a PNA derivative to develop a nanomaterial that could selectively target cancer cells.

References:

[1] M. Massaro, E. Licandro, S. Cauteruccio, G. Lazzara, L. F. Liotta, M. Notarbartolo, F. M. Raymo, R. Sánchez-Espejo, C. Viseras-Iborra, S. Riela, J. Colloid Interface Sci. 2022, 620, 221-233.
[2] M. Massaro, M. Notarbartolo, F. M. Raymo, G. Cavallaro, G. Lazzara, M. M. A. Mazza, C. Viseras-Iborra, S. Riela, ACS Appl. Nano Mater. 2022, 5, 10, 13729–13736.
[3] P. Semeraro, Z. Syrgiannis, S. Bettini, G. Giancane, F. Guerra, A. Fraix, C. Bucca, S. Sortino, M. Prato, L. Valli, J. Colloid Interface Sci. 2019, 553, 390–401.

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Melanin hybrids with transition metal ions: new sustainable strategies in heterogeneous catalysis

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In the last decade, several attempts have been made to develop innovative materials provided with tunable nanometer-scale porosity for innovative applications in heterogeneous catalysis.[1,2]

With respect to the general interest for even cheaper and easier to prepare materials, in the last years the focus has been moved toward the research for other and less investigated materials as heterogeneous catalysts such as: carbon nanostructures (*e.g.*, carbon nanotubes) and graphene[3] with high surface area and thermal stability, agri-food waste materials characterized by low-cost and easy availability,[4] and materials inspired by biopolymers that are fully biocompatible and eco-sustainable. In this context, recently special attention has been given to the use of melanins as potential catalysts. Melanins are pigments widely diffused in nature that, due to the unique physicochemical properties, have been used as a multifunctional material in various sectors ranging from (bio)electronics[5] to nanomedicine, energy storage and conversion, and tissue engineering.[6] Moreover, because of their ability to interact with metal ions, melanins have also found applications as chelating agents and in the design of polyfunctional hybrids nanoparticles.

Starting from this evidence herein we report the main results of a research activity aimed at the development of melanin-based catalysts by designing novel metal-melanin hybrid materials.

References:

[1] V. Pascanu, G. Gonzilez Miera, A. Ken lnge, B. Martin-Matute *J. Am. Chem. Soc.* **2019**, *141*, 7223-7234.
[2] Y. Yusran, H. Li, X. Guan, Q. Fang, S. Qiu *Energy Chem* **2020**, *2*, 100035.
[3] K.M. Yam, N. Guo, Z. Jiang, S. Li, C. Zhang *Catalysts* **2020**, *10*, 53.
[4] H.M. Khan, T. Iqbal, S. Yasin, C. H. Ali, et al. *Catalysts* **2021**, *11*, 1215.
[5] M. d'Ischia, A. Napolitano, A. Pezzella, P. Meredith, M. Buehler *Angew. Chem. Int. Ed.* **2020**, *132*, l1292-11301.
[6] U. D'Amora, A. Soriente, A. Ronca, S. Scialla, et al. *Biomedicines* **2022**, *10*, 2945.

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ORG-PO-094

Calixarene-based RAFT polymers: synthesis and supramolecular properties

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Calixarenes are considered the third generation of supramolecular macrocycles after cyclodextrins and crown ethers.[1] Thanks to their supramolecular properties, calixarenes have been included into polymers to develop chemical sensors, selective membranes, heterogeneous catalysts, microelectronic devices, and drug delivery systems.[2]

In this work we concentrated our efforts on the synthesis and characterization of calixarene-based RAFT polymers, that have never been reported in the literature. RAFT polymerization is a highly reproducible and reliable reversible deactivation living radical polymerization that ensures the synthesis of polymers with low molar mass, dispersity, and uniform chemical composition.[3] We synthesized and characterized different calixarene-polymer hybrid macromolecules based on N-isopropylacrylamide (Figure 1) and having a different number of polymer arms at the calixarene lower rim. The preliminary thermoresponsive and supramolecular properties of such hybrids were also investigated together with their possible future applications in material science.

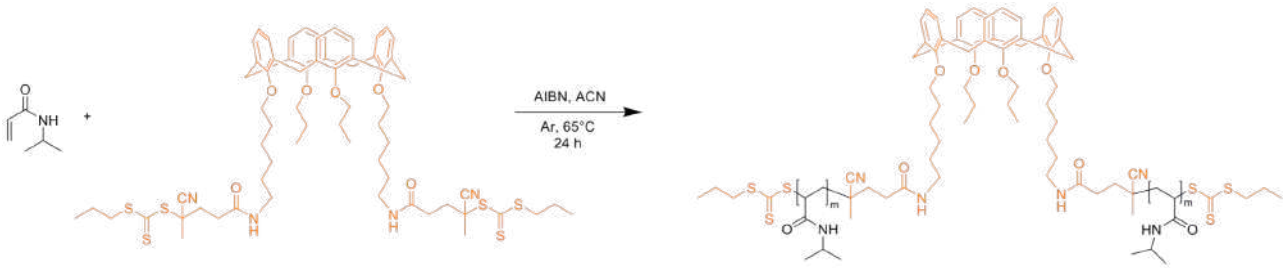

Figure 1. Synthesis of calixarene-based RAFT polymer having two arms at the lower rim.

Funder: Project funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.1 - Call for tender No. 104 of 02.02.2022 of Italian Ministry of University and Research funded by the European Union – NextGenerationEU. Award Number: Project code 2022285HC5, Concession Decree No. 1064 of 18.07.2023 adopted by the Italian Ministry of the University and Research, CUP D53D23010030006, SAMBA: Self-assembly of bacteria-targeting materials across the mesoscale. PG also acknowledges the ERC Starting Grant (PROTOMAT, 101039578).

References:

1. Giuliani M, Morbioli I, Sansone F, Casnati A. *Chem Commun*. 2015;51(75):14140-14159
2. Zadmard R, Hokmabadi F, Jalali MR, Akbarzadeh A. *RSC Adv*. 2020;10(54):32690-32722
3. Moad G. *Polym Chem*. 2017;8(1):177-219

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ORG-PO-095

A multi spectrophotometric approach for the comprehensive study on α –glucosidase, α–amylase and tyrosinase inhibitory activity of anacardic acids

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Anacardic acids are 6-alkylsalicylic acids with varying alkyl chain lengths and degrees of unsaturation, which have demonstrated strong antibacterial and anti-inflammatory properties.[1] In our recent studies, anacardic acids were for the first time discovered in *Pistacia vera* and *Juglans regia* shells extracted in hydroalcoholic solutions by an optimized microwave-assisted method.[2,3] Both extracts showed remarkable hypoglycemic properties by inhibiting key carbohydrate-hydrolysing enzymes (α-amylase and α-glucosidase). Additionally, the *P. vera* shell extract efficiently inhibited tyrosinase, an oxidase enzyme involved in dermatological disorders. According to HPLC-MS/MS analysis, anacardic acids were the most abundant components of the extracts. However, their role towards α-glucosidase, α-amylase, and tyrosinase has not been deeply explored to date.

Herein, (C15:0)-anacardic acid and (C17:1)-anacardic acid (Fig. 1) were selected to investigate the inhibitory behaviour of such class of phenolic lipids towards α-glucosidase, α-amylase and tyrosinase. Notably, tested compounds resulted superior metabolic enzyme inhibitors than the anti-diabetic drug acarbose. In addition, (C15:0) and (C17:1) anacardic acids exhibited a higher anti-tyrosinase activity (IC_{50} of 26.55 and 29.36 μM, respectively) than kojic acid (IC_{50} = 34.96 μM), used as a reference standard. Kinetics analyses uncovered these compounds as competitive inhibitors, while fluorescence experiments allowed the determination of the dynamic quenching (K_{sv}) and binding (K_a) constants. Altogether, these results introduce anacardic acids as interesting natural hypoglycaemic and anti-melanogenic agents.

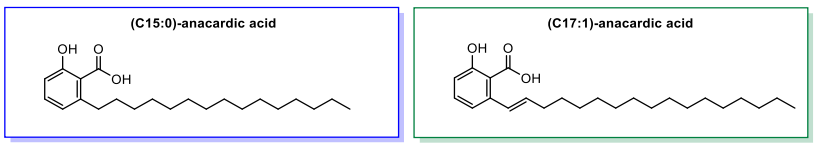

Figure 1: Chemical structures of anacardic acid constituents from *P. vera* shells

Acknowledgements
This work was financed by MUR ITALY PRIN 2022 PNRR (Project No. P2022MWY3P).

References:
[1] S. M. Morais, et al. Pharmaceuticals, 2017, 10 (1), 31.
[2] A. E. Maccarronello, et al. Food chemistry, 2024, 443, 138504.
[3] V. Muccilli et al. Heliyon, 2024, 10 (2), e24469.

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ORG-PO-096

Developing a Sustainable Method for Taming Short-lived Cyclopropenyllithium in Flow

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Functionalized cyclopropenes are highly strained reactive molecules, widely used in numerous reactions,[1] showing metabolic stability when incorporated in bioactive molecules,[2] and used as bioorthogonal chemical reporters.[3] Additionally, substituted cyclopropenyllithium compounds are also valuable synthetic reagents, serving as reactive intermediates for synthesizing diverse organic molecules.[4,5] However, the reported synthetic batch protocols for accessing cyclopropenyllithiums present practical challenges, requiring a cooling-heating-cooling process in the range of -78 °C to -20 °C to -50 °C within one hour. This poses reproducibility issues, especially on a larger scale. Furthermore, the utilization of flash chemistry in flow microreactors enables the control of short-lived organolithiums at higher temperatures compared to batch processes, ensuring reproducibility and precise control. In this presentation, we introduce a sustainable and reproducible protocol for generating and utilizing cyclopropenyllithium intermediates using a continuous flow microreactor for the first time. This reaction can be conducted under more practical conditions without compromising the selectivity and reactivity of the employed cyclopropenyllithium. [6,7]

In this presentation, we report, for the first time, a sustainable and reproducible protocol for the generation and use of cyclopropenyllithiums intermediates using a continuous flow microreactor. The reaction can be conducted under more practical conditions without compromising selectivity and reactivity of the employed cyclopropenyllithium.

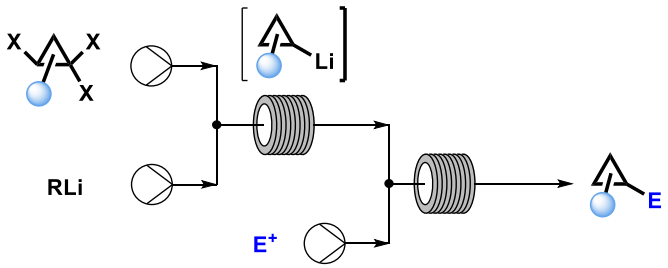

Figure: Flash process to perform lithiation of substituted tribromocyclopropanes.

References:

[1] Z. B. Zhu, Y. Wei, M. Shi, 2011, 40, 5534 – 5563
[2] H. F. Tu, A. Jeandin, C. Bon, C. Brocklehurst, F. Lima, M. G. Suero, 2023, 62, e202308379
[3] D. M. Patterson, L. A. Nazarova, B. Xie, D. N. Kamber, J. A. Prescher, 2012, 134, 18638–18643
[4] V. Smyrnov, J. Waser, 2023, 25, 6999–7003
[5] S. Simaan, A. Masarwa, E. Zohar, A. Stanger, P. Bertus, I. Marek, 2009, 15, 8449 – 8464
[6] P. Natho, M. Colella, M. Andresini, L. Degennaro, R. Luisi, 2024
[7] M. Andresini, S. Carret, L. Degennaro, F. Ciriaco, J.F. Poisson, R. Luisi, 2022, 28, e202202066

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Iron-Catalyzed Aminocarbonylation of Alkyl-Boronic Pinacol Esters via SET

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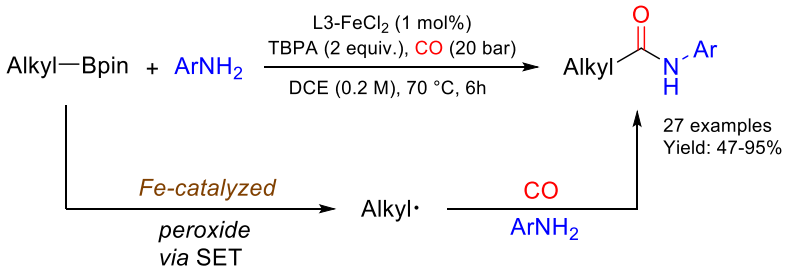
The amide bond is an essential linkage in organic chemistry and, represent the key functional group in peptides, polymers and many natural products and pharmaceuticals [1]. Furthermore, alkyl-boronic acid or esters have attracted much attention due to their high stability, low toxicity, simplicity of preparation and the wide applicability [2]. For this reason, the aminocarbonylation of alkyl-boronic pinacol esters toward amides has been developed. The reactions took place in presence of L3-$FeCl_2$ (L3: 4,4'-di-tert-butyl-2,2'-bipyridine), TBPA (tert-butylperoxiacetate), under 20 bar of CO in DCE at 70 °C for six hours (eq 1).



Eq. 1: aminocarbonilation of alkylboronic pinacol esters via radical generation.

27 examples have been reported with yields up to 95%. The reaction radical mechanism has been confirmed through tests by using BHT as radical inhibitor, a free-radical compound (TEMPO) and a chemical able to react with free-radicals: the 1,1-diphenylethylene.

References:

[1] (a) A. Greenberg, C.M. Breneman, J.F. Liebman, Wiley, New York, **2000**. (b) J.W. Clader, J. of Med. Chem. 47, **2004**, 1-9. (c) K. Bush, M.J. Macielag, Exp. Opin. on Ther. Patents **2010**, 1277-1293. (d) X. Guo, A. Facchetti, T.J. Marks, Chem Rev. 114, **2014**, 8943-9021.

[2] (a) P. Renaud, A. Beauseigneur, A. Brecht-Forster, B. Becattini, V. Darmency, S. Kandhasamy, F. Montermini, C. Ollivier, P. Panchaud, D. Pozzi, E.M. Scanlan, A.-P. Schaffner, V. Weber, Pure Appl. Chem., 79, **2007**, 223-233. (b) G. Duret, R. Quinlan, P. Bisseret, N. Blanchard, Chem. Sci. 6, **2015**, 5366-5382. (c) H.-L. Jiang, Y.-H. Yang, Y.-H. He, Z. Guan, Org. Lett. 24, **2022**, 4258-4263.

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ORG-PO-098

The inverse electron demand [4+2] hetero Diels-Alder reaction allows to easy access to tetracyclic fused glycomimetics as precision tools in cancer settings

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Glycomimetics, molecules that mimic the structural and functional features of native carbohydrates, possess vast therapeutic potential and are emerging within the drug development market.[1] It is well established that by proper modulation of their structure, researchers can overcome the inherent limitations of native carbohydrates leading to molecules with enhanced selectivity/potency for the target and improved drug-like properties. With this in mind, straightforward synthetic strategies that allow to access to such compounds have emerged at the frontier of drug design thus making glycomimetics more and more available tools for advancing our understanding of the glyco-code and as therapeutics for a great variety of diseases.[1b, 2]

In this framework, the use of glycals as electron-rich dienophiles in the [4+2] inverse electron-demand hetero-Diels-Alder (ihDA) reaction allows as easy access of an array of glycomimetics with a high degree of structural diversity. In this communication, we describe our last contribution in the field in providing a new class of electron-poor heterodienes, the N-substituted-3-thioxo-benzo[c][1,2]thiazin-4-one-2,2-dioxides.[3] The use of such heterodienes in the ihDA allows either to further widen the structural diversity of the glycomimetics and to foster the understanding of the mechanistic details and the reactivity of some glycals in the ihDA. The implications of our recent insights in the development of precision therapeutics in cancer settings will be also described.

References:

[1] (a) B. Ernst, J.L Magnani, Nat Rev Drug Discov 2009, 8, 661–677; (b) A. Tamburrini, C. Colombo, A. Bernardi, Med Res Rev 2020, 40, 459-531; (c) S. Leusmann, P. Ménová, E. Shanin, A. Titz, C. Rademacher, Chem. Soc. Rev. 2023, 52, 3663–3740.

[2] M. Cacciarini, S. Menichetti, C. Nativi, B. Richichi, Curr. Org. Synth, 2007, 4, 47–57. ; B. Richichi, A. Imberty, E. Gillon, R. Bosco, I. Sutkeviciute, F. Fieschi, C.Nativi, Org. Biomol. Chem. 2013, 11, 4086–4094.

[3] G. Biagiotti, L. Legnani, G. Aresta, M. Chiacchio, B. Richichi, Eur JOC 2022, 24-32; K.C. Martin, J. Tricomi, F. Corzana, A. García-García, L. Ceballos, L. Hicks, S. Monaco, J. Angulo, R. Hurtado-Guerrero, B. Richichi, R. Sackstein, Chem Commun 2021, 57, 1145-1148.

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ORG-PO-099

Synthesis and characterization of Gadopiclenol bifunctional derivatives

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Due to its optimal thermodynamic stability, kinetic inertness and efficiency (in terms of relaxivity), Gadopiclenol has been proved to be a valuable GBCA (gadolinium based contrast agent) for Magnetic Resonance Imaging (MRI) applications[1]. In this work we performed the synthesis of a bifunctional Gadopiclenol analogue bearing an amino group on the pyridine moiety (Figure 1); this scaffold could be used in order to link the complex to a molecule with high affinity with human serum albumin (such as adamantane group) or to build a dimeric derivative.

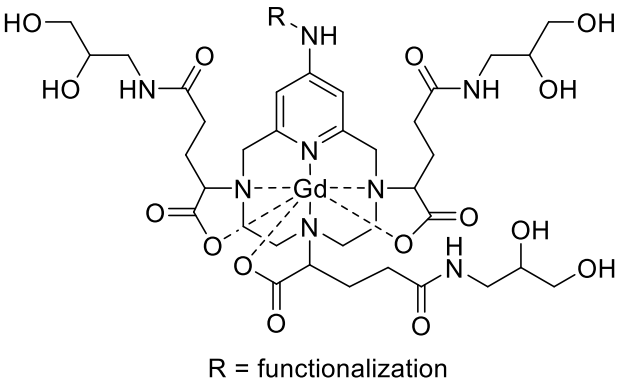

Figure 1: Bifunctional Gadopiclenol amine derivative.

These paramagnetic contrast agents show improved efficiency because of their higher molecular weight (which leads higher rotational correlation time values). In addition, Gadopiclenol and its derivatives are neutral complexes, so they are suitable for MRI-guided therapeutic applications based on the administration of sonosensitive liposomes co-encapsulating the anticancer drug doxorubicin and the paramagnetic agent[2].

References:

[1] C. Robic, M. Port, *Invest. Radiol.* 2019, 58, 475-484.
[2] S. Rizzitelli, P. Giustetto, D. Faletto, D. Delli Castelli, S. Aime, E. Terreno, *J. Control. Rel.* 2016, 230, 57–63.

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D-Glucamine-functionalized self-assembling fluorophores for the sensing of drugs in water

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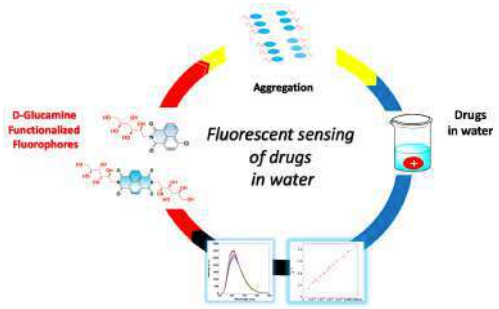
Fast and sensitive quantification of drug residues in water is increasingly required, due to the relevant presence of such pollutants in water bodies. This explains the rising interest in fluorescent sensing probes for this purpose. In this context, we synthesized two D-glucamine functionalized fluorophores bearing self-assembling cores, as 1,8-naphthalimide and naphthalene diimide. We studied their self-assembly in water solution, and characterized the aggregates formed by determining their stability constant, their morphology and size by scanning electron microscopy, resonance light scattering and dynamic light scattering. Then, we studied their sensing ability, in water, towards pharmaceutically active compounds such as ciprofloxacin, nalidixic acid, carbamazepine and diclofenac sodium salt, by fluorescence investigation.



Data collected show that the self-assembling ability is significantly affected by the fluorophore structure, which in turn also determines sensing ability. In particular, the naphtalene diimide-based probe was the most sensitive, with LOD as low as 0.01 μM in the presence of nalidixic acid, which is in line and competitive with more complex sensing systems, recently reported in the literature.

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References:

[1] J. Krämer, R. Kang, L. M. Grimm, L. De Cola, P. Picchetti, F. Biedermann, Chem. Rev. 2022, 122, 3459–3636.

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ORG-PO-101

A new sustainable approach to the synthesis of Benzofurans

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In the last years, the interest in the synthesis of heterocycles is largely increasing for their wide range of industrial application[1], from the pharmaceutical industry to the agricultural[2]. Between the numerous types of molecules studied, some of the most interesting are probably the Benzofurans; these are in fact really useful in pharmaceutical industry, because they are found as scaffolds in a large amount of API, with different applications, such as antitumorals[3],anti-infiammatory[4], antiarrythmic[5] and many more.

To answer to the high demand for this scaffolds, a great number of synthetic pathways were created and can be easily found in literature; most of them, however, present problematics, mainly for the expensive chemicals and catalysts applied, but also for safety and sustainability reasons, such as the use of dangerous solvents and the generation of wastes. To try to achieve better and more sustainable processes for these compounds of great industrial relevance, this work tried to optimize their synthetic paths, applying the principles of Green chemistry. To achieve this, we selected a process form literature between diphenylacetylene and phenol[6], in which was used the C-H activation reaction, that is highly desirable for a more sustainable process since it doesn't require any prefunctionalization steps. We then started to apply safer solvents, heterogeneous catalysis and different type of bases and oxidizing agent to decrease the wastes.

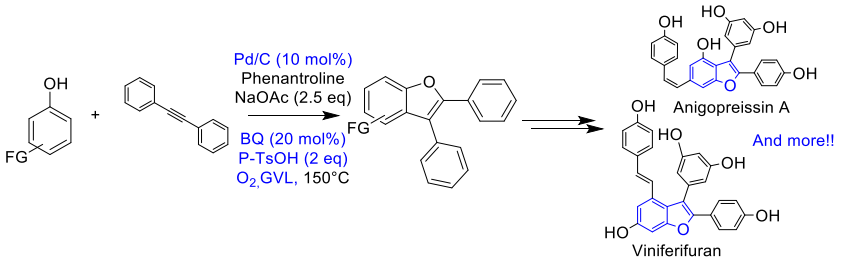

Figure 1: Optimized protocol for the synthesis of Benzofurans

References:

[1] P. Arora, V. Arora, H. S. Lamba, D. Wadhwa, *Int. J. of Pharma. Sciences and Research*, **2012**, *3*, 2947-2954
[2] B. H. Lipshutz, *Chem. Rev.*, **1986**, *86*, 795 – 819
[3] C. T. Lavranos, A. F. Leske, D. Inglis, C. Brown, D. Bibby, G. Kremmidiots, *Cancer res*., **2012**, *72*, 2774
[4] Y. Li, C. Yao, J. Bai, M. Lin, G. Cheng, *Acta Pharmacologica Sinica*, **2006**, *27*, 735-740
[5] S. Shimazu, K. Takahata, H. Katsuki, H. Tsunekawa, A. Tanigawa, F. Yoneda, J. Knoll, A. Akaike, *European Journal of Pharmacology*, **2001**, *421*, 181-189
[6] M. Kuram, M. Bhanuchandra, A. Sahoo, *Angew. Chem. Int. Ed*., **2013**, *52*, 4607-4612

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ORG-PO-102

Immobilization of enzymes on clay minerals surfaces

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Enzyme immobilization is a powerful tool for the design of green and sustainable production processes. Given the diversity of methodologies and carriers, the proper approach for the specific requirements of a given process can be pinpointed. Enzyme immobilization helps to maintain the catalytic activity and stability under a range of pH, temperatures, and inhibitors, along with maintaining their recyclability over successive catalytic cycles. Also, the immobilization of enzymes to solid supports ensures highly purified products by easily removing the biocatalyst from the medium.[1] The high expense associated with the support systems hinders the commercial applicability of immobilized enzymes. In this light, clay minerals being natural and low-cost, represent valuable candidates to be used as support for enzyme immobilization.[2]

Herein, we report the covalent grafting of laccase and, collagenase, on clay minerals' surface to develop functional nanomaterials for different purposes. The obtained nanomaterials were thoroughly characterized by different physical chemical techniques, aiming to confirm the successful grafting. Furthermore, UV-vis experiments were performed in order to validate that the enzymes can retain their enzymatic activity after the covalent grafting on clay surface.

Currently, since immobilized enzymes seem to have immeasurable prospects in all areas of science from targeted drug delivery to the development of sensor and bioremediation to develop functional materials that can be used in different fields.

ACKNOWLEDGEMENTS: "SiciliAn MicronanOTecH Research And Innovation CEnter "SAMOTHRACE" (MUR, PNRR-M4C2, ECS_00000022), spoke 3 - Università degli Studi di Palermo "S2-COMMs - Micro and Nanotechnologies for Smart & Sustainable Communities", spoke 1, WP2-Environment, Task "Application of new materials for the real-time control of contaminants of emerging concern in water".

References:

[1] Cardullo, N.; Muccilli, V.; Tringali, C. RSC Chemical Biology 2022, 3, 614.
[2] Massaro, M.; Ghersi, G.; de Melo Barbosa, R.; Campora, S.; Rigogliuso, S.; Sànchez-Espejo, R.; Viseras-Iborra, C.; Riela, S. Coll. Surf. B 2023, 230.

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ORG-PO-103

Investigation of the interactions between BMH-21, namitecan and doxorubicin and the Quadruplex-Duplex Junction in LTR-III

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Quadruplex-Duplex (Q–D) junctions are unique structural motifs garnering increasing interest as drug targets, due to their frequent occurrence in genomic sequences. The viral HIV LTR-III sequence was chosen as a Q–D junction model to study the affinity of the selected compounds BMH-21, namitecan, and doxorubicin, all containing a planar polycyclic aromatic moiety, linked to either one short aminoalkyl or an aminoglycosyl group. A multidisciplinary approach that combines NMR spectroscopy, molecular modelling, circular dichroism (CD) and fluorescence spectroscopy was employed to investigate the interactions of BMH-21, namitecan and doxorubicin with the Q–D junction LTR-III. In particular, the binding of BMH-21 and namitecan to the LTR-III target was not associated to a significant stabilizing effect. However, doxorubicin was found to be the best Q–D junction binder, as evidenced by the complex denaturation curve, which showed higher melting temperature values. Interestingly, the removal of the aminoglycosyl group significantly changed the pattern of the interactions, indicating that highly polar substituents have a stronger affinity with the exposed regions of the Q–D junction, particularly at the level of the interfacial tetrad. Our chemical investigations, supported by biophysical data and molecular modeling studies, provide guidelines for the identification of new scaffolds for selective Q–D recognition. Since CPTs and doxorubicin have been found to inhibit HIV virus with unknown mechanisms of action, the results may be useful to extend the search for potential antiviral agents in the management of HIV infections.

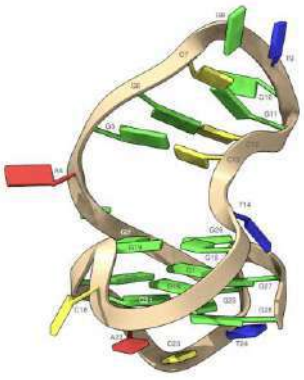

Figure 1: Schematic representation of the Q–D junction present in the LTR-III nucleotidic sequence

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ORG-PO-104

C-1 and C-5 quaternarization of β-fucosides by HAT reactions

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The functionalization of C-H bonds gives access to complex molecules in fewer steps relative to classical methods. However, the modification of polyfunctionalized structures like carbohydrates is very challenging and still underdeveloped. The challenge arises from the unreactive nature of carbohydrates' C–H bonds and from the regioselectivity problems associated to the presence of many similar functionalities.[1]

Hydrogen atom transfer (HAT) reactions enable a direct activation of C-H bonds, without the need of pre-functionalization or the presence of a directing group. As such, they are synthetically attractive and have been used on carbohydrates mostly to obtain regioselective inversion of stereocenters of unprotected sugars.[2]

In the context of glycomimetic design, we are interested in the potential of HAT reactions to modify desired ligands while maintaining the sugar structure intact. This allows to target secondary binding sites in proteins and/or create multivalent ligand presentations, thus expanding the toolbox for glycomimetic development.

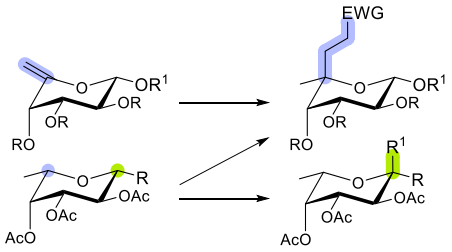

Figure 1: C-1 and C-5 functionalization of β-fucosides.

Here we report on the functionalization of the C-1 and C-5 position of β-fucosides (Figure 1) that we are exploring for the synthesis of antimicrobial antiadhesive agents targeting the *N*-terminal domain of the bacterial lectin BC2L-C.[3]

Acknowledgement
The project is supported by EU funding within the NextGeneration EU-MUR PNRR Extended Partnership initiative on Emerging Infectious Diseases (Project no. PE00000007, INF-ACT) and, in part, within the MUSA – Multilayered Urban Sustainability Action – project.

References:
[1] T. Frihed, M. Bols, C.M. Pedersen, Eur. J. Org. Chem. 2016, 16, 2740–2756
[2] Y. Wang, H. M. Carder, A.E. Wendlandt, Nature 2020, 578, 403–408
[3] S. Mazzotta, G. Antonini, F. Vasile *et al*, Molecules 2023, 28, 1494

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Robust, reproducible, low waste and large scale procedure for high quality $CsPbBr_3$ nanobricks synthesis for scintillation.

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Research interest in all inorganic lead halide perovskite nanocrystals (LHP-NCs), described by the general chemical formula of CsPbX3, has recently grown fast thanks to their outstanding and highly tunable chemical and physical properties that make them optimal candidates for a wide range of technological applications[1]. Amidst this rapidly expanding and diverse landscape, we present a robust, reproducible, and easily scalable synthetic method that enables the production of high-quality CsPbBr3 NCs on an unprecedented scale, reaching up to 8 grams. To achieve this, we modified the synthetic procedure originally outlined by Akkerman et al.[2], introducing a turbo emulsifier (Ultra Turrax Homogenizer) for the first time. This emulsifier, typically used in formulating large batches, enhances the homogenization of the reaction mixture, addressing concentration gradients and reproducibility issues that commonly impact liter-scale reactions of LHP-NCs. Additionally, we employed tetrabutylammonium bromide (TBAB) as an extra bromide precursor to ensure the correct stoichiometry. Operating in a halogen-rich environment is known to reduce defectivity, and the bulkiness of this specific quaternary ammonium salt prevents it from competing with other cations in the perovskite crystal lattice. Our results indicate that the amount of recovered solid material is directly proportional to the solution volume used at every scale, affirming the well-controlled nature of the process even at larger scales. There are also evidences that increasing the scale, magnetic stirring becomes insufficient where turbo-emulsifier remains reliable. Furthermore, the procedure is easy extendable to CsPbCl3 and mixed phase and other acid and amine ligands. We pushed the boundaries by demonstrating that our approach allows for the recovery and reuse of low-boiling solvents and excess reactants, particularly lead bromide, without compromising the final product's quality. This not only reduces the environmental impact associated with waste production but also represents a significant step toward eventual industrial applications. We finally tested radioluminescence properties and radiation hardness in polymer matrix, confirming their competitiveness in scintillation field[3].

References:

[1] Pan, Y., Zhang, Y., Kang, W., Deng, N., Yan, Z., Sun, W., Kang, X., Ni, J., Mater. Adv. 2022, 3 (10), 4053–4068.
[2] Akkerman, Q. A., Gandini, M., Di Stasio, F., Rastogi, P., Palazon, F., Bertoni, G., Ball, J. M., Prato, M., Petrozza, A., Manna, L., Nat Energy 2017, 2 (2), 16194.
[3] Erroi, A., Mecca, S., Zaffalon, M. L., Frank, I., Carulli, F., Cemmi, A., Di Sarcina, I., Debellis, D., Rossi, F., Cova, F., Pauwels, K., Mauri, M., Perego, J., Pinchetti, V., Comotti, A., Meinardi, F., Vedda, A., Auffray, E., Beverina, L., Brovelli, S., ACS Energy Lett. 2023, 8 (9), 3883–3894.

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Dissipative Dynamic Covalent Chemistry (DDCvC) Based on The Transimination Reaction

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This work reports the possibility to control over time the composition of a dynamic library (DL) of imines that interconvert among them through reversible equilibria of transimination.[1] These transimination equilibria studied in organic media involve the conversion of one or more *N*-aliphatic imines to *N*-aromatic ones, and the composition of these libraries is strongly shifted toward the *N*-aliphatic imines, that have attached the more basic amines. A representative situation of these systems is the first minimal DL studied, between *p*-brome-*N*-benzylidenebutylamine and *p*-brome-*N*-benzylidenetoluidine (Figure 1A).
Since this kind of DL is sensitive to acid-base stimulus, by adding an acid to the environment we can subtract from the equilibrium the most basic substance (the aliphatic amine) in order to overexpress its protonated form and the *N*-aromatic imine through Le Chatelier's principle. By adding a decarbossilative acid fuel like the 2-cyano-2-(4'-chloro)-phenylpropanoic one instead, this dramatic change of composition can be realized temporarily (with the creation of a dissipative dynamic library, DDL, Figure 1B), because then through the decarboxylation of the fuel coniugate base (the rate determining step) a strong carbon base would be generated *in situ* in order to revert the starting situation back:[1]

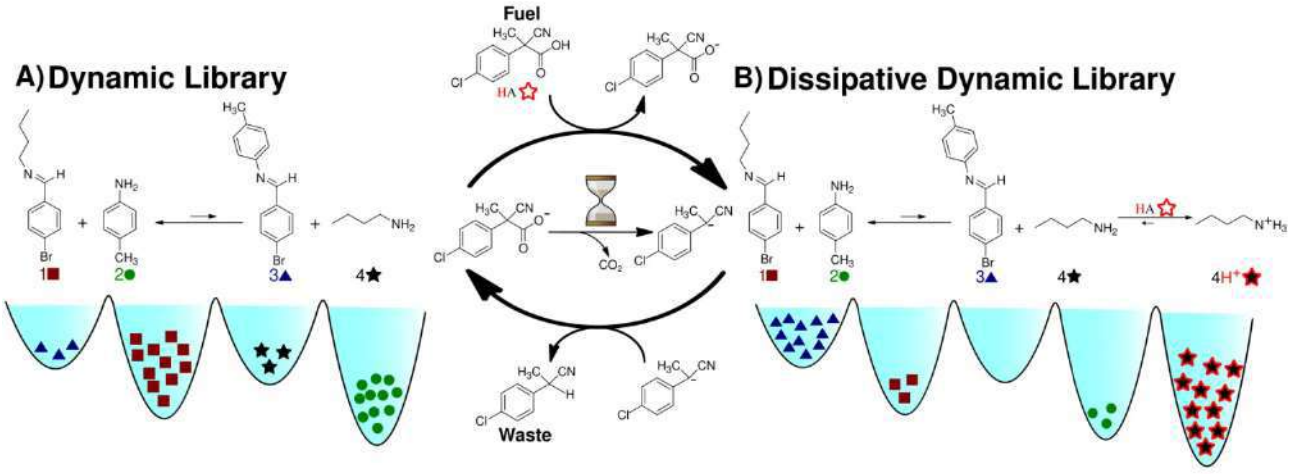

Figure 1: A) A minimal DL that consists of *p*-brome-*N*-benzylidenebutylamine (1) in equilibrium with *p*-brome-*N*-benzylidenetoluidine (3), and the relative amines. A qualitative free energies profile of the substrates is shown for representing the composition of the system. B) The addition of the fuel shifts the equilibrium toward the imine 3 and the butylammonium, and this state persists until the fuel consumption.

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Copper catalyzed sequential Glaser coupling and bicyclocarboxylation of propargylic amines to bis(2-oxazolidinones)

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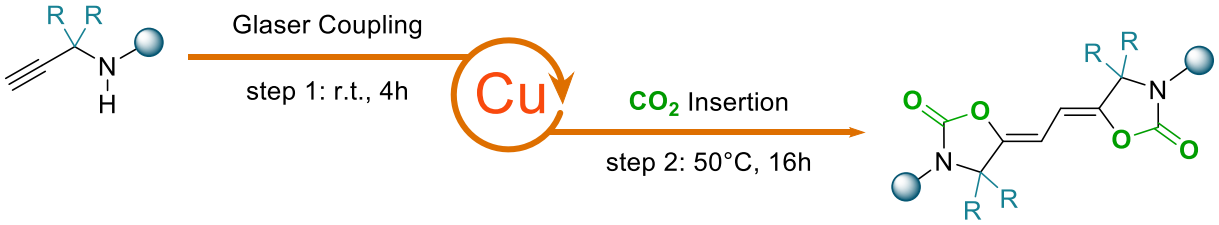
With the continual increase in atmospheric CO_2 levels, scientists globally have undertaken research to develop innovative methods for the effective capture and utilization of this well-known greenhouse gas. To tackle this challenge, the Carbon Capture and Utilization (CCU) strategy is designed to capture CO_2 from emission sources and transform it into valuable products[1]. The carboxylic cyclization of propargylic amines to produce 2-oxazolidinones stands out as a highly appealing chemical approach for trapping carbon dioxide. One of the possible reactions of propargylamine is the Glaser coupling on terminal alkynes, that enables easy access to 1,3-diynes, essential intermediates for polymers, macrocycles, and complex scaffolds[2].



Scheme 1. Inexpensive copper catalyst for sequential Glaser coupling and carboxylation of propargylic amines.

As a part of our research on catalytic conversion of carbon dioxide into novel and useful compound utilizing CO_2[3,4], we embraced the task of integrating the copper-catalysed reaction of terminal alkynes with the carboxylation of propargylamine (Scheme 1). As far as our knowledge extends, a comprehensive synthesis of bis(2-oxazolidinone)s has not been documented. We try to investigate the Cu/DBU catalytic system, observing a manifold role of copper salt, which acts as a catalyst both for the Glaser coupling and the carboxylative cyclization. We successfully devised a straightforward and efficient one-pot two steps procedure that can be used for a vast range of propargylamines, resulting in a substantial collection of products with excellent yields. Importantly, the purification of the resulting products can be easily accomplished by directly precipitating them from the reaction medium. Finally, we observed a spontaneous polymerization of these butadiene-containing monomers leading to the formation of a category of specialized polymers, accomplished through a solid-state Single Crystal to Single Crystal transformation.

References:

[1] A. Yagmur Goren, D. Erdemir and I. Dincer, Environ. Res., 2024, 240, 117503.
[2] K. S. Sindhua, G. Anilkumar, RSC Adv., 2014, 4, 27867-27887.
[3] M. Marchegiani, M. Nodari, F. Tansini, C. Massera, R. Mancuso, B. Gabriele, M. Costa and N. Della Ca', J. CO_2 Utilization, 2017, 21, 553.
[4] L. Soldi, C. Massera, M. Costa and N. Della Ca', Tetrahedron Lett., 2014, 55, 1379.

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ORG-PO-108

Gold catalyzed asymmetric synthesis of axially chiral indole-fused diazocines.

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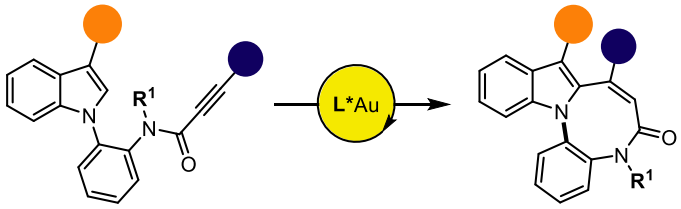
Atropisomerism, also called axial chirality, is a particular kind of chirality in which the rotation of a σ bond is constrained because of the steric or electric effects of bulky substituents. The main difference between classical stereoisomers and atropisomers is that classical stereocenters are often stable and racemize via a bond-breaking, while racemization for axially chiral compounds is possible through an intramolecular dynamic process that simply involves bond rotation.[1] This time-dependent chirality shows great potential for drug development and has been observed in natural products. In addition many chiral catalysts and ligands that are frequently used in asymmetric synthesis are axially chiral compounds.[2] Among these substrates, axially chiral indole derivatives have been recognized as an important class of five-membered heterobiaryls, because of their presence in some natural alkaloids, chiral phosphine ligands and bioactive molecules.[3] Taking into account these premises, this poster will deal with our recent developments in the gold catalyzed asymmetric synthesis of axially chiral indole-fused diazocines. In particular, optimization of catalytic conditions and preliminary substrate scope of the reaction will be presented together with a mechanistic proposal.



- **Gold catalyzed enantioselective cyclization**
- **Synthesis of axially chiral benzo[2,3][1,4]diazocino[1,8-*a*]indol-6(5*H*)-one**

Figure 1: Gold catalyzed enantioselective reaction for the synthesis of indole-fused diazocines.

References:

[1] X. L. Min, X. L. Zhang, R. Shen, Q. Zhang, Y. He, *Org. Chem. Front*. **2022**, *9*, 2280–2292.
[2] S. R. Laplante, L. D. Fader, K. R. Fandrick, D. R. Fandrick, O. Hucke, R. Kemper, S. P. F. Miller, P. J. Edwards, *J. Med. Chem.* **2011**, *54*, 7005–7022.
[3] T. Z. Li, S. J. Liu, W. Tan, F. Shi, *Chem. Eur. J.* **2020**, *26*, 15779–15792.

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C(sp^3)-H bond activation: an effective synthetic tool for the synthesis of complex molecules

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Over recent years, there has been a growing interest in the exploitation of transition metal-catalyzed C-H bond activation for the synthesis of natural products and biologically active compounds.[1] While the activation of C(sp^2)-H bond benefits from a higher acidity and effective reactant-catalyst interactions, the activation of C(sp^3)-H bonds remains a more challenging process yet very useful for making carbon-carbon or carbon-heteroatom bonds.[2] In addition, considering the increasing importance of environmental issues, the attention of the scientific community is shifting towards the use of processes employing safer solvents and recoverable, reusable catalytic systems.[3]

In this contribution, we report our study on the definition of sustainable C-H activation methods to synthesize indolines both in batch and/or flow conditions.[4] In addition, we report our exploration towards the development of enantioselective protocol.[5]

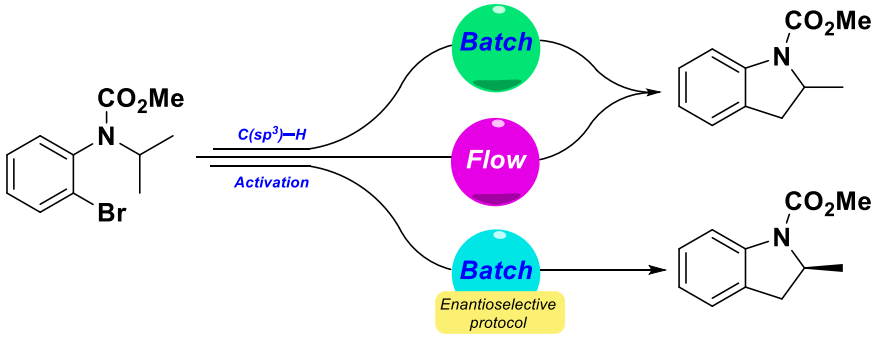

Figure 1: Three different synthetic procedures to achieve indolines

References:

[1] N. Y. S. Lam, K. Wu, J.-Q. Yu, *Angew. Chem. Int. Ed.* 2021, 60, 15676–157.
[2] J. C. K. Chu, T. Rovis, *Angew. Chem. Int. Ed.* 2018, 57, 62–10.
[3] T. Dalton, T. Faber, F. Glorius. *ACS Cent. Sci.*, 2021,7, 245–261.
[4] F Ferlin, I Anastasiou, N Salameh, T Miyakoshi, O Baudoin, L Vaccaro, *ChemSusChem,* 15 (6), e202102736.
[5] N Salameh, F Valentini, O Baudoin, L Vaccaro, *ChemSusChem,* 16 (23), e202300609.

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ORG-PO-110

Synthesis, characterization and mechanism of action of a highly cytotoxic ruthenium (II) based photosensitizer

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Photodynamic therapy (PDT) is an efficient method for cancer treatment due to its high selectivity for the targeted tissues and minimal side effects resulting from its non-invasive nature.[1,2] In this research study, a novel luminescent ruthenium(II) complex **1** incorporating a ligand inspired from isoquinoline alkaloids is introduced as a new photosensitizer. The results of biological assays carried out on human breast cancer (Hs578T) and melanoma (A375) cell lines have shown that: 1) at low concentrations as 0.5 and 1 μM, in the case of Hs578T, and 1 and 1.5 μM, in the case of A375, **1** proved to be cytotoxic only after irradiation at 525 nm (Figure 1b); 2) the light activation of **1** induce an overproduction of reactive oxygen species (ROS), an event that is crucial for pathways associated with mitochondrial dysfunction, caspase activation and apoptosis; 3) the cell death is also induced by cell cycle arrest via DNA photocleavage.

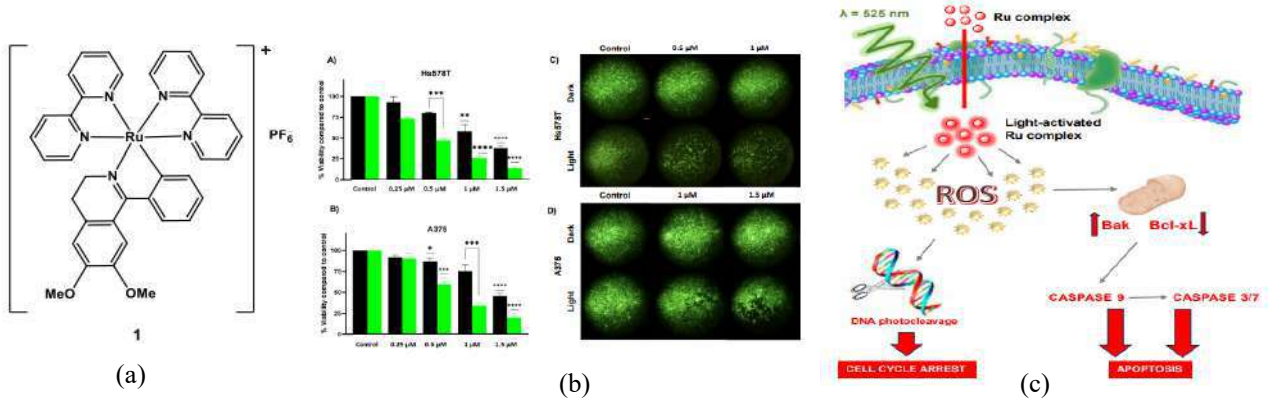

Figure 1: (a) Structure of **1**; (b) in vitro cytotoxicity assay (CellTiter-GLO and Live Cell Explorer) of **1** on Hs578T (A, C) and A375 (B, D) cell lines, (c) Proposed mechanism of action of **1** under light irradiation.

References:

[1] B. Kar, U. Das, N. Roy, P. Paira, *Coordination Chemistry Reviews* **2023**, *474*, 214860.
[2] X. Chen, B. B. Mendes, Y. Zhuang, et al. *Journal of the American Chemical Society* **2024**, *146(2),* 1644-1656.

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ORG-PO-111

A study on the chemoselectivity of 2-aminobenzaldehyde self-condensation promoted by transition metal ions

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2-aminobenzaldehydes are versatile building blocks in organic synthesis enabling a variety of bond-forming strategies.[1] These molecules are also well-known for their high reactivity in self-condensation reaction.[2] Indeed, for over 80 years, this domino reaction has garnered interest due to the variety of nitrogen-containing polyheterocycles it can produce.[3] In addition, the process plays a considerable role in synthesizing macrocyclic ligands using transition metal ions as templates (figure 1a).[4]

Despite being intrinsically straightforward, controlling the chemoselectivity of the self-condensation presents a significant challenge, as it is strongly influenced by the stereo-electronic effect of the substituents and the reaction parameters such as solvent, temperature and nature of the acidic catalyst.

Herein we present a systematic study on transition metal ions at various oxidation states aimed to address the selective synthesis of trimer derivatives **A**, using non-innocent alcoholic solvents (figure 1b).

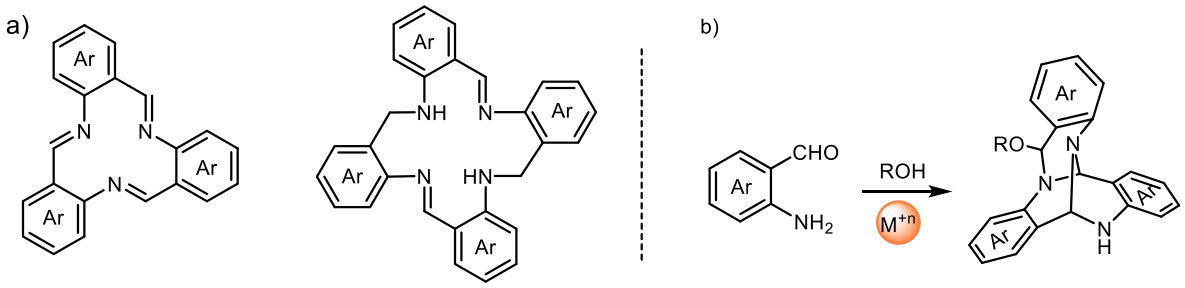

Figure 1. a) Nitrogen-containing macrocycles. b) Self-condensation products addressed in this study.

References:

[1] (a) J. Marco-Contelles, E. Perez-Mayoral, A. Samadi, M.C. Carreiras, E. Soriano, *Chem. Rev.* 2009, 109, 6, 2652–2671; (b) G. Tian, W.-L. Jin, C. Qin, J. Wang *Org. Biomol. Chem.*, 2023,*21*, 5757-5761; (c) S. Debbarma, M. M. Sudan, *Eur. J. Org. Chem.,* 2017, 3699-3706; (d)

[2] D. H. Busch, S. C. Cummings, *Inorg. Chem.* 1971, 10, 6, 1220–1224.

[3] A. G. Kolchinski, *Coord. Chem. Rev.* 1998, *174*, 207-239.

[4] A. J. Jircitano, S. O. Sommerer, J. J. Shelley, B. L. Westcott Jnr and I.-H. Suh,*Acta Cryst.* (1994). C50, 445-447.

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ORG-PO-112

Mechanistic Insights Into The Base-Mediated Deuteration Of Pyridyl Phosphonium And Ammonium Salts

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The past decade has witnessed great progress in the field of "deuterium switch", a strategy based on the replacement of hydrogen with deuterium. Due to the greater activation energy for the cleavage of the C-D bond, the metabolic stability and safety of a drug containing deuterium atoms can improve compared with the non-deuterated counterparts. Given the importance of pyridines in drugs, novel methodologies to access diverse selectivity patterns in their deuteration are highly desirable; inspired by its reported base-mediated *meta*, *para*-deuteration[1,2], we wondered how the deuteration of model compound 2-phenylpyridine (**1**) could be modified to allow for a different labelling selectivity. We envisaged that the temporary installation of an electron-withdrawing group on the pyridine could promote the deuterium switch and alter the deuteration pattern, and in particular that phosphonium salt **[2]**$^+$ or ammonium salt **[3]**$^+$ could promote *ortho*/*meta*-deuteration by increasing the corresponding acidity in these positions while blocking the *para*-position. A phosphine ligand was then installed on the Ph_3P^+ moiety as a directing group (compound **[4]**$^+$) to facilitate the approach of the base by pre-coordination of its cation. In this work, we evaluated, computationally and experimentally (including by in situ NMR analysis) the deuteration of compounds **[2]**$^+$ to **[4]**$^+$.

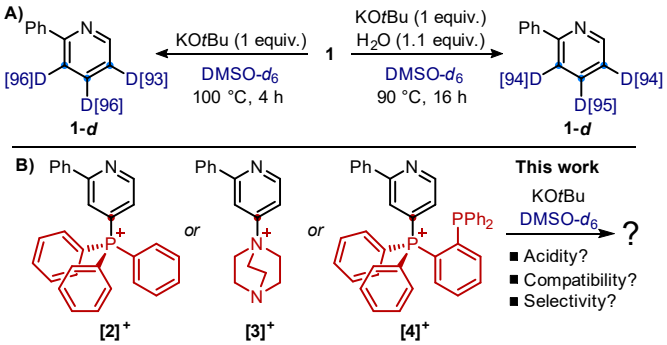

Figure 1: **A)** Base-promoted deuteration of 1-*d*. **B)** Phosphonium and ammonium salts used in this work.

References:

[1] Y. Li, C. Zheng, Z.-J. Jiang, J. Tang, B. Tang, Z. Gao, *Chem. Commun.* **2022**, *58*, 3497.
[2] S. Kopf, J. Liu, R. Franke, H. Jiao, H. Neumann, M. Beller, *Eur. J. Org. Chem*. **2022**, e202200204.

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ORG-PO-113

Dual target approach for the treatment of Gaucher disease: new iminosugar pharmacological chaperones with antioxidant/anti-inflammatory properties

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The design and synthesis of multitarget directed ligands represents one of the most attractive and challenging fields in medicinal chemistry research. Nitrogen-containing glycomimetics, such as iminosugars, have proven to be inhibitors of glycosidases and glycosyltransferases. More recently, these compounds have been introduced as therapeutic agents towards lysosomal storage disorders (LSDs), acting as pharmacological chaperones (PCs)[1]. PCs are small molecules able to rescue the activity of mutated enzymes. In the context of LSDs, they favor the correct folding of the enzymes and facilitate their translocation to the lysosomes when used at subinhibitory concentration. In this work, we report a series of trihydroxypiperidine iminosugars bearing different antioxidant or anti-inflammatory moieties as potential bifunctional agents for the treatment of Gaucher disease (GD) (Figure 1), starting from low-cost D-mannose. GD is the most prevalent LSD, caused by mutation in the *GBA* gene encoding for lysosomal β-glucocerebrosidase (GCase), which is responsible for the hydrolysis of glucosylceramide[2]. The new compounds are potentially able to mend GCase dysfunction while reducing the severe oxidative stress/inflammatory state observed in GD patients. Since *GBA* mutations are also known as the most recurrent genetic risk factors for Parkinson disease (PD)[3], these novel compounds are interesting for the treatment of PD as well. The synthesis of the new bifunctional compounds and their biological evaluation towards GCase will be presented.

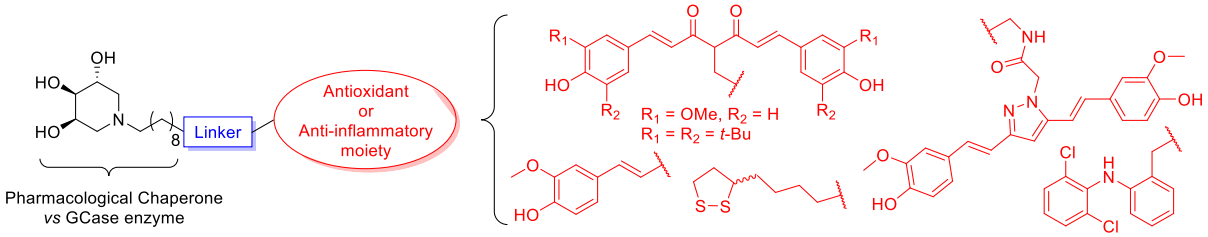

Figure 1: New potential bifunctional antioxidant/anti-inflammatory pharmacological chaperones

Acknowledgements: Fondazione Telethon ETS and Associazione Italiana Gaucher (GSA22P001), NGEU funded by MUR for projects MNESYS (PE0000006), and MULTIFUN (Prin2022, Project code 2022N9E847) and Fondo di Beneficienza Intesa Sanpaolo (B/2021/0187).

References:

[1] P. Compain, O.R. Martin (Eds.), Iminosugars: From synthesis to therapeutic applications. John Wiley & Sons, 2007.
[2] G.A. Grabowski, S. Gatt, M. Horowitz, Crit. Rev. Biochem. Mol. Biol. 1990, 25, 385-414.
[3] L. Smith, A.H.V. Schapira, Cells, 2022, 11, 1261.

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ORG-PO-114

Synthesis of 2-oxazolidinones by oxidative carbonylation of *β*-amino alcohols catalyzed by Pd supported on silica-POSS-Imi

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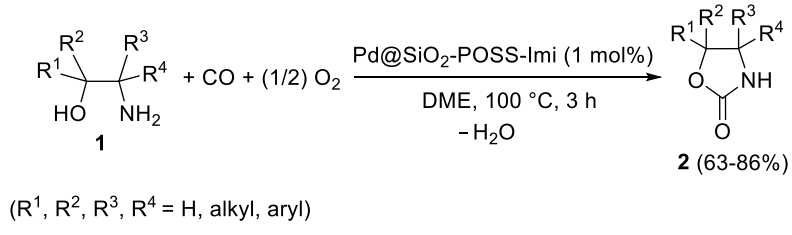
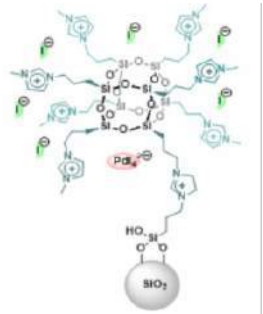
The direct synthesis of 2-oxazolidinones by the oxidative carbonylation of *β*-amino alcohols[1] allows obtaining high value added molecules with several biological applications. 2-Oxazolidinones are known, in particular, to possess significant antibacterial[2] and antitumor activities.[3]

We have now found that it is possible to perform this kind of transformation by supporting our PdI_4^{2-} catalyst (already widely applied in the development of oxidative carbonylation processes under homogeneous catalysis conditions)[4] on a hybrid material based on imidazolium modified polyhedral oligomeric silsesquioxanes (POSS-Imi) grafted on amorphous silica (SiO_2).

The newly developed heterogeneous catalyst was proved effective with a wide range of *β*-amino alcohols **1** to give the 2-oxazolidinone derivatives **2** in fair to high isolated yields (63-86%) as shown in Scheme 1.



Scheme 1



The recyclability of the catalysts has been successfully verified for three consecutive runs.

References:

[1] B. Gabriele, R. Mancuso, G. Salerno, M. Costa, *J. Org. Chem.* **2003**, *68*, 601-604.
[2] G. F. S. Fernandes, C. B. Scarim, S. Kim, J. Wu, D. Castagnolo, *RSC Med. Chem.* **2023**,14, 823-847.
[3] B. Armentano, R. Curcio, M. Brindisi, R. Mancuso, V. Rago, I. Ziccarelli, L. Frattaruolo, M. Fiorillo , V. Dolce, B. Gabriele, A. R. Cappello, *Biomedicines* **2020**, *8*, 35.
[4] R. Mancuso, R., N. Della Ca, L. Veltri, I. Ziccarelli, B. Gabriele, *Catalysts* **2019**, 9, 610.

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ORG-PO-115

Synthesis of organic sensitizers for H_2 evolution in DS-PEC

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Visible-light-driven splitting of water into oxygen and hydrogen, often referred to as "artificial photosynthesis", is an attractive way to convert solar energy into fuels. In this context, dye-sensitized photoelectrochemical cells (DS-PECs) have been deeply investigated as a promising technology to convert solar energy into renewable hydrogen fuel. A crucial strategy to increase the efficiency of DS-PEC is the optimization of the dye used in the sensitization of nanostructured TiO_2 photoanodes, whose electrochemical properties must match those of the ruthenium complex used as water oxidation catalyst (WOC).[1] We designed metal-free sensitizers having a D(donor)–π–A(acceptor) structure (**Figure 1**) according to the photoelectrochemical requirements for applicability in DS-PEC.

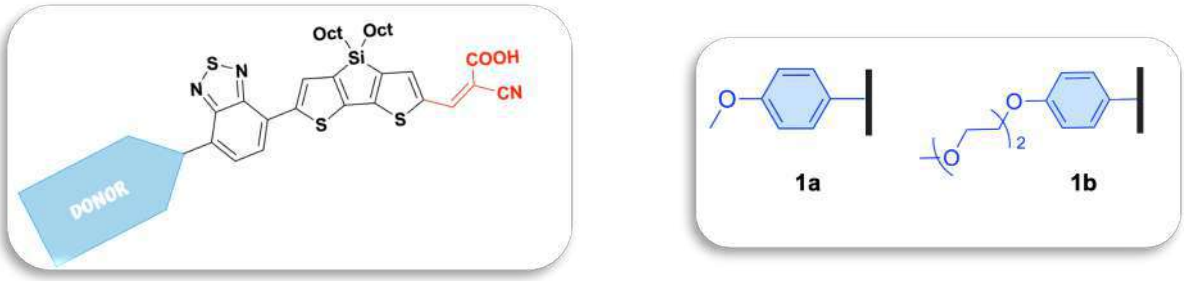

Figure 1: Structures of the designed D–π–A Sensitizers

Taking advantage of the modulation of HOMO energy through the insertion of different donor groups, we synthesized molecules **1a-b** by means of a short sequence featuring a direct arylation reaction as the key step. In this communication, the optimization of the synthetic conditions and the characterization of the final compounds will be described.

Acknowledgments: This research was funded by the European Union – NextGeneration EU through the Italian Ministry of Environment and Energy Security, POR H_2 AdP MMES/ENEA with CNR and RSE, PNRR - Mission 2, Component 2, Investment 3.5 "Ricerca e sviluppo sull'idrogeno", CUP: B93C22000630006.

References:

[1] Zhang, S.; Ye, H.; Hua, J.; Tian, H. *EnergyChem* **2019**, *1*, 100015.

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ORG-PO-116

Metabolomics of Antarctic soils: an NMR and MS-based pilot study

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In Antarctica, ice-free areas can be found along the coast, on mountain peaks, and in the McMurdo Dry Valleys, where microorganisms well-adapted to harsh conditions can survive and reproduce. Metabolic analysis can shed light on the survival mechanisms of Antarctic soil communities from both coastal sites, under different plant coverage stages, and inner sites where slow-growing or dormant microorganisms, low water availability, salt accumulation, and a limited number of primary producers make metabolomic pro-filing difficult. Here we report, for the first time, an efficient protocol for the extraction and the metabolic profiling of Antarctic soils based on the combination of NMR spectroscopy and mass spectrometry (MS)[1]. This approach was set up on samples harvested along different localities of Victoria Land, in Continental Antarctica, devoid of or covered by differently developed biological crusts.
NMR allowed the identification of thirty metabolites (mainly sugars, amino acids and organic acids) and the quantification of just over twenty of them. UPLC-MS analysis identified more than twenty other metabolites, in particular flavonoids, medium and long chain fatty acids, benzoic acid derivatives, anthracenes, quinones.
Our results highlighted the complementarity of the two analytical techniques. Moreover, we demonstrated that their combined use represents the "gold standard" for the quali/quantitative analysis of very little explored samples such as those collected from Antarctic soils.

Acknowledgements
The authors acknowledge the Italian National Programme for Antarctic Research for funding research activities in the framework of projects Whycrust (PNRA 2013/AZ1.19) and MicroBiomA-S (PNRA18_00015). Authors wish to thank the logistic personnel of the Mario Zucchelli Italian station for their support in the field activities during the XXXI and XXXVII Italian Antarctic expeditions.

References:
[1] C. Ciaramelli, A. Palmioli, M. Brioschi, S. Viglio, M. D'Amato, P. Iadarola, S. Tosi, L. Zucconi, C. Airoldi, Int J Mol Sci. (2023) 24, 15, 12340.

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ORG-PO-117

Solid supported Cu(I): an efficient catalyst for additive free C-H amination of benzoxazole

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Among nitrogenous heterocyclic compounds 2-aminoazoles, especially 2-aminobenzoxazoles, possess high relevance due to their biological and pharmaceutical activities.

Selective C-N bond formation of benzoxazoles is usually performed by reactions as Buchwald Hartwig or Ullmann and Goldberg couplings but still some disadvantages are needed to be solved for better agreement with green chemistry criteria. Thus, developing greener and simpler methodologies, the direct amination of aromatic C–H bonds is regarded as a more powerful alternative.

Many transition metals had been exploited as catalysts, however Copper use has risen thanks to its low cost, high functional group tolerance, high environmental abundance and safety, and low overall toxicity.[1, 2]

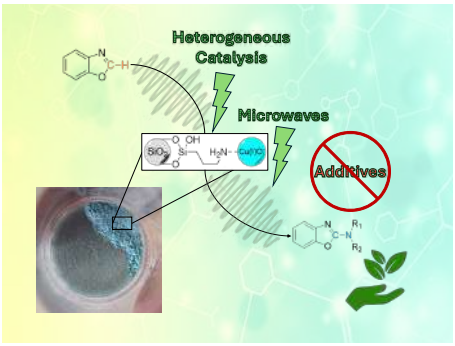

Figure 1: Graphical representation of microwave assisted C-H amination of benzoxazole

Successfully examples of benzoxazole selective C-H amination are reported in literature, however they usually show limits such as the use of stoichiometric amount of an acid or base as a promoter, non-greener peroxide oxidants or solvents, pre-functionalised amino-reactants as well as high temperature.

The aim of the present work is the optimization of a simple, efficient and green direct C-H amination which avoids the use of any acidic, basic or oxidant additive. The reaction was proved to take advantage from microwave irradiation and excellent results were achieved in presence of a silica supported Cu(I) catalyst. The catalyst allowed a convenient isolation of the final product, and a simple procedure for catalyst regeneration was exploited to reuse the catalyst up to eight times without losing catalytic activity.

References:

[1] Martina, K.; Moran, M. J.; Manzoli, M.; Trukhan, M. V.; Kuhn, S.; Van Gerven, T.; Cravotto, G. Organic Process Research & Development 2023, https://doi.org/10.1021/acs.oprd.3c00144

[2] Moran, M. J.; Martina, K.; Bieliunas, V.; Baricco, F.; Tagliapietra, S.; Berlier, G.; De Borggraeve, W. M.; Cravotto, G. Advanced Synthesis & Catalysis 2021, 363 (11), 2850-2860.

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ORG-PO-118

Tandem photo-enzymatic catalysis with imine reductase enzymes (IREDs) in the stereocontrolled synthesis of cyclic amines

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The growing interest in the synergistic use of photocatalysis and biocatalysis, merging the reactivity provided by photocatalysts with the selectivity of enzymes, highlights the potential of photobiocatalysis for achieving novel syntheses of valuable chemicals,[1] for example α-stereogenic amines. Indeed, they are ubiquitous among natural products and active pharmaceutical ingredients (APIs) and are crucial in organic synthesis as chiral auxiliaries and resolving agents. Recently, their preparation via the Dynamic Kinetic Resolution (DKR) of linear and cyclic amines has been improved by the combination of the enzymatic activity of monoamine oxidases (MAOs),[2] and lipases,[3] with different photocatalysts. In this context, our interest in the preparation of cyclic chiral amines has recently brought our attention to imine reductases (IREDs),[4] an emergent class of nicotinamide-dependent enzymes, discovered in 2010 by Mitsukura and co-workers,[5] catalysing the asymmetric reduction of imines. Their use in photobiocatalysis is still unprecedented but given the well-established reactivity of imidoyl,[6] and iminyl radicals,[7] it could provide an original route to *N*-heterocycles.

Here we report the first application of imine reductases (IREDs) in photobiocatalysis in the stereocontrolled synthesis of 2,5-disubstituted pyrrolidines. The presented methodology leverages the photochemical generation of a nitrogen-centred radical which triggers an intramolecular hydroamination of a non-activated alkene. The cyclization is telescoped with the enzymatic reduction of the in situ formed imine, providing the final saturated heterocycle.

References:

[1] M. A. Emmanuel, T. K. Hyster, *et al., Chem. Rev.* **2023**, *123*, 5459 – 5520.
[2] X. Guo, Y. Okamoto, M. R. Schreier, T. R. Ward, O. S. Wenger, *Chem. Sci.* **2018**, *9*, 5052 – 5056.
[3] Q. Yang, F. Zhao, N. Zhang, M. Liu, H. Hu, J. Zhang, S. Zhou, *Chem. Commun.* **2018,** *54*, 14065 – 14068.
[4] D. Arnodo, F. De Nardi, S. Parisotto, E. De Nardo, S. Cananà, F. Salvatico, E. De Marchi, D. Scarpi, M. Blangetti, E. G. Occhiato, C. Prandi, *ChemSusChem*, DOI: 10.1002/cssc.202301243.
[5] K. Mitsukura, M. Suzuki, S. Shinoda, T. Kuramoto, T. Yoshida, T. Nagasawa, *Biosci. Biotechnol. Biochem.* **2011,** *75*, 1778 – 1782.
[6] S. Sharma, A. P. Pandey, A. Sharma, *Adv. Synt. Catal.* **2020,** *362*, 5196 – 5218.
[7] W. Yin, X. Wang, *New J. Chem.* **2019,** *43*, 3254 – 3264.

ORG-PO-119

Radical fluoroalkylation and multicomponent radical polar crossover reaction under continuous flow conditions

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The presence of fluorine atoms in a wide range of pharmaceuticals is well-established, with over 20% of drugs on the market containing at least one fluorine atom.[1] Consequently, the synthesis of complex chemical structures that incorporate fluorine atoms has become a highly sought-after area of research in organic chemistry.[2] The advent of photo(redox)catalysis has enabled the development of new and innovative synthetic methodologies that were previously impossible using traditional ground state pathways. This approach has proven particularly useful in the synthesis of fluorinated compounds. While several strategies have been proposed for generating fluoroalkyl radicals using photocatalytic mechanisms, little research has been conducted on the reactivity of monofluoroalkyl radicals.[3,4,5,6] In this study, we present a novel photocatalytic monofluoroalkylation strategy that employs a decarboxylation of α-fluoro carboxylic acids (Figure 1) in a Giese reaction and in a subsequent multicomponent radical polar crossover reaction for the one-pot synthesis of highly complex chemical structures performed effectively under continuous flow conditions.

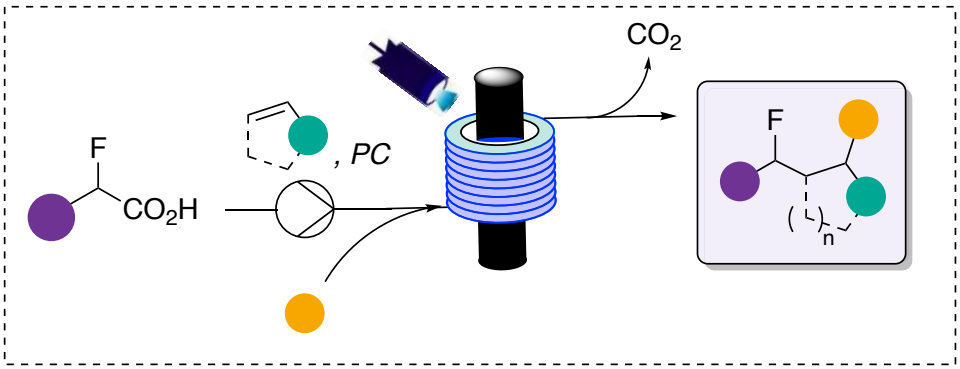

Figure 1: General approach to radical monofluoroalkylation in flow.

References:
[1]. Ming Joo Koh et al., ACS Catal., 2020, 10, 4451−4459.
[2]. David W. C. MacMillan et al., J. Am. Chem. Soc., 2016, 138, 6, 1832–1835.
[3]. Á. Gutiérrez-Bonet and W. Liu, Org. Lett., 2023, 25, 483−487.
[4]. C. Sambiagio, T. Noël, Trend in Chemistry, 2020, 2, 92-106.
[5]. W. Yue, C. S. Day, A. J. B. Rucinski, and R. Martin, Org. Lett., 2022, 24, 5109−5114.
[6]. N. J. Venditto and J. A. Boerth, Org. Lett. 2023, 25, 3429−3434.

ORG-PO-120

Pioneering Low Environmental Impact Methodologies for Polymer Waste Transformation with Deep Eutectic Solvents

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Polymeric materials play a ubiquitous role in nearly every facet of human activity, thanks to their remarkable chemical and mechanical resilience. However, their exceptional properties come at a cost: most polymers are notoriously non-biodegradable, posing a significant ecological challenge due to their persistent accumulation in the biosphere.

In recent years, significant efforts have been focused on reducing plastic consumption and improving chemical recycling methods.[1] However, there is still a pressing need for innovative green technologies to address the recovery, treatment, and chemical recycling of polymer waste. This would enable their transformation into reusable raw materials or high-value products. Among the myriad thermoplastic polymers utilized in daily life and plastic manufacturing, polyethylene terephthalate (PET) and polyurethane (PU) stand out as both prevalent and environmentally detrimental pollutants.

Our research is committed to developing greener and more environmentally sustainable depolymerization techniques as viable alternatives to conventional processes. To achieve this goal, we are investigating the application of Deep Eutectic Solvents (DESs) or their aqueous solutions as reaction media for plastic depolymerization. These solvents offer favorable chemical and physical properties, ease of production and utilization, and recyclability.[2]

In this communication, we present our findings on the DES-promoted depolymerization of PET and PU chains, enabling the recovery of monomers as new raw building blocks for use in the synthesis of other polymers or fine chemicals. This represents a crucial step towards a more sustainable approach to polymer waste management and resource utilization.

Acknowledgements: This research work was funded by Ministero dell'Università e della Ricerca (MIUR) through the PRIN project "REPLAY" (2020SBNHLH_003), Ministero dell'Ambiente e della Sicurezza Energetica (MASE, ex MITE) through the project "GreenChemBioDEP" (H93C22000380001), and by the Apulian Regional Project "Green Chemistry and Biocatalysis for the development of new low environmentally friendly methodologies for the transformation of polymer waste" (996968a3) "Programma Regionale RIPARTI" POC PUGLIA FESR-FSE 2014/2020.

References:

[1] H. Jung, G. Shin, H. Kwak, L. T. Hao, J. Jegal, H. J. Kim, H. Jeon, J. Park, D. X. Oh, *Chemosphere* **2023**, 320.
[2] A.N. Paparella, S. Perrone, A. Salomone, F. Messa, L. Cicco, V. Capriati, F.M. Perna, P. Vitale *Catalysts* **2023**, *13*, 1035.

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ORG-PO-121

New approach for the development of Streptococcus pneumoniae 6A and 6C vaccine

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The control of *Streptococcus pneumoniae* (SPn) infections is a dynamic and evolving field, particularly in developing vaccines that can provide broad protection against different serotypes. The first pneumococcal polysaccharide conjugate vaccine (PCV7), which covered only a few of the many serotypes of SPn, has been expanded over the years to cover more serotypes due to the serotype replacement phenomenon[1], whereby an increase in cases of infection by serotypes not present in available glycoconjugate vaccines (NVTs) is observed. An example is serogroup 6, where serotypes 6A and 6B are included in PCV13 vaccine, but 6C[2] has subsequently shown serotype replacement, highlighting the need for continuous innovation in vaccine design. The use of molecular dynamics simulations[3] represents a novel approach in this regard, allowing researchers to explore conformational differences between serotypes within the group 6. Particularly the study of conformations on capsular polysaccharide (CPS) fragments, allows critical data to be collected to predict cross-protection between serotypes. This information is invaluable in synthesizing the most effective vaccine candidate, particularly for serotypes with similar epitope structures, such as 6A and 6C, and provides an opportunity to hypothesize the structure that will achieve a total cross-reactivity. The CPS repeating units of SPn 6 serotypes have minimal structural differences: 6A and 6C have the same glycosidic linkages, but they differ in their monosaccharide composition, with glucose replacing galactose in 6C[4]. The tetrasaccharide fragments of SPn 6A (Target 1) and 6C (Target 2) serotypes are the primary synthetic goals of this project (Scheme 1). In addition, we designed the 4-deoxy derivative of both tetrasaccharides (Target 3), where the only structural difference between 6A and 6C CPS is removed. According to the retrosynthetic approach, compound **4** was synthesized from a suitable rhamnose derivative, which can be used both as an acceptor for the synthesis of disaccharide **8** and as a donor for the glycosylation of ribitol **9**. Finally, target tetrasaccharides **1**, **2** and **3** have been assembled using the phosphoramidite derivatives **5**, **6** and **7**. The synthetic tetrasaccharides will be eventually conjugated to a carrier protein, and the glycoconjugates obtained will be subjected to in-depth immunological studies. The results will help to identify protective epitopes to be employed for the development of an effective anti-SPn 6A/6C glycoconjugate vaccine. A new approach to pneumococcal vaccine design is needed to stop serotype replacement and consequently the phenomenon of antimicrobial drug resistance, which is estimated to cause 10 million deaths annually by 2050[5].

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ORG-PO-122

Outright DFT method for determining pKa and pKb of small organic compounds.

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We have developed a method characterized by exceptional reliability, for determining the pKa of a wide panel of organic acids, such as phenols[1] and carboxylic acids[2]. Our "easy to use methodology" returned minimum average error (MAE) lower than 0.3 for phenols pKa, and 0.5 for carboxylic acids. Further, it can predict with great reliability the pKa of difficult to model compounds (i.e. trichloroacetic acid) with a simple level of theory[2]. It exploits CAM-B3LYP as functional, the solvation model based on density (SMD) and 6-311G+(d,p) as basis set[1-3]. In our approach, we draw the very first solvation shell, adding two explicit water molecules at the reaction centre. The pKa is calculated applying the ionogenic equation, without the usage of experimental energy values for H^+ nor *ex post facto* correction. Recently, we explored the possibility of applying this methodology in predicting the pKb of primary aromatic and aliphatic amine, obtaining impressive results, *i.e.* MAE=0.3. Such striking result strengthens the reliability of our approach[1-3] providing, for the first time, the possibility to predict the pKa and pKb of small organic compounds with the same methodology, always ensuring trustworthy outputs.

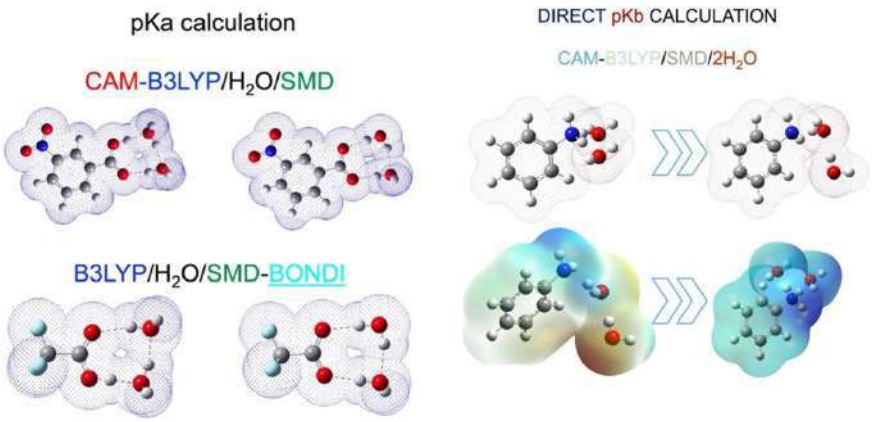

Figure 1: Accurate prediction of the pKa and pKb of small organic compounds in ***one-pot method***. Geometry optimization CAM-B3LYP/SMD/2H_2O/6-311G+(d,p) or B3LYP/SMD-BONDI/2H_2O/6-311G+(d,p).

References:

[1] S. Pezzola, S. Tarallo, A. Iannini, M. Venanzi, P. Galloni, V. Conte, F. Sabuzi, Molecules 2022, 27, 8590.
[2] S. Pezzola, M. Venanzi, P. Galloni, V. Conte, F. Sabuzi, Molecules 2024, 29, 1255
[3] S. Pezzola, M. Venanzi, P. Galloni, V. Conte, F. Sabuzi, Chem. Eur. J. 2024, 30, e202303167

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ORG-PO-123

Preliminary evaluation of new bicyclic chelators for Ac-225 targeted α-therapy

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^{225}Ac is an α-particle emitting isotope studied in nuclear medicine for α-therapy applications. The isotopes generated by radioactive decay of ^{225}Ac have different physico-chemical characteristics compared to the parent nuclide, that can lead to the release of the free isotopes during the in vivo application. One of the chelators most suitable for the stable complexation of ^{225}Ac is the 4,13-diaza-18-crown-6 macrocycle functionalized with picolinic arms (Macropa).[1] Unfortunately, one of the main problem of such ligand for the ^{225}Ac radiolabelling is the possible release of ^{221}Fr or ^{213}Bi after radioactive decay of the parent radionuclide.

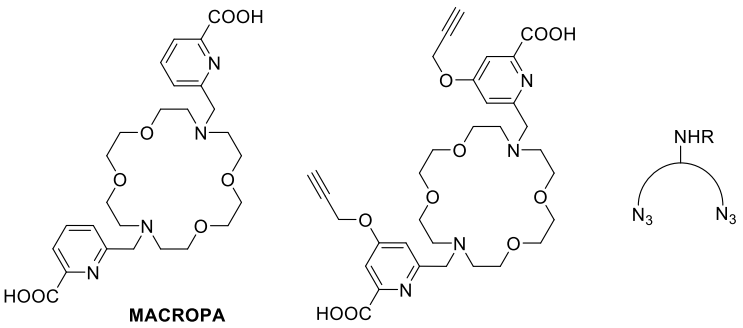

Figure 1: Macropa, funzionalized macropa and the bis-azide containing element

In this work we synthetized the bis-alkyne ligand in Fig.1 through the alkylation of the 4,13-diaza-18-crown-6 macrocycle with methyl 6-(chloromethyl)-4-(prop-2-yn-1-yloxy)picolinate as already reported in literature[2]. Two bis-azide-functionalized amines are then synthetized with different lengths with the aim to obtain a macrobicyclic structure able to create a cage around the isotopes preventing the release of both parent and daughter isotopes. The Cu(I) catalyzed Azide-Alkyne reaction has been carried out on the La(III) complex that is considered the non-radioactive surrogate of Actinium. The bicyclic La(III) complex has been characterized via ^{1}H NMR and the its kinetic inertness evaluated in acidic conditions.

After these preliminary studies, the amino groups on the closing molecules will be used for the bioconjugation of the radiopharmaceutical with biomolecules for targeting purposes.

References:

[1] N.A. Thiele, et al. Angew. Chem., Int. Ed. 2017, 56, 14712−14717.
[2] F. Reissig, D. Bauer, Cancers 2021, 13, 8.

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ORG-PO-124

Efficient Catalytic Reduction of Nitroarenes Using Zirconium Carboxy-Aminophosponate Nanosheets Loaded with Nickel Nanoparticles

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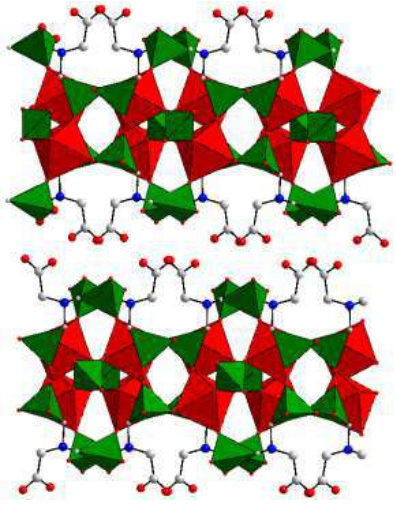
Supported metal nanoparticles are widely explored for their sustainability, activity and recyclability. Among metal nanoparticles, nickel nanocatalyst is the preferred choice due to its availability, minimal toxicity, and low cost.[1] As known, a careful choice of the support plays a pivotal role in designing stable and high active supported metal NPs catalysts. In this context, layered zirconium phosphate and phosphonates with high surface area offer an attractive support for metal nanoparticles because of their chemical and thermal stability, along with a facile tunability of their structural features.[2-5]



Polyhedral representation of ZrPGly

Zirconium phosphate carboxy-aminophosponates (ZrPGly) possess a layered structure with exposed phosphonate and carboxylic groups on the surface, allowing efficient interactions with cations. To increase the accessibility, the solid was completely exfoliated in water by adding n-propylamine, resulting in a stable dispersion of zirconium phosphonate nanosheets. The ion exchange with a solution of nickel acetate provides zirconium carboxy-aminophosponate nanosheets loaded with nickel as a green pale solid (**Ni@ZrPGly**). The resulting Ni-catalysts were fully characterized and tested in the reduction of nitroarenes with $NaBH_4$ at room temperature. The catalytic system proved its efficiency as it was reused for five cycles with a negligible loss of catalytic activity and with a very low Ni leaching.

References:

[1] A. Ghatak, M. Das. ChemistrySelect **6** (2021) 3656-3682.
[2] F. Costantino, R. Vivani, M. Bastianini, L. Ortolani, O. Piermatti, M. Nocchetti, L. Vaccaro. Chem Commun. 2015, 51, 15990-15993.
[3] V. Kozell, T. Giannoni, M. Nocchetti, R. Vivani, O. Piermatti, L. Vaccaro. Catalysts 2017, 7, 186.
[4] O. Rosati, D. Lanari, R. Scavo, D. Persia, D.; Marmottini, F.; Nocchetti, M.; Curini, M.; Piermatti O. Microp. and Mesop. Mater. 2018, 268, 251-259.
[5] F. Ferlin, M. Cappelletti, R. Vivani, M. Pica, O. Piermatti, L. Vaccaro. Green Chem 2019, 21, 614-626

ORG-PO-125

Characterization of the protein fraction by high resolution mass spectrometry reveals specific post translational modifications in extracellular vesicles secretes by astrocytes

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Parkinson's disease (PD) is characterized by the progressive loss of dopaminergic (DAergic) neuronal cell bodies in the ventral midbrain (VMB) and their terminals in the striatum (STR). Astrocytes (AS) play a crucial role in maintaining the homeostasis of DAergic neurons, and extracellular vesicles (EVs) secreted by astrocytes (AS-EVs) can have either destructive or beneficial effects [1]. To identify the mechanisms involved in the neuroprotective effects of AS-EVs, we have characterized their protein fraction and specific post translational modifications (PTMs), comparing vesicles secreted by astrocytes from the VMB vs. the STR, both in basal conditions (AS-EVs CTRL) and activated by the pre-treatment with the neuroprotective chemokine CCL3 (AS-EVs CCL3) [2].

Intact EVs were purified from primary cultures of postnatal VMB and STR astrocytes. EVs were lysed using 0.1% RapiGest SF and proteins were reduced with DTT, alkylated with iodoacetamide and digested using trypsin. Analysis was conducted in triplicate by a shotgun approach and nanoUHPLC/High-Resolution nanoESI-MS/MS [3].

The results showed a different protein content and a different pattern of PTMs in AS-EVs CTRL and AS-EVs CCL3 extracted from VMB and STR. In particular, we focused the attention on PTMs related to protection and degradation pathways of proteins as ubiquitination, SUMOylation, oxidation, phosphorylation and deamidation. The assignment of functional roles to these PTMs will be a further step towards the full understanding of the impact of EVs on neurodegeneration.

Overall, our study suggests the existence of a molecular machinery capable of organizing the sorting of specific proteins towards EVs, in nigrostriatal astrocytes. Furthermore, it implies the possibility that secreted proteins with specific PTMs may have specific functions when transferred to target cells and thus the reprogramming of AS-EVs as a novel strategy for brain repair. Finally, the knowledge generated within this study may pave the way for the development of innovative therapeutic approaches to tackle PD.

References:

[1] B. Marchetti, et al., J. Clin. Med., 2020, 9, 1941.
[2] L. Leggio, et al., Adv. Healthc. Mater., 2022, e2201203.
[3] M.G.G. Pittalà, et al., Int. J. Mol. Sci., 2021, 22, 12833.

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ORG-PO-126

Synthesis of Bivalent Natural Products-Based Inhibitors of SARS-CoV-2 Spike Protein

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SARS-CoV-2 is a virus responsible for COVID-19 pandemic, which caused more than 6.7 million deaths worldwide. Viral mutations could compromise the efficacy of vaccines, so developing drugs capable of suppressing viral replication to treat COVID-19 remains an open therapeutic challenge. In SARS-CoV-2 morphology, a crucial region is the receptor-binding domain (RBD), located in subunit S1 of Spike glycoproteins, since it is involved in the binding with Angiotensin-Converting Enzyme 2 (ACE2)[1] receptor of human cells in the early internalization step. Through virtual screening of the RBD active recognition region, several natural products (NPs) capable to bind in two different portions of the RBD were identified. Triterpenoids were reported as pocket 1 binders, while bile acids derivatives should bind to pocket 5.[2] In this work, bivalent compounds formed by a triterpenoid and a bile acid linked by a spacer were developed, with the aim of obtaining more potent and selective antiviral molecules capable of blocking the fusion between SARS-CoV-2 and host cell. Computational studies have guided the synthesis, providing indications on the size and flexibility of the compounds. Azide-alkyne cycloadditions and amide couplings were used as synthetic strategies to connect the selected triterpenoids (betulinic acid and glycyrrhetinic acid) and bile acid (obeticolic acid). Neutralization assays using pseudotyping lentiviral particles with specific SARS-CoV-2 Spike proteins were performed to evaluate the antiviral activity of these bivalent compounds, demonstrating a higher ability to reduce SARS-CoV-2 infection than single natural products.

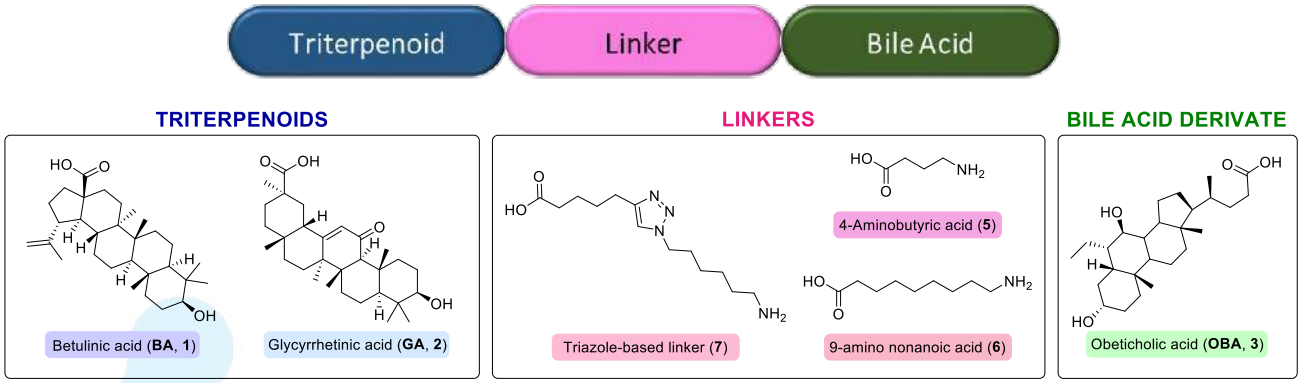

Figure 1: *Schematic structure of synthesized NPs-bivalent compounds to inhibit SARS-CoV-2 Spike protein.*

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Stereoselective Sustainable Synthesis of α,β-Unsaturated Esters via Horner-Wadsworth-Emmons reaction in Deep Eutectic Solvents

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α,β-Unsaturated esters represent a class of organic compounds commonly encountered in nature and utilized in various applications. They are frequently found as components in essential oils for perfume production and also serve as key substrates for synthesizing pharmacologically active compounds.[1] Among various synthetic methodologies, the Horner–Wadsworth–Emmons (HWE) reaction is commonly employed for the synthesis of (E)-α,β-unsaturated esters.[2] In this work, we present a straightforward, scalable and environmentally friendly protocol for synthesizing (E)-α,β-unsaturated esters via the HWE reaction.[3]

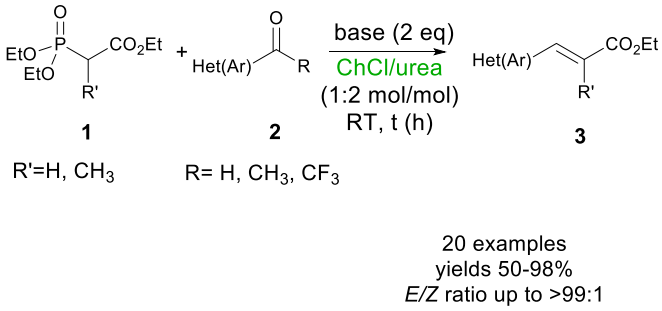

Figure 1: Stereoselective syntheses of α,β-unsaturated esters by HWE.

This innovative method employs deep eutectic solvents, known for their non-toxic, biodegradable, and cost-effective properties, thereby eliminating the need for volatile organic compounds. Highly efficient HWE reactions were successfully conducted using choline chloride/urea (1:2 mol/mol) as a solvent, under mild conditions at room temperature. The reactions exhibited excellent yields (50-98%) and *E*/*Z* ratios (up to 99%). Notably, this protocol demonstrates remarkable stereoselectivity in synthesizing (*E*)-α,β-unsaturated esters **3** from **1** and (hetero)aromatic aldehydes and ketones **2** containing halogens, electron-withdrawing, and electron-donating groups (**Figure 1**).

References:

[1] J. B. Metternich and R. Gilmour, *J. Am. Chem. Soc.,* **2016**, *138*, 1040–1045.
[2] (a) E. B. Maryanoff, A. B. Reitz, *Chem. Rev*., **1989**, *89*, 863; (b) M. A. Blanchette, W. Choy, J. T. Davis, A. P. Essenfeld, S. Masamune, W. R. Roush, T. Sakai, *Tetrahedron Lett*., **1984**, *25*, 2183.
[3] A. N. Paparella, M. Stallone, M. Pulpito, F. M. Perna, V. Capriati, P. Vitale, *Org. Biomol. Chem.*, **2024**, 22, 1885–1891.

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ORG-PO-128

Preclinical pharmacokinetic investigation of BAR502 metabolic profile

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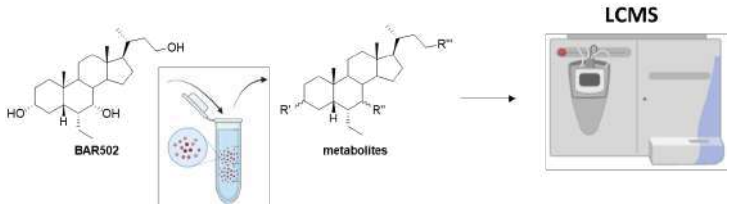
GPBAR1 and FXR have been found to be the two most involved receptors in inflammatory liver conditions. Currently, the only semi-synthetic steroid derivative to have been successfully employed in human therapy for primary biliary cholangitis (PBC) is obeticholic acid (OCA).[1] Its only drawback is the induction of a moderate to severe itching in treated patients. To identify a safer alternative to OCA, my research team performed extensive modifications to the bile acid scaffold and was able to identify several selective or dual FXR/GPBAR1 agonists.[2] Among these, BAR502 emerged from the pharmacological studies were carried out as the most active without inducing itching. It is a double FXR/GPBAR1 agonist and has a shortened side chain. It is a 3,7,23-triol that shares the same stereochemistry as the substituents on rings A and B with OCA. BAR502 was also tested in several *in vivo* tests such as HFD and CCl_4 induced damage models. The excellent results from all of these tests prompted the start of phase I clinical trial: safety, tolerability, pharmacokinetics, and pharmacodynamics of BAR502 in healthy subjects.[3] Subsequent *in vitro* studies were executed by incubating the molecule in two well-known enzymatic systems and then analysed by LC-MS. To this end, conceivable metabolites both identified in our enzymatic assays or hypothesized as plausible by rational biotransformation prevision were synthesized and used as analytical standards.[4] Obtained analyses and fragmentations spectra perfectly overlap with the authentic standard assuring high confidence in the identification.



References:

[1] Girisa, S.; Henamayee, S.; Parama, D.; Rana, V.; Dutta, U.; Kunnumakkara, A. B. Molecular biomedicine 2021, 2 (1), 21.

[2] Festa, C.; Renga, B.; D'Amore, C.; Sepe, V.; Finamore, C.; de Marino, S.; Carino, A.; Cipriani, S.; Monti, M. C.; Zampella, A.; Fiorucci. J Med Chem 2014, 57 (20), 8477–8495.

[3] Carino, A.; Cipriani, S.; Marchianò, S.; Biagioli, M.; Santorelli, C.; Donini, A.; Zampella, A.; Monti, M. C.; Fiorucci, S. Nature Publishing Group 7, 42801 (2017)

[4] Hofmann, A. F.; Zakko, S. F.; Lira, M.; Clerici, C.; Hagey, L. R.; Lambert, K. K.; Steinbach, J. H.; Schteingart, C. D.; Olinga, P.; Groothuis, G. M. M. Hepatology 2005, 42 (6), 1391–1398.

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ORG-PO-129

Novel approaches toward sp^2-sp^3 medicinal chemistry relevant scaffolds

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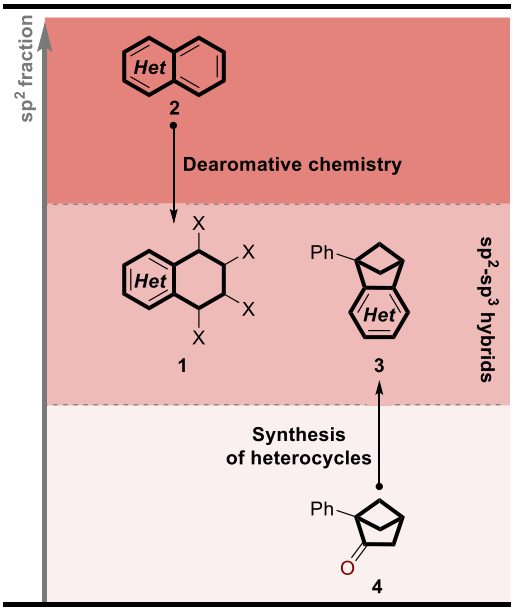

Figure 1: Two approaches to sp^2-sp^3 hybrids, increasing and decreasing the sp^2 fraction.

Over the past years, sp^2-sp^3 hybrids are emerging as medicinal chemistry relevant building blosks[1–3] attracting the interest of the synthetic community. In this communication two different strategies to reach sp^2-sp^3 hybrids will be discussed (**Figure 1**). The first one relies on the development of a dearomative platform for the synthesis of (amino)cyclitols-aryls sp^2-sp^3 hybrids **1**,[4] this approach allows to reduce the sp^2-fraction of polynuclear aryls and (hetero)aryls **2**, giving access to aryl condensed cyclohexane rings.
In the second approach the sp^2-fraction of the ketone **4** has been increased exploiting the ketone chemistry to get (hetero)aryls-bicyclo[2.1.1]hexanes sp^2-sp^3 hybrids **3**. Those scaffolds represent an attractive class of benzene rings bioisosteres.[5]

References:

[1] D. Tomohiro, Y. Hiroki, N. Takahiro, α, β-UNSATURATED AMIDE COMPOUND, December 27, 2018.
[2] K. D. Janda, T. J. Dickerson, Nicotine Immunoconjugates. WO2009120954A2, October 1, 2009.
[3] R. Graceffa, M. Kaller, D. La, P. Lopez, V. F. Patel, W. Zhong. Substituted Pyrano [2,3-b] Pyridinamine Compounds as Beta-Secretase Modulators and Methods of Use. US20100120774A1, May 13, 2010.
[4] E. Angelini, M. Martinelli, E. Roà, C. N. Ungarean, C. Salome, Q. Lefebvre, C. Bournez, T. C. Fessard, D. Sarlah, Chem.Eur. J. 2024, 30, e202303262.
[4] A. Denisenko, P. Garbuz, Y. Makovetska, O. Shablykin, D. Lesyk, G. Al-Maali, R. Korzh, I. V. Sadkova, P. K. Mykhailiuk, Chem. Sci. 2023, 14, 14092–14099.

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Hit-to-lead optimization of flavone-based tyrosine kinase inhibitor inhibiting L858R/T790M EGFR activation in NSCLC

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EGFR is one of the most molecular targets in non-small lung cancer (NSCLC) where the mutant forms of EGFR are expressed. The efficacy of tyrosine kinase inhibitors (TKIs) could be compromised by additional mutations in EGFR. Since several flavonoid have been reported to possess protein kinase inhibitory activity [1-2], a flavone core was used as a scaffold for the design of novel ATP-competitive inhibitors. The core is modified by introducing several chemical groups able to interact with the key regions of the ATP-binding pocket. A homemade virtual library was generated, and a three-track virtual screening was made to identify compounds with a higher affinity toward both mutated forms with respect to the wild type one. This process allowed us to select two novel flavone-based TKIs (FL4 and FL5), that were then synthetized and tested in kinase enzyme assay. One of these two hits compound (FL4) shows effective selectivity against both $EGFR^{L858R/T790M}$ and $EGFRL^{858R/T790M/C797S}$ while sparing the wild type ones [3]. At this point, our goal was to optimize this hit compound to obtain a lead compound with a better efficacy profile. We also aimed to improve its lipophilicity profile. The LogP of compound FL4 is 6.9, a value that does not comply with one of Lipinski's 5 rules (LogP<5). Starting from this hit compound, novel TKIs are therefore designed to obtain molecules with nanomolar inhibitory activity. Molecular Docking approach was used for the identification of the most promising compound (F2) which was then synthetised and tested in the enzyme-based assay. This novel flavone compound showed an IC50 of 0.1 μM against EGFRL858R/T790M form, 120-times lower with the respect to compound FL4 and it did not inhibit the phosphorylation of wild type EGFR. Finally, it can be stated that the new lead compound also has a better lipophilicity profile compared to compound FL4, with a LogP value of 4.

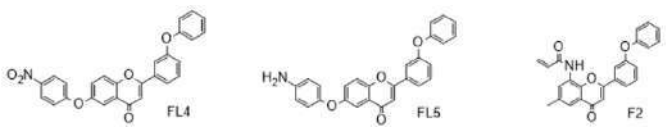

Figure 1

References:
[1] C. Minnelli, E. Laudadio, G. Mobbili, R. Galeazzi, IJMS 2020, 21, 1721
[2] F. Teillet, A. Boumendjel, J. Boutonnat, X. Rono Med. Res. Rev. 2007, 28, 715-745
[3] C. Minnelli, E. Laudadio, et al. Bioorganic Chemistry 2022, 129, 106219

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Structural Identification of the main Impurities of Voclosporin, a semisynthetic API with immunosuppressant Activity

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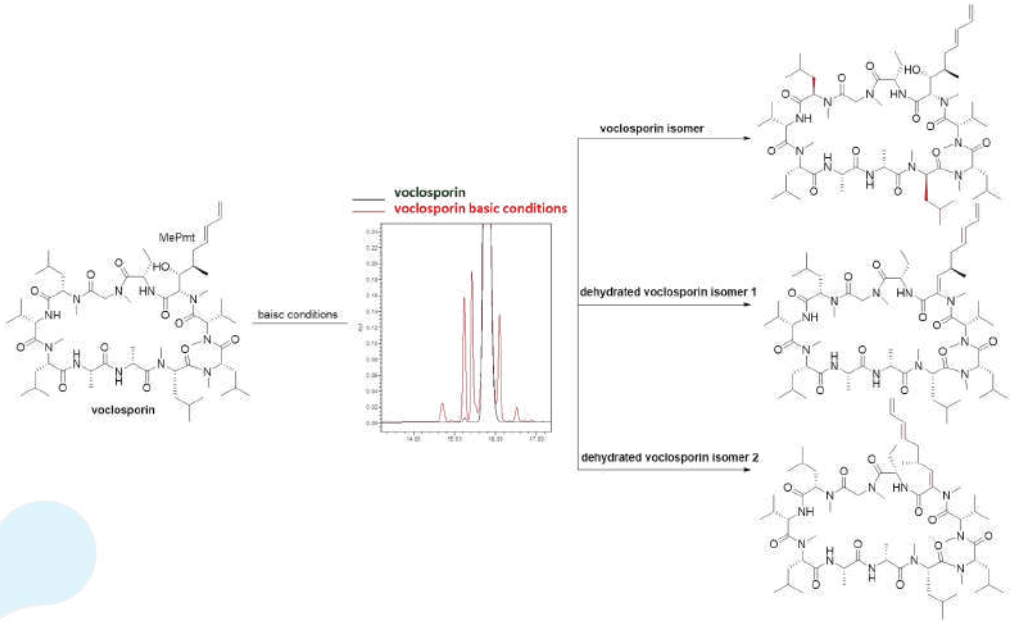
Voclosporin (tradename: LUPKYNIS) is a semisynthetic immunosuppressant drug derived from cyclosporin A. The presence of a diene system instead of a single double bond, at the noncoded amino acid methyl-pentadienyl-*N*-methylthreonine (MePmt1), gives higher activity and lower toxicity than cyclosporine A,[1] enough to be approved by FDA in 2021 for the treatment of Lupus nephritis.

In the development of the API process, the study of the potential impurities which could arise during the synthesis, purification and storage, is a key aspect.[2] The most critical impurities of voclosporin are generated due to the instability of this API in basic conditions.

Three main impurities were synthesized, isolated and their structures were elucidated by orthogonal analytical techniques such as LC-MS, mono and bi-dimensional NMR. One of them was identified as an isomer of voclosporin, produced by epimerization of specific stereogenic centres in the cyclic undecapeptide, while the other two impurities are dehydrated voclosporins, generated by elimination reaction of the hydroxyl group at the noncoded amino acid (MePmt1).



Scheme 1: voclosporin impurities generated in basic conditions.

References:

[1] T. Van Gelder, E. Lerma, K. Engelke, R. Huinzinga, Expert Rev. Clin. Pharmacol., 2022, 15 (5), 515–529.
[2] ICH Q 3 A (R2) Impurities in new Drug Substances.

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ORG-PO-132

Synthesis of phlorotannins as potential antifungal agents

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Plant diseases are caused by pathogenic microorganisms, mainly fungi, which affect the quality and the yield of produced crops, causing losses up to the 30% at all stages of crop production. Pathogen control has been effectively performed mostly by synthetic fungicides. However, nowadays only a few of them are allowed worldwide, and their continuous use has resulted in resistance emergence and spread of several pathogenic fungi.[1] Furthermore, synthetic pesticides have created a high environmental impact over the years, also causing bioaccumulation. To address the growing urgency in managing fungal diseases, there is the need to find novel compounds able to effectively inhibit pathogens, with lower human and environmental impact. In this context, the development of natural and nature-derived agrochemicals is a promising strategy.

In the last decades phlorotannins emerged as an important class of polyphenols. They are isolated from various brown seaweeds as a very complex mixture of phloroglucinol oligomers. In the present work, given the promising antifungal activity showed by the phlorotannin crude extracts,[2] phloroglucinol dimers, namely diphenylethers and biphenyls (Figure 1) were synthesized. The potential antifungal activity of the single pure compounds and their methylated/acetylated analogues (Figure 1) was investigated. Furthermore, Differential Scanning Calorimetry (DSC) experiments were designed to study the potential interaction of the bioactives with the phospholipidic membrane[3] of pathogenic fungi.

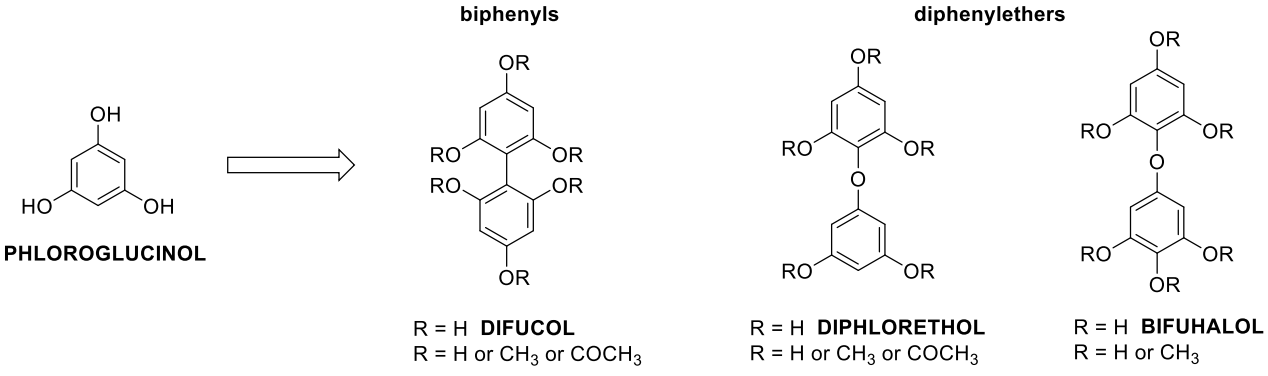

Figure 1: Structure of natural dimers difucol, diphlorethol, bifuhalol and derivatives

References:

[1] A. Kunova, C. Pizzatti, M. Bonaldi, P. Cortesi, *Pest Manag Sci*, 2016, 72, 398–404

[2] U. De Corato, R. Salimbeni, A. De Pretis, N. Avella, G. Patruno, *Postharvest Biol. Technol.*, 2017, 131, 16–30

[3] M.H. Lee, K.B. Lee, S.M. Oh, B.H. Lee, H.Y. Chee, *J. Korean Soc. Appl. Biol. Chem.*, 2010, 53(4), 504–507

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Tailored Metal Porphyrin-Based Electrocatalysts for Artificial Nitrogen Fixation to Ammonia

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Ammonia is an essential raw ingredient for fertilizers, a carbon-free hydrogen carrier, and an alternative fuel. The over one-century old Haber-Bosch process is still used today for the synthesis of ammonia, from nitrogen and hydrogen, but it is strongly energy demanding (ca. 2% of global energy demand) and generates massive greenhouse gases (ca. 2% of global emissions). It is therefore mandatory to develop clean access to ammonia to match the net zero decarbonation targets for 2050. Recently, research has focussed attention on alternative routes and, among those proposed, the electrocatalytic reduction from nitrogen to ammonia is the most accredited. The strongly inert N_2 molecule can be activated thought an electrocatalytic approach under mild conditions. However, so far, the use of organic-based electrocatalysts is very rare in the literature and systematic studies are almost absent.

Following our previous general approach for organic design for solar generation of green hydrogen,[1] in this communication we present our recent preliminary work on the investigation of a series of metal-porphyrins, which have been properly functionalized to enhance nitrogen fixation performance (**Figure 1**). We have developed two series of hydrophilic and hydrophobic derivatives, able to show different interactions at the interface with the aqueous electrolytic environment of the electrochemical cell, thus affecting the device interface phenomena and, eventually, the final response.

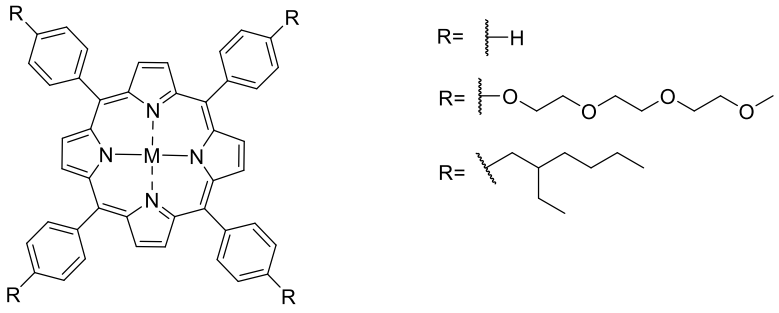

Figure 1: metal-porphyrins functionalized to enhance nitrogen fixation performance.

References:

[1] Boldrini, C. L.; Quivelli, A.F.; Manfredi, N.; Capriati, V.; Abbotto, A., *Molecules* **2022**, G. Salerno, B. Cecconi, O. Bettucci, M. Monai, L. Zani, D. Franchi, M. Calamante, A. Mordini, T. Montini, P. Fornasiero, N. Manfredi, A. Abbotto, *EurJOC* **2023**, 26.

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Metabolomic Analysis of *Malus domestica* (Suckow) Borkh. Varieties From Molise Region (Italy) by NMR and Mass Spectrometry

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Apples (*Malus domestica* Borkh.) are one of the most extensively produced and consumed fruits worldwide[1] and represent an important source of bioactive compounds like polyphenols which are responsible for their antioxidant and anti-inflammatory properties and possess a role in the prevention of degenerative diseases[2]. The proposed project is based on the valorization of the Molise region, exploiting specific autochthonous cultivars belonging to *Malus domestica*: although the nutritional characteristics of these species are well known, knowledge of the Molise products is still incomplete compared to other Italian regions (e.g., Annurca apple of Campania region). Thus, the comprehensive phytochemical investigation of metabolomes of these cultivars represents a partially unexplored research field that could be helpful to trace and/or complete their fingerprint. The metabolomic profile will be assessed through a quali-quantitative determination of the constituents of each selected variety by 1D and 2D NMR Spectroscopy for the polar extracts while UHPLC coupled to Mass Spectrometry will be applied to identify fatty acids in the apolar extracts. Chemometric analysis with the PCA and PLS-DA techniques will be performed in order to observe differences among the varieties. Moreover, LC-MS/MS will be applied to identify polyphenols obtained with a specific extraction protocol with the aim to disclose active secondary metabolites that can be used for nutraceuticals, cosmeceuticals, food supplements and cosmetics. Furthermore, the total phenolic, flavonoids, and condensed tannins content will be assessed, and in vitro antioxidant activity will be evaluated by using DPPH scavenging activity, the ABTS scavenging assay, and ferric-reducing antioxidant power (FRAP).

References:

[1] T. C. Pires, M.I. Dias, Food chemistry 2018, 240, 701-706.
[2] E. I. Geană, C. T. Ciucure, Foods 2021, 10.2: 267.

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Waste-minimized C(sp3)-H activation for the preparation of fused N-heterocycles

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One of the most effective strategies for reducing environmental pollution associated with chemical production is the use of efficient catalytic reactions. Transition-metal-catalyzed C–H functionalization technologies have emerged as a valid alternative to traditional cross-coupling reactions for the effective formation of carbon-carbon and carbon-heteroatom bonds. Particularly, heterogeneous palladium catalysts have received widespread attention because they can be easily separated from the reaction mixture and reused.[1]

Nitrogenous heterocyclic compounds, such as oxindoles and pyrrole derivatives, are important structural motifs in many molecules of biological and pharmaceutical interest.[2] Herein we present the development of a waste-minimized protocol for the synthesis of oxindoles using cyclopentyl methyl ether (CPME) as a safe and green reaction medium and palladium on carbon (Pd/C) as a reusable catalyst, up to at least 4 reaction runs, with negligible loss of reactivity and stability, with low values of palladium leaching in solution. Meanwhile, the E-factor calculated for this protocol is very low demonstrating its validity from a sustainable point of view.[3] Then we developed an effective waste minimized approach for the intramolecular Pd-catalyzed C(sp3)-H activation of methyl pyrrole derivatives, by using of a heterogeneous recyclable palladium(II)-bis(N-heterocyclic carbene) catalyst and CPME, the heterogeneous catalytic system could be recovered and reused up to representative five runs without any loss in efficiency. The target products have been obtained selectively and with excellent isolated yields and the approach leads to the definition of a protocol with a very good E-factor.[4]

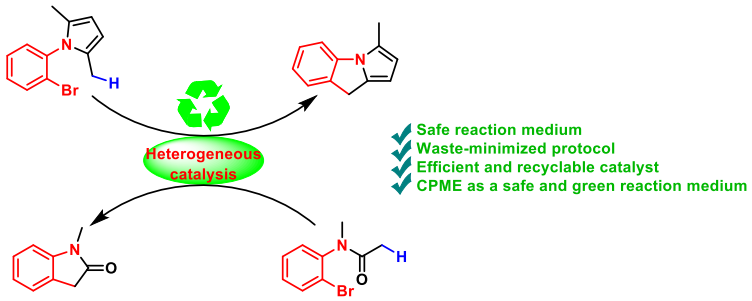

Figure 1: Waste-minimized C(sp3)-H activation for the preparation of fused N-heterocycles.

References:

[1] F. Valentini, H. Mahmoudi, L.A. Bivona, O. Piermatti, M. Bagherzadeh, L. Fusaro, C. Aprile, A. Marrocchi, L. Vaccaro, 2019, 7, 6939-6946.
[2] T. Rogge, N. Kaplaneris, N. Chatani, J. Kim, S. Chang, B. Punji, L. Schafer, D. Musaev, J. Wencel-Delord, C. Roberts, R. Sarpong, Z. Wilson, M. Brimble, M. Johansson, L. Ackermann, 2021, 43, 1–31.
[3] N. Salameh, I. Anastasiou, F. Ferlin, F. Minio, S M. Chen, S. Santoro, P. Liu, Y L. Gu, L. Vaccaro, 2022, 522, 112211.
[4] N. Salameh, F. Minio, G. Rossini, A. Marrocchi, L. Vaccaro, 2023, 4, 240-245.

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ORG-PO-136

Pentaerythritol Tetra Esters: a Novel Spiro DiKetal Mediated, Water Catalyzed Synthetic Method is Presented

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Pentaerythritol tetra esters are widely used as additives in the lubricant oils industry.[1] A novel two step one pot convenient method for the preparation of these molecules will be presented. Pentaerythritol is a notoriously problematic molecule because of its poor solubility in almost all organic solvents. This characteristic makes the synthesis of its esters very difficult, resulting in the creation of synthetic procedures over the years that are characterized by high solvent consumption, long reaction times and the use of dangerous reagents like thionyl chloride.[2] This new method unlocks the possibility of preparing larger amounts of esters in smaller reaction mixture volumes thanks to the key intermediate 3,3,9,9-Tetramethyl-2,4,8,10-tetraoxaspiro[5.5]undecane. The reaction proceeds in 3 major steps: first, the spiro diketal is prepared; then, it react in the presence of a catalytic amount of acid with trace amounts of water in the solvent that act as initiator, hydrolysing one ketal. The two hydroxyl groups liberated are then able to undergo esterification, yielding water that continue the cycle. The method will be tested on other polyalchols to increase its applicability

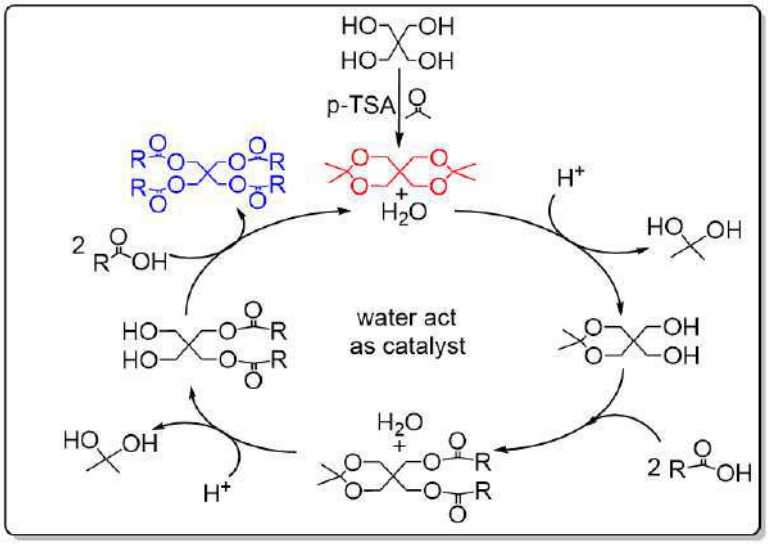

Figure 1: : spiro diketal mediated, water catalyzed pentaerythritol esterification.

References:

[1] Cottington, R. L.; Ravner, H.; Sniegoski, P. J. *E Trans.* **1971**, *14* (3), 163–169..

[2] Padmaja, K. V.; Rao, B. V. S. K.; Reddy, R. K.; Bhaskar, P. S.; Singh, A. K.; Prasad, R. B. N. *Ind. Crops Prod.* **2012**, *35* (1), 237–240.

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Calixarene derivatives reduce α-synuclein-induced toxicity in a Parkinson's disease model

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Parkinson's disease (PD) is one of the most common neurological disorders, with a growing trend and a heavy impact on persons and public health systems, in particular in developed countries with elderly populations. A PD molecular hallmark is the accumulation of intracellular inclusions (Lewy bodies) containing misfolded and aggregated α-synuclein (AS) in oligomeric form. AS is a small protein abundant in the brain, primarily found in nerve terminals, involved in the regulation of vesicle trafficking network. Targeting lysine in AS, especially in its partially conserved motif KTKEGV, could prevent its aggregation due to the role of this amino acid in stabilizing toxic oligomers.[1] Starting from the well-known ability of negatively-charged calix[4]arenes to complex lysine side chain,[2] we prepared different anionic calix[4]arenes as potential ligands of AS. These were tested (Fig. 1) in a yeast model of PD that overexpresses AS leading to the formation of toxic oligomers associated to intracellular foci, causing global cellular dysfunction. We observed that some of the calix[4]arenes indeed counteract AS-induced toxicity, through the reduction of oligomer formation, restoring different metabolic pathways impaired by AS and hindering other damaging events such as oxidative stress.

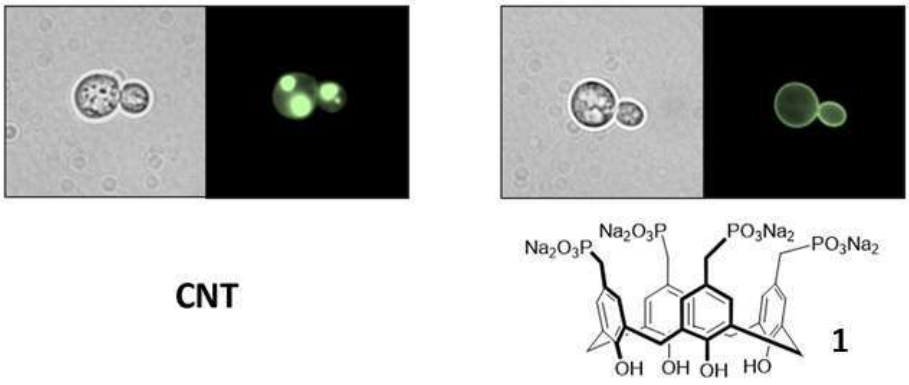

Figure 1: Calix[4]arene **1** affects AS localization and toxic inclusion accumulations. AS oligomers in intracellular foci are observed in untreated yeast cells (CNT; *left*), but not in cells treated with **1** (*right*).

References:

[1] V. Oliveri, *Eur. J. Med. Chem.*, 2019, 167, 10–36.
[2] P. B. Crowley, *Acc. Chem. Res.*, 2022, 55, 15, 2019–2032.

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ORG-PO-138

Development of copper-catalyzed regio- and stereoselective tandem functionalizations using strained heterocyclic rings

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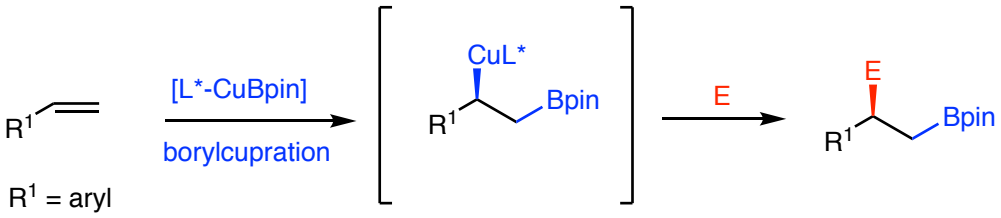
The synthesis of complex molecules through efficient and streamlined processes represent one of the most coveted goals in organic synthesis. In this sense, multicomponent reactions represent nowadays a fascinating as well as challenging method that provide access to variously functionalised building blocks, starting from readily available reactants with a higher atom and step economy.[1,2] In this context, three-component copper-catalysed borylative difunctionalization of olefins has become a powerful method for a concomitant installation of a C–C bond and a boryl group.[3] These procedures pave the way for an easy access to borylated building blocks, of great interest in organic chemistry due to their exclusive reactivity and divergent synthetic capability. As shown in **Scheme 1**, a boryl-copper species formed *in situ* undergo an insertion an alkene and the resulting alkyl-copper intermediate is then intercepted by an electrophile (E) to generate the desired product bearing a boryl group.[3,4] On these bases, we developed some novel three-component stereoselective copper-catalysed tandem procedures, consisting in an overall assembly of a styrene molecule, a pinacol-borane (BPin) unit and strained heterocyclic rings as the electrophilic partners.



Scheme 1: General mechanism for three-component borylative difunctionalisation of alkenes.

References:

[1] E. Ruijter, R. Scheffelaar, R. V. A. Orru, *Angew. Chem. Int. Ed.*, 2011, **50**, 6234 – 6246.
[2] Q. Guan, L. Zhou, Y. Dong, *J. Am. Chem. Soc.*, 2023, **145**, 1475 – 1496.
[3] A. Whyte, A. Torelli, B. Mirabi, A. Zhang, M. Lautens, *ACS Catal.*, 2020, **10**, 11578 – 11622.
[4] C. Borner, L. Anders, K. Brandhorst, C. Kleeberg, *Organometallics*, 2017, **36**, 4687 – 4690.

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ORG-PO-139

CATALYSIS *VIA* DISPERSION FORCES IN VISIBLE-LIGHT-PROMOTED REACTIONS

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The generation of (bi)radical intermediates under mild conditions has opened broad synthetic opportunities during the last century, but these reactive intermediates are present in solution in tiny concentrations, and they require a tailored tuning of experimental parameters to efficiently convert substrates into desired products. Here, we report a general approach that can overcome those limitations using bi-naphthyl derivatives. These species can act catalytically in energy-transfer mediated processes, showing a dramatic effect on the efficiency of several visible-light promoted reactions,[1] such as the E/Z isomerization of conjugated alkenes, and a [1,5]-HAT/cyclization[2] or an arene para-cycloaddition of functionalized allenamides[3] (Figure 1). These results show that this family of bi-naphthyl derivatives represent a new class of catalysts, which might become widely used for several photocatalytic applications.

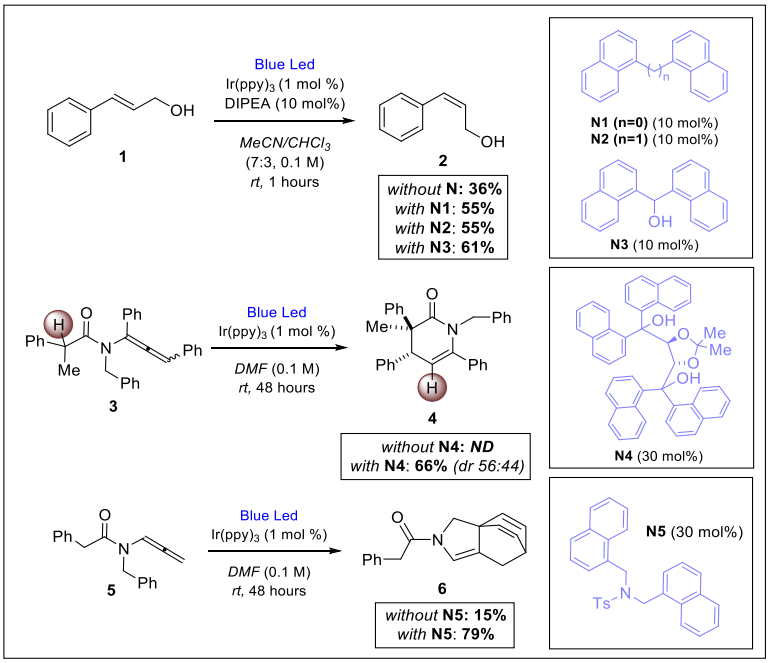

Figure 1: Examples of Visible-Light Promoted reactions by bi-naphtyl derivatives.

References:

1. M. Chiminelli, G. Scarica, D. Balestri, L. Marchiò, N. Della Cà, G. Maestri, *Tetrahedron Chem.* **2023**, 8.
2. S. Sarkar, K.P.S. Cheung, V. Gevorgyan, *Chem. Sci.* **2020**, 11.
3. M. Chiminelli, A. Serafino, D. Ruggeri, L. Marchiò, F. Bigi, R. Maggi, M. Malacria, G. Maestri, *Angew. Chem. Int.* Ed. **2023**, 62.

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Synthesis of triple strand glycan structures with rigid conformations

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The main feature of proteins is to encode specific information by folding, allowing these biopolymers to carry out sophisticated functions. The understanding of peptides folding rules has permitted to design and synthesize linear chains programmed to adopt a defined 3D structure[1]. Conversely, synthetic polysaccharides capable of autonomously folding into a defined 3D structure have not been explored so far, due to their complexity and lack of folding rules.
A glycan hairpin, namely two *strands* chains attached to a *turn unit*, has recently been synthesized[2] adopting: an α-L-Rha-(1,3)-[β-D-Glc-(1-4)]-D-Glc trisaccharide (similar to Lewis X conformation[3]) as a *turn unit* and two linear β-1,4-Glc repeating units (cellulose) as the two *strands* (Figure **1**).

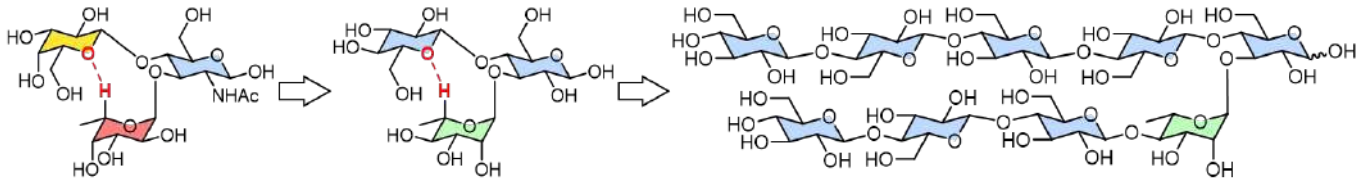

Figure1: evolutionary study of glycan hairpins. From left to right: Lewis X trimer, 3mer-l turn unit, 9-mer glycan hairpin. *Legend: D-Gal, L-Fuc, D-Glc, L-Rha*, CH—O non-conventional hydrogen bond.

Exploiting the design principles developed so far and with the aid of molecular dynamics simulations, we intend to synthesized more complex structures with rigid conformations, mimicking proteins' β-sheets (Figure **2**). Recent progress towards the synthesis of these structures by Automated Glycan Assembly (AGA) on solid phase will be described.[4]

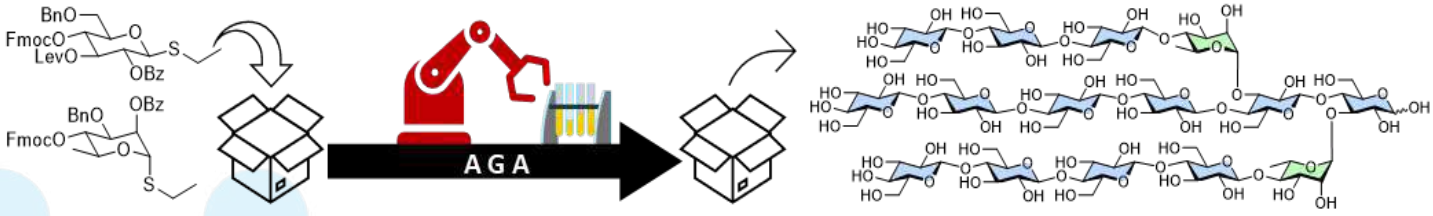

Figure2: one of the most promising to rigid conformation (by molecular dynamics simulation) target molecule

References:
[1] J. Venkatraman, S. C. Shankaramma and P. Balaram, *ACS Chem. Rev.* **2001**, 101, 10, 3131–3152.
[2] G. Fittolani, T. Tyrikos-Ergas, A. Poveda, *et al. Nat. Chem.* **2023**, 15, 1461–1469.
[3] M. Zierke, M. Smieško, S. Rabbani, *et al. J. Am. Chem. Soc.* **2013** 135 (36), 13464-13472.
[4] J. Y. Huang, M. Del Bianco, *Synthesis* **2023**; 55(09): 1337-1354.
Acknowledgements: The fellowship of S.S. is supported by EU funding within the NextGeneration EU-MUR PNRR (Dottorati Industriali)

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Employment of natural products for laccase immobilization on organic films for efficient biocatalysis

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Laccases, multicopper oxidases, exhibit significant catalytic activity in oxidizing a wide range of substrates, such as polyphenols, diamine, and some inorganic compounds, in the presence of molecular oxygen. Despite their high activity, selectivity, and specificity, laccases have disadvantages such as low chemical and thermal stability, difficulty in recovery and reuse, and high cost. To overcome these limitations, enzyme immobilization is considered a promising technology for implementing catalytic efficiency and controlling enzymatic reactions. The immobilization of enzymes is typically done using different strategies[1]: i) physical adsorption; ii) ionic adsorption; iii) covalent binding between the enzyme's support and amino acid side chain; iv) entrapment through a physical encapsulation. This work aims to immobilize laccase from *Trametes versicolor* (LTV) onto two different systems: a) a blend formulation of PLA/PBAT loaded with walnut shell extract,[2] b) nylon films activated with APTES and natural products.[3] FT-IR, SEM and TGA will characterize the new systems. The immobilized enzyme's activity and its reusability will be spectrophotometrically tested. These newly developed immobilized enzyme systems can be potentially used to synthesize organic compounds, bioremediate wastewater from organic compounds and for biosensor development.

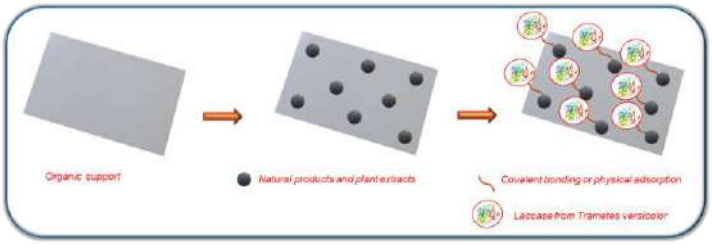

Figure 1. Schematic diagrams of LTV immobilization.

Acknowledgement: This work was funded by the European Union (NextGeneration EU) through the MUR-PNRR project SAMOTHRACE (ECS00000022).

References:

[1] Z.N. Chen, W.D. Oh, P.S. Yap, Chemosphere 2022, 307, 135824.
[2] V. Muccilli, A.E. Maccarronello, C. Rasoanadrasana, N. Cardullo, M.S. De Luna, M.G.G. Pittalà, P.M. Riccobene, S.C. Carroccio, A.A. Scamporrino, Heliyon 2024, 10, e24469.
[3] F.F. Zhou, J.Q. Luo, SQ. Song, Y.H Wan, Industrial&Engineering Chemistry Research 2020, 59, 2708 – 2717.

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Synthesis of bioprintable polymers for the development of lung cancer tissue mimetics

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The extracellular matrix (ECM) of lung cancer is characterized by interconnected biomacromolecules, including fibrous proteins (i.e. elastin and collagen) and proteo- and glycosaminoglycans (i.e. hyaluronic acid, versican)[1]. The identity and the gradient of ECM components in cancer reflect the cancer grade and localization and it is differential from the ECM fingerprint and structural organization of healthy lung tissue[2]. To produce lung cancer tissue models that mimic the *in vivo* microenvironment, the generation of ECM mimics that can recapitulate the key components involved in cell-ECM crosstalk are needed[2]. Here in this work, biomaterials-based ECM mimics have been produced using chemoselective ligation approaches on different biopolymers[3]. The introduced functional groups have been employed to crosslink polymers of different nature using multiarms linkers in order to control the stiffness and the printability. The produced biomaterials have been characterized by NMR and FT-IR analysis. Morphological features have been also evaluated using SEM analysis in order to compare the porosity and the structural features of decellularized ECM and lung ECM mimics. The formulation with optimal rheological properties were employed in bioprinting protocol to generate 3D in vitro lung advanced models employable for drug screening and cell biology studies.

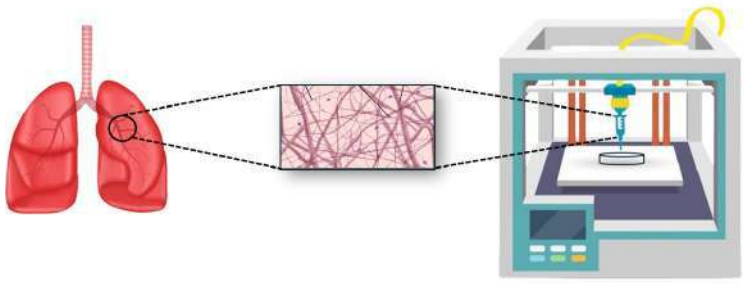

Figure 1: 3D bioprinting of ECM- lung model

Acknowledgments: Ministero della Salute, RF-2021-12371959 Tackling immunomodulatory properties of stromal cells to improve therapeutic strategies in lung cancer.

References:

[1] Parker, A.L., Cox, T. R. 2020, Frontiers in Oncology, 10, 1766
[2] Cadamuro, F., Nicotra, F., Russo L. 2023, Journal of Controlled Release, 354, 726-745.
[3] Cadamuro, F., Sampaolesi, S., Bertolini, G., Roz, L., Nicotra, F., Russo, L. 2023, ChemNanoMat, 9, e202200508

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ORG-PO-143

FAST ONE-POT SYNTHESIS OF AZA-S(VI) FLUORIDES FROM SULFINYL AMINES

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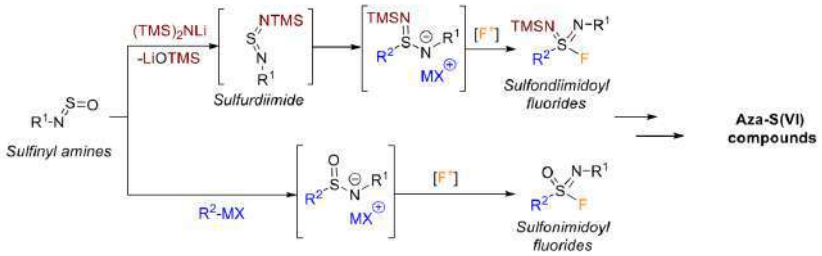
Hexavalent sulfur fluorides are strategic electrophilic reagents in organic synthesis enabling the linkage of S-O, S-N and S-C bonds[1]. While the preparation and use of sulfonyl fluorides have been widely explored, very little information about the synthesis and reactivity of sulfonyl fluoride aza-isosters, namely sulfonimidoyl fluorides and sulfondiimidoyl fluorides, is currently available[2,3]. Moreover, these compounds can be prepared through lengthy and time-consuming synthetic routes, that often require the generation of more reactive intermediates such as aza-S(VI) chlorides[4], or gaseous reagents[5]. Considering the great potential of such S(VI) derivatives in enabling the straightforward preparation of sulfur pharmacophores, here we present a fast one-pot synthesis of both sulfonimidoyl fluorides and sulfondiimidoyl fluorides starting from sulfinyl amines. The transformations proceed via nucleophilic addition of organometallic reagents to sulfinyl amines and sulfurdiimides[6,7], in turn prepared in situ from sulfinyl amines, followed by subsequent quenching with an electrophilic fluorine source. This process affords the products within a few minutes. Further reactions of such aza-S(VI) fluorides have also been investigated, disclosing their synthetic utility in the preparation of diverse S(VI) compounds.



References:

[1] D. Zeng, Y. Ma, W. Deng, M. Wang, X. Jiang, *Angew. Chem. Int. Ed.* **2022**, *61*, DOI 10.1002/anie.202207100.

[2] S. Greed, E. L. Briggs, F. I. M. Idiris, A. J. P. White, U. Lücking, J. A. Bull, *Chem. Eur. J.* **2020**, *26*, 12533–12538.

[3] Z.-X. Zhang, M. C. Willis, *Chem* **2022**, *8*, 1137-1146.

[4] R. Kowalczyk, A. J. F. Edmunds, R. G. Hall, C. Bolm, *Org. Lett*. **2011**, *13*, 768-771.

[5] B. Gao, S. Li, P. Wu, J. E. Moses, K. B. Sharpless, *Angew. Chem. Int. Ed.* **2018**, *57*, 1939-1943.

[6] M. Andresini, S. Carret, L. Degennaro, F. Ciriaco, J. Poisson, R. Luisi, *Chem. Eur. J.* **2022**, *28*, DOI 10.1002/chem.202202066.

[7] M. Andresini, M. Colella, L. Degennaro, R. Luisi, *Org. Biomol. Chem.* **2023**, *21*, 7681-7690.

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Sustainable Synthesis of Sulfonamides in Deep Eutectic Solvents Under Mild Conditions

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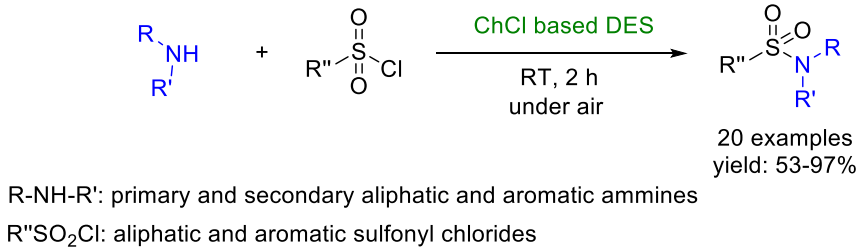
Sulfonamides represent a crucial structural motif in numerous pharmacologically active compounds.[1] Recognizing their diverse applications and significance in the pharmaceutical industry, scientists have been actively seeking sustainable methods for their synthesis since the turn of the century. This pursuit aims to eliminate the use of toxic chemicals and volatile organic compounds (VOCs), such as pyridine and dichloromethane, which are commonly employed.[2] Our research contributes to this endeavor by establishing environmentally benign procedures for the synthesis of sulfonamides under sustainable conditions.

Deep eutectic solvents (DESs) have proven to be highly effective reaction media[3] for facilitating N–S bond-forming processes under remarkably mild conditions, notably at room temperature and under ambient air. This innovative approach enables us to circumvent the need for VOCs, stringent pH control, and the issues associated with poor solubility of starting materials,[4] ultimately leading to improved yields and minimized waste generation, thus enhancing the atom economy of the reaction. Utilizing choline chloride (ChCl)-based DESs, we have successfully synthesized various types of sulfonamides from primary and secondary aliphatic and aromatic amines, as well as sulfonyl chlorides. The reactions typically reach completion within two hours, affording the desired products in yields of up to 97% (**Scheme 1**).



Scheme 1. Synthesis of secondary and tertiary sulfonamides in choline chloride (ChCl)-based DESs.

References:

[1] A. Kolaczek, I. Fusiarz, J. Laweck, D. Branowska, *CHEMIK*, **2014**, *68*, 620–628.
[2] S. M. Sparks, G. Chen, J. L. Collins, D. Danger, S. T. Dock, C. Jayawickreme, S. Jenkinson, C. Laudeman, M. A. Leesnitzer, X. Liang, P. Maloney, D. C. McCoy, D. Moncol, V. Rash, T. Rimele, P. Vulimiri, J. M. Waya, S. Ross, *BMCL,* **2014**, *24*, 3100 - 3103.
[4] A. P. Abbott, G. Capper, D. L. Davies, R. K. Rasheed, V. Tambyrajah, *Chem. Commun*. **2003**, 1, 70-71
[5] X. Deng, N. S. Mani, *Green Chem*. **2006**, *8*, 835–838

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Optimization of a Nanoparticles Protein Corona Isolation and Identification Platform using Omics

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Since the engagement of nanoparticles is becoming more and more relevant in modern medicine, scientific attention has been drawn toward the characterization of the "bio-molecular corona", which is described as a layer of biomolecules assembling on the surface of nanoparticles when they encounter biological fluids.

The dynamic structure of the corona is composed of different biomolecules, such as lipids, sugars, nucleic acids and, first and foremost, proteins accounting for most of the overall mass. Therefore, we mostly refer to this entity as "protein corona".[1]

The "protein corona" provides a new identity to the nanoparticles, hence redefining their pharmacokinetics and fate in the body ranging from their uptake by cells to immunologic responses and resulting in a decrease in their half-life. Therefore, the "protein corona" characterization is essential in the development of nanoparticles with better bioavailability, but it can also help in resolving the nanoparticles path inside the body, opening the way to a targeted delivery of therapeutics.[2]

One of the main challenges in the corona characterization is the optimization of its isolation from the biological environment. In literature, centrifugation is the most frequently described technique since it can be applied to the vast majority of nanoparticle types even though many drawbacks are evident, such as potential disruption of the physiological corona or the creation of artefacts caused by the applied centrifugal force.[3]
Thus, with the aim of an in-depth protein corona characterization, we set to establish the best strategy for corona analysis using polylactic-co-glycolic acid (PLGA) nanoparticles as a model. In particular, preliminary experiments were performed to define the optimal isolation method for the nanoparticle-corona complexes, starting from centrifugation and moving on to less common methodologies, such as microfiltration and size exclusion chromatography, also implementing an array of different variables for the biological fluids.

References:

[1] M. Mahmoudi, M. P. Landry, A. Moore, R. Coreas, Nature Review Materials, 2023, Vol 8, 422–438.
[2] A. A. Yetisgin, S. Cetinel, M. Zuvin, A. Kosar, O. Kutlu, Molecules, 2020, Vol 25 (9), 2193.
[3] L. Bohmert, L. Voss, V. Stock, A Braeuning, A. Lampen, H. Sieg, Nanoscale advances, 2020, Vol 2 (2), 563-582.

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ORG-PO-146

Synthesis and characterization of diketopyrrolopyrrole-based small molecules for singlet fission in crystalline molecular thin films

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A key aspect towards a green and carbon-neutral transition involves enhancing the efficiency of solar cells. However, traditional photovoltaic (PV) devices face inherent limitations due to thermodynamic constraints, such as thermalization losses, which restrict the maximum achievable power conversion efficiency (PCE) to around 29% for an ideal single-junction Si cell[1]. The exploitation of Singlet Fission (SF) is a promising strategy to enhance the PCE[2], relying on the efficient conversion of a singlet exciton into two triplet excitons: in suitably engineered devices this could yield light conversion quantum efficiencies ≈ 100% in the spectral region where the SF material absorbs.

Recently the diketopyrrolopyrrole (DPP)[3,4] core has been proposed as a promising platform for SF, thanks to its excellent photostability, diradical character and the easily modifiable chemical structure, that enables concurrent control over the singlet-triplet energy gap and the molecular packing configuration; the latter, in particular, is known to influence both the efficiency of SF and its successful exploitation in solar cells.

Here we present the synthesis and characterization of a series of DPPs based molecules, with different alkyl chain and different aromatic substituents, which should enhance the diradical character of the molecules and favor the slip-stacked packing in solid thin films.

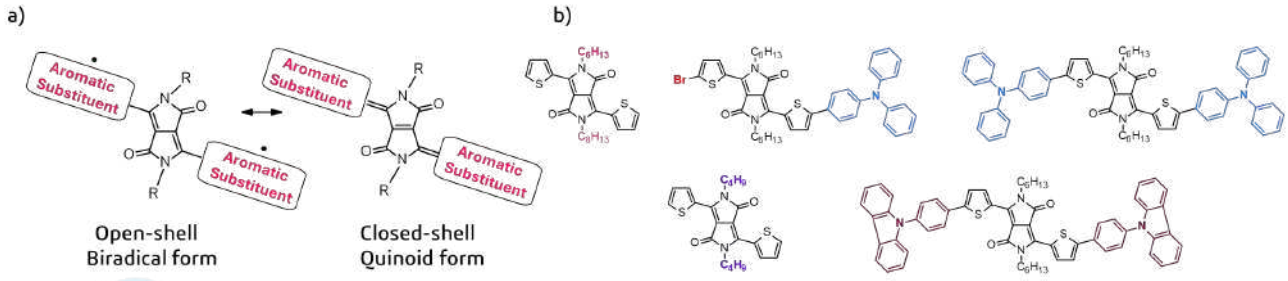

Figure 1: a) the biradical and quinoid form of DPP, b) chemical structures of the synthesized molecules.

References:

[1] Daiber, B., et al., ACS Energy Letters, 2021, 6, 2800–2808.
[2] M. Einzinger, et al., Nature, 2019, 571, 90–94.
[3] D. Rais, et al., Chempluschem, 2020, 85, 2689–2703.
[4] C. J. Lee, et al., Advanced Optical Materials, 2024, 12, 2301539.

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ORG-PO-147

Synthesis and preliminary conformational analysis of 1-deoxy-L-idonojirimycin derivatives as potential α-L-iduronidase modulators

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Herein we present the synthesis of a series of novel 1-deoxy-L-idonojirimycin derivatives exploiting an unexplored synthetic pathway. In recent years this class of piperidines have emerged as promising active-site modulators of the lysosomal glycosidase α-L-iduronidase (IDUA). IDUA deficiency is involved in a neurodegenerative lysosomal disorder known as Mucopolysaccharidosis type I (MPS I). In this context, the proposed synthetic approach led to the successful seven-steps preparation of compound **7** as an analogue of L-iduronic acid (Fig. **1**).[1] Moreover, with the attempt to improve the affinity towards IDUA and investigate conformational features, this synthetic route was expanded for the preparation of compounds **11-14**.[2] A preliminary computational conformational analysis supported the NMR-based evidence that introducing an acyl- or alkyl- moiety at the nitrogen position can switch the $^1C_4$ chair conformation of compounds **4** and **7** into a $^4C_1$ chair in compounds **11-14**. This behaviour suggests that different substitutions at the nitrogen position and the presence of the carboxylic acid at the C6 position can be exploited to modulate the conformation of these small molecules. Furthermore, as a change in conformation of iminosugars has a profound effect on their binding properties towards glycosidases, this strategy could provide preliminary information about the potential biological activity of this class of piperidines.

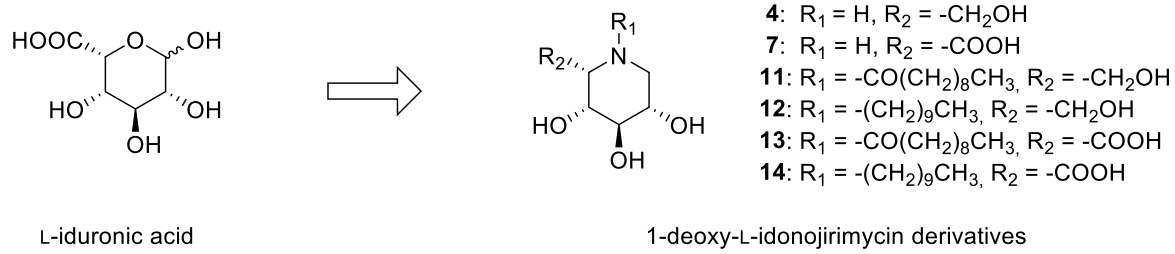

Figure 1: 1-deoxy-L-idonojirimycin derivatives proposed in this work rationally designed as analogues of L-iduronic acid.

References:

[1] H. Y. Lin *et al*., European Journal of Medicinal Chemistry 2023, 247, 115005.
[2] M. Artola *et al.*, Chemistry - A European Journal 2018, 24, 19081 – 19088.

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ORG-PO-148

Luminescent micro- and nanostructures from organic fluorophores and microalgae

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Among the living organisms that generate nanostructured components, diatoms are very attractive. Diatoms are a large and prolific class of single cell photosynthetic microalgae, whose mesoporous biomineralized silica shells (frustules) encase the organic protoplasm.[1] Frustules exhibit interesting properties such as high surface area, mechanical resistance, unique optical characteristics and mesoporosity, which make them appealing materials for applications in photonics, sensing, optoelectronics and biomedicine. The availability of numerous chemical and biological approaches to modify the frustules composition represents a powerful resource to produce nanostructured materials with properties tailored for specific applications.[2] Frustules chemically modified with organic dyes have seldom been investigated for their optical properties thus far. We have demonstrated that in vivo incorporation of organic molecular emitters into frustules through diatoms' silica biomineralization represents an efficient biotechnological route to new photonic materials whose properties result from the combination of the frustule hierarchical nanostructure with the luminescence of incorporated emitting molecules.[3] In particular, our study points out that the functionalization of diatoms biosilica with tailored photoactive molecules can represent a powerful tool in order to obtain luminescent micro- and nanostructured biomaterials for applications in biomedicine, optics, photonics and agriculture technologies.

References:

[1] R. Ragni, S. R. Cicco, D. Vona, G. M. Farinola, Green Materials for Electronics 2017, Ch 11.
[2] R. Ragni, S. R. Cicco, D. Vona and G. M. Farinola, Advanced Materials 2017, 30, 1704289 – 1704302.
[3] R. Ragni, F. Scotognella, D. Vona, L. Moretti, E. Altamura, G. Ceccone, D. Mehn, S. R. Cicco, F. Palumbo, G. Lanzani, G. M. Farinola, Advanced Functional Material 2018, 28, 1706214 – 1706223.

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ORG-PO-149

Zwitterionic calixarenes interact with real and artificial membranes of Gram-negative bacteria

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The overuse of antibiotics to treat bacterial infections leads to antimicrobial resistance, one of the most serious threats in our century.[1] The ability to distinguish between bacterial species can provide a useful tool to overcome this dangerous problem with the possible development of a selective, rapid and inexpensive sensor. Knowing that calixarenes are able to selectively bind different types of macromolecules,[2] we studied a series of water-soluble zwitterionic calix[4]arenes, and found that those functionalised at the upper rim with four zwitterionic amino acid moieties, were able to selectively interact with the cell wall of Gram-negative bacteria, among the other families tested. The proline and phenylalanine derivatives (**1** and **2** respectively, Figure 1) have been shown to bind Gram-negative bacteria using on-cell Saturation Transfer Difference NMR techniques.[3] Preliminary results suggest that they are able to interact with the lipopolysaccharide (LPS) portion. LPS-containing lipid interfaces are developed as a mimic of the cell wall of Gram-negative bacteria, and their interaction with the calixarenes is investigated using quartz crystal microbalance with dissipation monitoring.

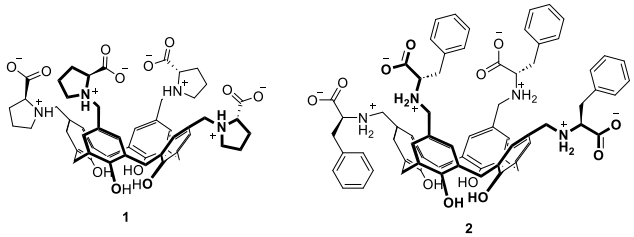

Figure 1: Zwitterionic calix[4]arene based molecular receptors selective for Gram-negative bacteria.

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References:

[1] T. Yu, Y. Xianyu, *Small* **2021**, *17*, 2006230.
[2] L. Baldini, A. Casnati, F. Sansone, *Eur. J. Org. Chem.* **2020**, 5056.
[3] A. Palmioli, P. Sperandeo, S. Bertuzzi, A. Polissi, C. Airoldi, *Biorg. Chem.* **2021**, *112*, 104876.

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ORG-PO-150

Chemically modified graphene oxide for short chain Per- and Polyfluoroalkyl substances (PFAS) adsorption from drinking water

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In the last years, graphene oxide nanosheets (GO) has emerged as potential sorbent materials for the removal of contaminants of emerging concern, (i.e. pharmaceuticals and personal care products, Per-and Polyfluoroalkyl substances (PFASs)) from drinking water.[1-5] Oxygenated groups on the surface of GO nanosheets enable specific adsorption selectivity and capacity, mainly driven by specific hydrophobic, van der Waals and electrostatic interactions.[6] Fine tuning of adsorption selectivity can be achieved by tailored chemical modification of GO nanosheets' surface.[1,4] On this line, here we report the design, synthesis and application of GO nanosheets modified with tertiary amines ended functionalities by epoxide ring opening reaction, and then quaternarized by nucleophiclic addition. The adsorption performances in water toward a mixture of PFASs with different alkyl chain length and end groups (carboxylated or sulfonated), will be reported and compared to those of granular activated carbons (GAC), the industrial sorbent benchmark.

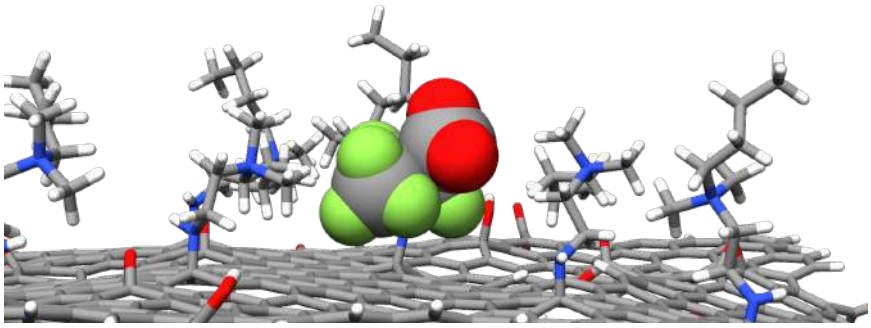

Figure 1: Surface chemical interaction between a modified GO nanosheet and perfluorobutanoic acid (PFBA) obtained by Molcular Dynamic (MD) simulation.

References:

[1] F. Tunioli, T.D. Marforio, Chem. Eur. J. 2023, 29, e202301854
[2] S. Mantovani, T. D. Marforio, Environ. Sci.: Water Res. Technol. 2023, 9, 1030-1040
[3] S. Khaliha, A. Bianchi, Separation and Purification Technology 2022, 300, 121826
[4] S. Mantovani, S. Khaliha, Chem. Commun., 2022, 58, 9766–9769
[5] M. Zambianchi, S. Khaliha, Journal of Membrane Science 2022, 658, 120707
[6] S. Khaliha, T. D. Marforio, FlatChem 2021, 29, 100283.

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ORG-PO-151

Sustainable conjugated polymer synthesis in OPV: a case study from conventional to flow and microvave-assisted synthesis.

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In the pursuit of more efficient and environmentally friendly energy sources, organic photovoltaics (OPVs) have emerged as a promising alternative to silicon-based solar cells, especially for indoor application. In order to achieve, not only economic viability but also sustainability of OPVs, low cost and large module production need to be coupled with increased greener conjugated polymers production and minimal batch-to-batch variation.

Continuous flow synthesis[1] and microwave assisted synthesis[2] (**Figure 1a**) represent two sustainable and efficient way compared to conventional polymer synthesis: the flow chemistry approach demonstrates a remarkable reduction in reaction times and solvent use, aligning with green chemistry principles, while microwave-assisted synthesis further enhances the sustainability quotient by using small volume of solvent, providing rapid heating and short reaction time, decreasing energy consumptions.

Here we present the case study of PSBTBT (**Figure 1b**) (poly(4,4-dioctyldithieno(3,2-b:2',3'-d)silole)-2,6-diyl-alt-(2,1,3-benzothiadiazole)-4,7-diyl), a wide used low-gap polymer for OPVs[3]. We have synthesized the polymer using Stille cross coupling polymerization with the three different approaches, comparing the molecular weight, the optical characteristics (**Figure 1c**) and the metal residual in the polymers.

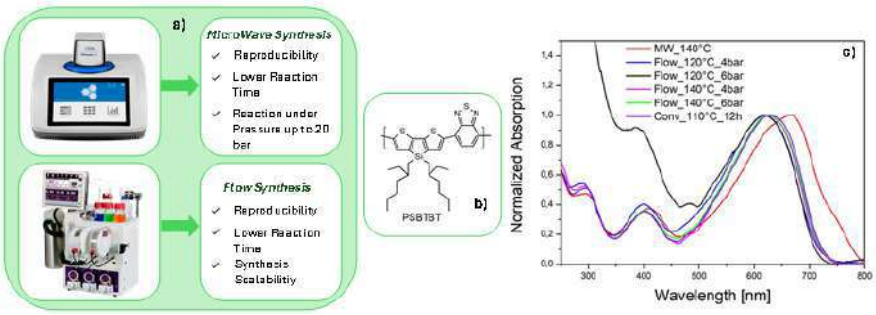

Figure 1: a) the flow and the microwave system for synthesis, **b)**, PSBTBT polymer's structures and **c)** the absorption spectra in chloroform solution.

References:

[1] G. Pirotte, J. Kesters, et al., Chem Sus Chem, 2015, 8, 3228-3347.
[2] E. Kabir, Results in Chemistry, 2023, 6, 101178.
[3] N. Gasparini, X. Jiao et al. Nature Energy, 2016, 1, 16118.

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Synthesis of lanthanide chelates for Time Resolved-Foster Resonance Energy Transfer (TR-FRET)

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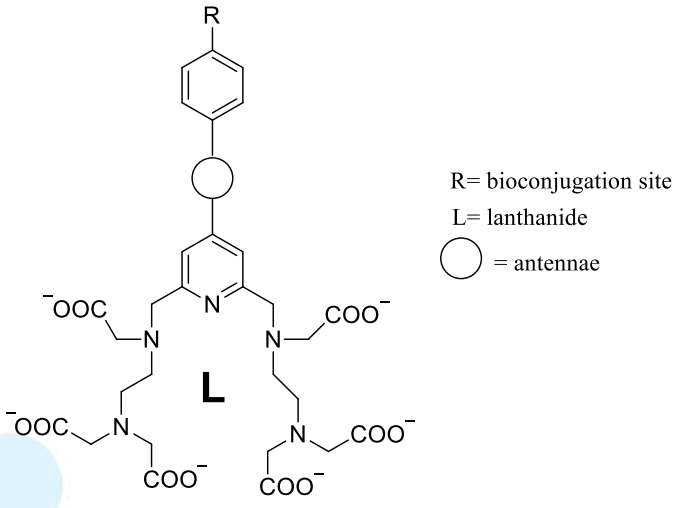
Time Resolved-Foster Resonance Energy Transfer (TR-FRET) is an analytical technique that combines Time-Resolved Fluorescence (TRF) and Foster Resonance Energy Transfer (FRET). These two spectrofluorimetry use fluorophores that, when exposed to a light source set at a specific wavelength, emit fluorescence at a higher wavelength with less energy, obtaining a fluorescence spectrum. Classical fluorophores (like fluorescein) have a very short emission time (nanosecond scale) 1. Since proteins also exhibit fluorescence, their emission produces a high background that interferes with the emission of the fluorophore. Unlike classical fluorophores, stable lanthanide chelates (typically europium and terbium) are used, which have large stokeshifts and longer emission times (microseconds to milliseconds). All this makes it possible, after excitation of the fluorophore, to wait for the background fluorescence switched off before making the measurement, thus improving the signal-to-noise ratio. The lanthanide probes, in addition to the chelanting site, has two important sites: the "antennae" site and the bioconjugation site. The antenna is characterised by a system conjugated to the chelating portion of the compound which, depending on its structure, allows light to be emitted at specific wavelength 2. For the bioconjugation component, there are several approaches depending on the type of macromolecule (usually protein) to be bound 3. In TR-FRET there are the fluorophore donor and the fluorophore acceptor 4. The aim of the work is to synthesise lanthanide chelates by modifying the antenna and the bioconjugation part, while keeping the size of the chelating site unchanged.



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Synthesis and electro/photochemical study of new pyridinium salts

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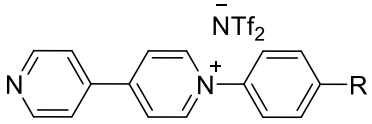
Bipyridinium chromophores are extensively studied for their interesting photochemical and electrochemical properties.[1] They find application as components for molecular batteries, electrochromic displays, redox-mediators, redox-sensors, and so on. For this reason, there is a great interest in designing new bipyridinium derivatives that behave not only as electroactive moieties but also as fluorophores.

In this contribution, we report on the synthesis and the photophysical/electrochemical characterization of a new series of 1-aryl-(4,4'-bipyridin)-1-ium salts bearing several different alkyl chains on the *para* position of the phenyl ring, as shown in Figure 1.



1 R = $(CH_2)_7CH_3$
2 R = $(CH_2)_9CH_3$
3 R = $(CH_2)_{11}CH_3$
4 R = $(CH_2)_{13}CH_3$

Figure 1

The new compounds **1-4** have been prepared by the ANRORC reaction [2] of 1-(2,4-dinitrophenyl)-(4,4'-bipyridin)-1-ium chloride with the corresponding 4-alkylanilines, followed by counterion exchange with $LiNTf_2$. The redox behavior of **1-4** has been examined by cyclic voltammetry (CV), while the photoluminescence properties were studied by UV/vis spectroscopy.

References:

[1] Monk S. M.P. (1998), *The Viologens: Physicochemical Properties, Synthesis and Applications of the Salts of 4,4'-Bipyridine*, Wiley, New York.

[2] Van Der Plas, Henk C. (1999) .*SN(ANRORC) Reactions in Azaheterocycles Containing an "Inside" Leaving Group*. In Katritzky, Alan R. (ed.). Degenerate Ring Transformations of Heterocyclic Compounds. Advances in Heterocyclic Chemistry. Vol. 74. Academic Press. pp. 87–151.

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ORG-PO-154

Organoselenium and organoarsenic molecules as promising opportunities for tomorrow's anticancer drugs

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Selenium, sharing most of its chemical properties with sulfur, can form reversible covalent bonds with other chalcogens. I recently synthetized several selenium (and sulfur) containing compounds (Fig 1, upper) as the first-in-class of covalent inhibitors of the YTHDF m6A binding domain, a class of cancer-related proteins for long been considered undruggable.[1] The covalent interaction with the protein was studied with several orthogonal assays: X-ray, MS, NMR, and biochemical assays.

Arsenic is perhaps one of the most frightening and captivating element in the periodic table. However, less known is that arsenic compounds have a huge historical legacy (Salvarsan/syphilis, arsenic trioxide/leukemia) and undeveloped potential to treat various diseases. Derived from a marine sponge, in 2006 prof. Mancini successfully isolated and characterized the first polyarsenical natural compound.[2] Recently, I expanded the chemical space of this scaffold, with the synthesis and the non-trivial structural elucidation of related organoarsenicals (Fig 1, down), highly potent and selective against glioblastoma stem cell growth.[3]

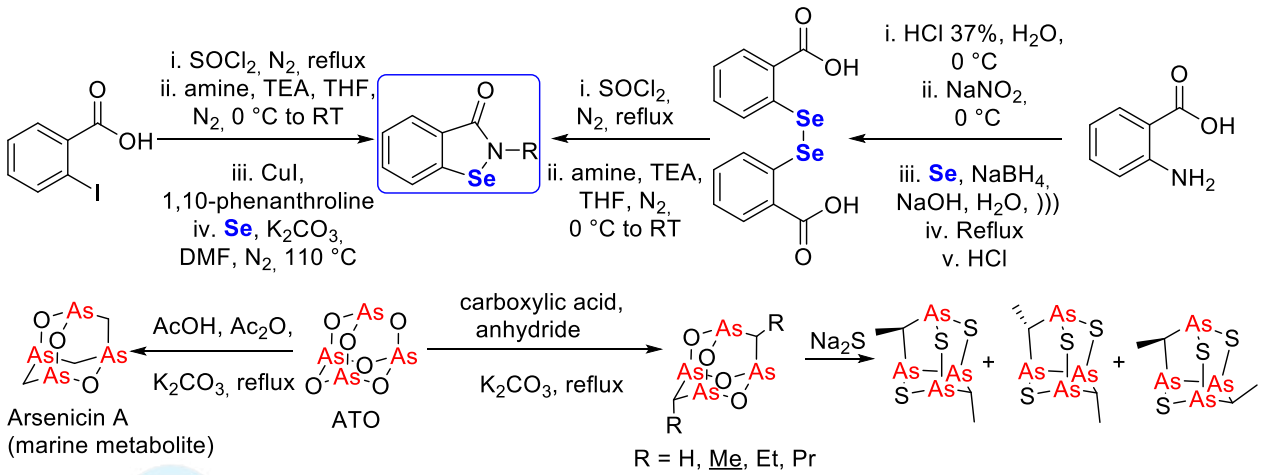

Figure 1: synthesis of organoselenium and organoarsenic anticancer compounds.

References:

[1] M. Micaelli, et al., ACS Pharmacology & Translational Science, 5, 2022, p. 872 – 891.
[2] I. Mancini, et al., Chemistry, 12, 2006, p. 8989 – 8994.
[3] J. Vigna, et al., Marine Drugs, 2023, 21, 186, p. 1 – 21.

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ORG-PO-155

Water-processable polymer nanoparticles as alternative organic photosensitizers for cofactor regeneration under visible light

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The increasing levels of carbon dioxide (CO_2) in the atmosphere and the growing global need for energy impose the development of renewable methods to convert CO_2 into valuable chemicals and fuels, for example by exploiting the coenzyme-dependent activity of formic acid dehydrogenase (FDH) to catalyze the reduction of CO_2 to formate.[1] Nevertheless, the high cost of the coenzymes, as NADH and $MV^{\bullet+}$, have so far limited the application of this technology. In this context, effective coenzymes regeneration methods using low-cost energy sources would provide a suitable pathway for CO_2 reduction with the improvement of artificial photosynthesis systems.[2]

Here we report the application of a semiconducting polymer, poly[2,2""-bis[[(2-butyloctyl)oxy]carbonyl][2,2':5',2":5",2"'-quaterthiophene]-5,5"'-diyl] (PDCBT) for the fabrication of water-processable nanoparticles (WPNPs) through the miniemulsion approach (**Figure 1**). Then, the polymer-based WPNPs were employed as photosensitizer in a visible-light-driven $MV^{\bullet+}$ regeneration system consisting of TEOA as electron donor and MV^{2+} as electron acceptors. Enzyme-catalyzed redox reactions were then used to validate the production of the regenerated cofactor (**Figure 1**).

Our results show a successful example of polymer WPNPs used for the selective coenzyme regeneration in an artificial photosynthesis system, which is easy to build and usable under mild conditions for the easy regeneration of different coenzymes. These results could pave the way for other photoredox reaction systems that enable the selective and sustainable production of chemicals and fuels through the use of solar light.

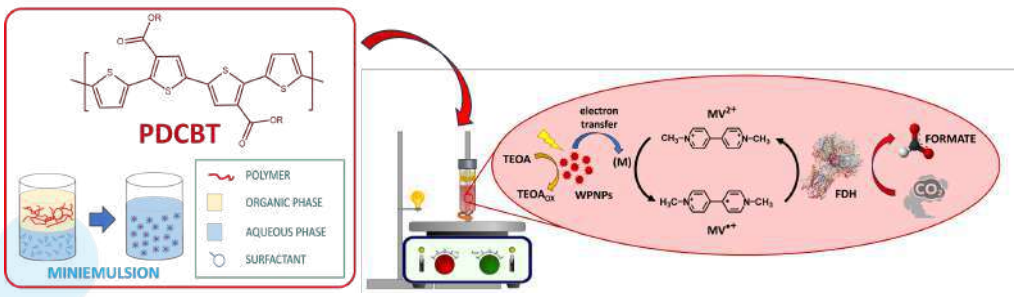

Figure 1: PDCBT-based WPNPs used as photosensitizers for MV^{2+} reduction.

References:

[1] L.S. Vidal, C.L., Kelly, *et al.*, Acta Proteins Proteomics, 2018, 1866, 327-347.
[2] F. Secundo, Y. Amao, RSC Advances 2020, 10, 42354-42362.

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ORG-PO-156

Calixarene - based luminescent mechanophores for mechanoresponsive polymers

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Mechanoresponsive polymers are materials capable of transducing a macroscopic mechanical force into molecular events that, in turn, trigger a response of the macroscopic material. The incorporation of mechanoresponsive dyes, also known as mechanophores, into the polymer matrix results in materials that change their optical properties upon mechanical stress. Various strategies have been explored, from the cleavage of weak covalent bonds, as in the case of spyropyranes[1] or triarylmethanes,[2] to the formation/disruption of pi-pi interactions between fluorescent dyes. Good reversible mechano-responses have been obtained by the use of supramolecular structures such as cyclophanes or rotaxanes, which guarantee a proper preorganization of the dyes.[3] Following this approach, we decided to exploit the peculiar conformational properties of the calix[4]arene scaffold to develop new supramolecular mechanophores. It is well known that calix[4]arenes, when functionalized at the lower rim with alkyl chains, are involved in a rapid interconversion between two equally stable pinched cone conformations.[4] On the contrary, in presence of suitable functional groups at the upper rim, the equilibrium can be strongly shifted towards only one of the two pinched cone conformations, and upon appropriate stimuli, the equilibrium can be reversed.[5]

We synthesized pyrene-functionalized calixarenes, which, in the stress-free state, are pinched in the closed cone conformation allowing intramolecular dimerization of the dyes. We covalently incorporated these calixarenes into polymer chains so that the transduction of an applied mechanical force to the calixarene could trigger the opening of the pinched cone conformation, thus resulting in the monomeric form of pyrene.

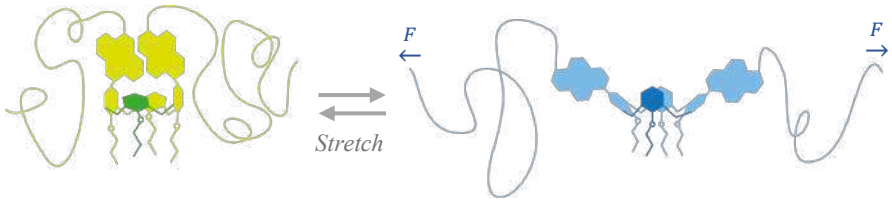

Figure 1: calixarene-based mechanophore behaviour upon application of a mechanical force.

References:
[1] D. A. Davis, A. Hamilton, J. S. Moore, N. R. Sottos et al., *Nature* **2009**, 459, 68 – 72.
[2] J. R. Hemmer, C. Rader, B. D. Wilts, C. Weder, J. A. Berrocal, *J. Am. Chem. Soc.* **2021**, 143, 18859 – 18863.
[3] Y. Sagara, H Trager, N. Tamaoki, C. Weder et al., *J. Am. Chem. Soc.* **2021**, 143, 5519 - 5525.
[4] A. Arduini, M. Fabbi, M. Mantovani, L. Mirione, A. Pochini, A. Secchi, R. Ungaro, *J. Org. Chem.* **1994**, 60, 1454.
[5] E. Spatola, F. Rispoli, D. Del Giudice, L. Baldini, S. Di Stefano et al., *Org. Biomol. Chem.* **2022**, 20, 132 – 138.

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ORG-PO-157

Exploit the Enzymatic Cleavable Linker GPLG-PABC to Enhance the Efficacy of an *iso*DGR based Small Molecule-Drug Conjugate

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In the field of cancer treatment, Small Molecule-Drug Conjugates (SMDCs) represent an effective strategy to overcome the drawbacks of traditional chemotherapeutic agents by conjugating a cytotoxic compound to a targeting ligand recognizing a specific overexpressed cell surface receptor.[1] To connect the ligand with the payload, a chemical linker is needed, which should be able to release the free payload inside or in proximity of the cancer cell upon external stimuli (i.e. enzymatical proteolysis). Thus, the linker plays a key role in the effectiveness of the final conjugate. Herein, we present the synthesis and the biological evaluation of a novel SMDC **1** bearing a new enzymatic cleavable linker composed by the peptide sequence Gly-Pro-Leu-Gly (GPLG) and by the self-immolative linker *p*-aminobenzyloxycarbamate (PABC).[2] In particular, the GPLG-PABC was here used for the first time to connect the $\alpha_v\beta_3$ integrin cyclic peptidomimetic ligand bearing the recognizing sequence *iso*Asp-Gly-Arg (*iso*DGR)[3] to the potent tubulin inhibitor monomethyl auristatin E (MMAE). The final SMDC **1** was tested for its antiproliferative activity, and the results confirmed a higher potency of the SMDC **1** compared to the corresponding conjugate **2** containing the Val-Ala-PABC cleavable linker recognized by the lysosomal enzyme Cathepsin B, previously reported by our group (Figure 1).[4] A further *in vitro* enzymatical assay assessed the fast release of MMAE from the GPLG-PABC linker through the proteolytic activity of lysosomal enzymes, although a specific protease was not identified. Further studies are currently ongoing in our laboratories to fully characterized this new enzymatical cleavable linker.

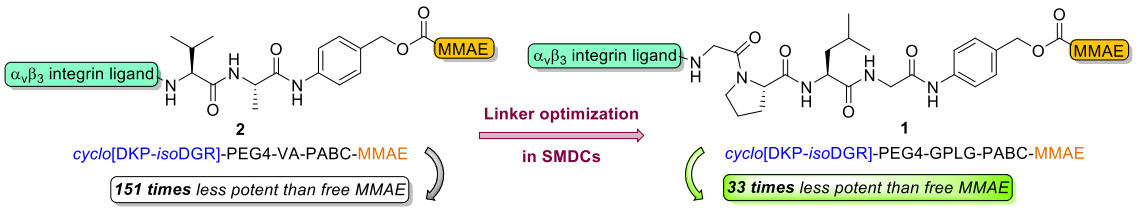

Figure 1

References:

[1] J. Zhang, F. Hu, O. Aras, Y. Chai, ChemMedChem, 2024, e202300720.

[2] M. Zambra, I. Ranđelović, F. Talarico, A. Borbély, L. Svajda, J. Tóvári; G. Mező; L. Bodero, S. Colombo, F. Arrigoni, E. Fasola, S. Gazzola, U. Piarulli, Front Pharmacol, 2023, 14.

[3] M. Mingozzi, A. Dal Corso, M. Marchini, I. Guzzetti, M. Civera, U. Piarulli, D. Arosio, L. Belvisi, D. Potenza, L. Pignataro, C. Gennari, Chem Eur J, 2013, 19 (11), 3563–3567.

[4] A. R. M. Dias, L. Bodero, A. Martins, D. Arosio, S. Gazzola, L. Belvisi, L. Pignataro, C. Steinkühler, A. Dal Corso, C. Gennari, U. Piarulli, ChemMedChem, 2019, 14 (9), 938-942.

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Synthesis of pseudodimeric triazine-based PD-L1 inhibitors.

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In the context of cancer immunotherapy, the inhibition of the interaction between the *programmed cell death receptor 1* (PD-1) and its ligand PD-L1 by monoclonal antibodies (mAbs) has achieved notable success in treating several types of cancers. Nevertheless, the use of mAbs is hampered by drawbacks such as high production costs, lack of oral bioavailability, poor tissue and/or tumor penetrability, and for these reasons small molecule inhibitors of the PD-1/PD-L1 axis could represent a promising alternative.[1]

Our research group has recently reported a small library of triazine-based small molecule PD-L1 inhibitors, among which, compound 10 (**CMP-10**, Figure 1, top) showed high affinity towards PD-L1 (IC_{50} = 115 nM),[2] and a significant anticancer activity in co-cultures of PD-L1-expressing NSCLC cells and peripheral blood mononuclear cells (PBMCs).

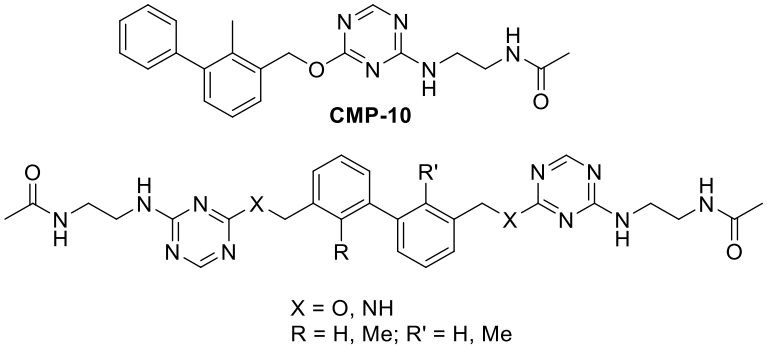

Figure 1: Chemical structure of lead **CMP-10** and general structure of pseudodimeric triazine-based PD-L1 inhibitors.

Here we present the synthesis of a new class of pseudodimeric PD-L1 inhibitors based on lead **CMP-10** (Figure 1, bottom) that, according to literature, should be significantly more active in blocking the PD-1/PD-L1 interaction by stabilizing the PD-L1 homodimer, when compared with their monomeric counterpart.[3]

References:

[1] Surmiak E. et al, Int. J. Mol. Sci., 2021, 22, 11797.
[2] Russomanno P. et al., J. Med. Chem., 2021, 64, 16020-16045.
[3] Park, J.-J. et al. Nat. Commun. 2021, 12, 1222.

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ORG-PO-159

Synthesis of Novel Chiral Supramolecular Architectures Based on Heptazine Derivatives

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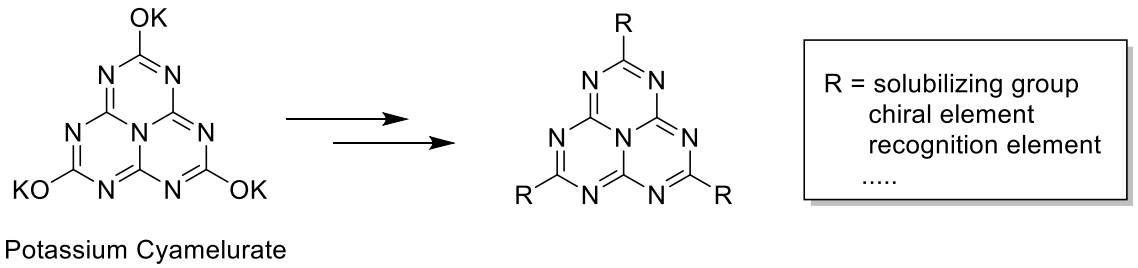

Figure 1: Heptazine derivatives functionalization.

S-Heptazines are a class of molecules within the carbon nitrides family. They are primarily synthesized from s-triazine, and these molecules exhibit remarkable optical and electronic behaviour, largely attributed to their conjugated π-system with a low-lying π* orbital, which arises from the electronegativity of the nitrogen atoms embedded in the skeleton[1].

However, their high stability and poor solubility pose significant challenges for the functionalization of these molecules[2].

The project aims to develop novel chiral and achiral derivatives of s-heptazines (Figure 1) with potential applications as OLED (Organic Light Emitting Diode) emitters.

In this poster we will show the various post-functionalization of these molecules and their optical properties.

References:

[1] P. Audebert, E. Kroke, 2021, 121, 2515-2544.
[2] E. Kroke, M. Schwarz, 2002, 26, 508-512.

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ORG-PO-160

IR irradiation-assisted Pd-catalyzed cross-dehydrogenative coupling of polyfluoroarenes with heteroarenes: proving the role of thermal and non-thermal effects

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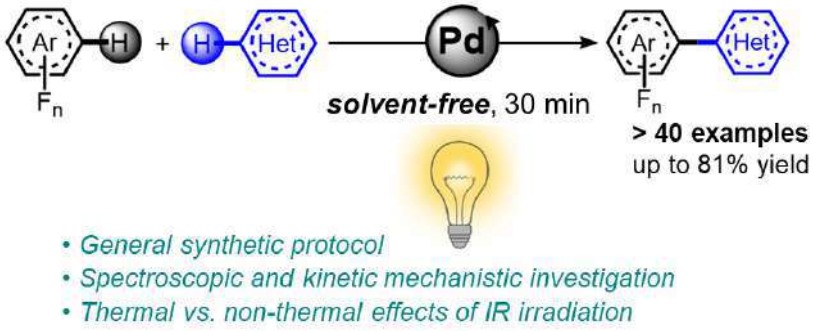
Infrared (IR) irradiation has recently attracted significant attention as non-conventional energy source for organic reactions. IR light sources are able to reduce energy requirement, shorten reaction time, increase product yields and avoid undesired by-products compared to traditional thermal heating with a thermostatic bath.[1] Despite all these advantages, the actual role of IR irradiation as energy source for promoting organic reactions has never been investigated in-depth, and it has been simply considered as a highly efficient form of heating.

Herein we present the use of IR irradiation to assist Pd-catalyzed cross-dehydrogenative coupling reactions.[2] The protocol, performed under solvent-free conditions, is applied to the coupling of polyfluoroarenes with five-membered heteroarenes, affording products with excellent yields in only 30 minutes.

For the first time, the ability of IR irradiation to directly affect the mechanism of a chemical reaction, rather than to simply act as an efficient heating source, is demonstrated by spectroscopic and kinetic studies: while the rate-determining step (RDS) under conventional thermal heating involves Pd(II)-mediated C−H bond activation on the heteroarene ring, the use of IR light shifts the RDS to the oxidation of Pd(0) by Ag(I) oxidant.

The unexpected role of IR irradiation in the reaction mechanism has been evaluated through a series of control experiments and theoretical calculations, concluding that it results from a combination of thermal and non-thermal effects. This finding is highly significant: IR irradiation can be considered as a new powerful enabling technology for synthetic organic chemistry.



References:

[1] G. Albano, G. Decandia, M. A. M. Capozzi, N. Zappimbulso, A. Punzi, G. M. Farinola, *ChemSusChem* **2021**, *14*, 3391-3401.

[2] G. Albano, G. Decandia, G. Pescitelli, A. Punzi, G. M. Farinola, *Submitted Manuscript*.

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ORG-PO-161

Preparation of selenoderivatives of tyrosol endowed with multi-defense activity

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Nowadays, molecular scaffold manipulation of natural phenols represents a largely pursued, effective approach to boost or modulate their antioxidant properties and bioactivity. For example, the insertion of S/Se/Te containing substituents on phenols/polyphenols scaffold may increase/decrease their H-donor/acceptor ability by electronic and stereoelectronic effects related to the site of substitution and geometrical constrains, which thus make them ideal prototypes of novel multifunctional compounds combining diverse scavenging and inhibitory activities against oxidative stress.[1-3]

In this frame, we herein report recent studies focused on the development of straightforward procedures for the preparation of selenoderivatives of tyrosol, a natural phenolic compound endowed with many beneficial properties for human health, such as antioxidant, anticancer, antinflammatory, and cardioprotective activities.

In particular, a mild selenylation procedure based on the use of selenium tetrachloride, followed by purification, allowed the isolation of two main products identified as the 3,3'-selenobistyrosol and the 3,3'-diselenobistyrosol based on MS and NMR analysis (Figure 1).

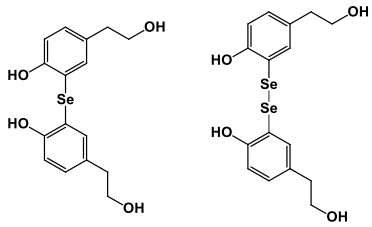

Figure 1: Selenoderivatives of tyrosol.

The selenoderivatives so obtained showed antioxidant activities up to 30-fold higher than that of tyrosol as evaluated by commonly used chemical assays. The results of the investigation of the peroxyl radical scavenging properties of the selenoderivatives using an integrated kinetic, EPR, and computational approach will also be presented. The efficacy of the diselenobistyrosol as potential glutathione peroxidase mimics to destroy H_2O_2 generated in the inflammatory processes will be illustrated.

References:

[1] M.L. Alfieri, L. Panzella, R. Amorati, A. Cariola, L. Valgimigli, A. Napolitano, Biomolecules 2022, 1, 1-24.
[2] D. Tanini, L. Panzella, R. Amorati, A. Capperucci, E. Pizzo, A. Napolitano, S. Menichetti, M. d'Ischia, Org. Biomol. Chem. 2015, 13, 5757-5764.
[3] R. Amorati, L. Valgimigli, L. Panzella, A. Napolitano, M. d'Ischia, J. Org. Chem. 2013, 78, 9857–9864.

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ORG-PO-162

1,3-Dipolar Cycloaddition Reaction for Regioselective Synthesis of Variously Substituted 1,2,3-Triazoles with Powerful Biological Activity

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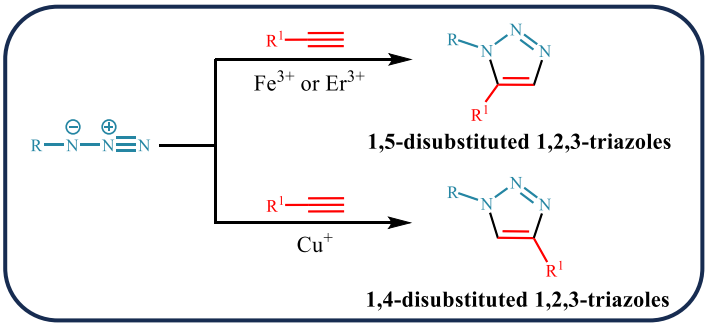
1,2,3-triazoles are five-member heterocyclic compounds bearing three nitrogen atoms in the ring. They are important nucleus for development of drugs because they are resistant to oxidation, reduction, and hydrolysis in both acidic and basic conditions for their aromatic nature. Thanks to active participation in hydrogen bond formation, dipole–dipole and π-stacking interactions they can mimic peptide bonds, enhancing their binding ability with different biological targets. Therefore, triazoles have important biological properties, such as antibacterial, anticancer, antivirus, antimalarial, anti-inflammatory and antituberculosis. In particular, 1,2,3-triazoles found a broad spectrum of biological applications such as β-lactum antibiotic tazobactum, cefatrizine, and anticancer compound carboxyamidotriazole, which are some drugs available on the market.[1]



Scheme 1: 1,3-dipolar cycloaddition reaction for regioselective synthesis of disubstituted 1,2,3-triazoles

In this work, our research group has designed and synthesized a new class of disubstituted 1,2,3-triazoles (**Scheme 1**) through 1,3-dipolar cycloaddition reaction using organic azides as 1,3-dipoles and several dipolarophiles. The reaction was catalyzed with metal Lewis acid and the products were obtained with high yields and excellent regioselectivity because only a single regioisomer was obtained in all proposed cases. In addition, some synthesized triazoles were tested on porcine aortic endothelial cells (pAECs) to evaluate their biological activity and demonstrated a very strong cardioprotective action in *in-vitro* and *ex-vivo* models of cardiovascular pathologies (i.e., hypoxia-reoxygenation and hypertension).[2]

References:

[1] A. De Nino, L. Maiuolo, P. Costanzo, V. Algieri, A. Jiritano, F. Olivito, M. A. Tallarida, *Catalysts* **2021**, 11, 1120.

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ORG-PO-163

Synthesis of Luminescent Indolizine Derivatives by Pd-Catalyzed Aminocarbonylation

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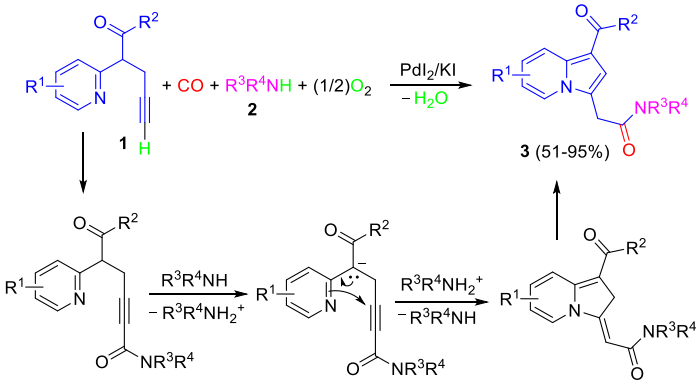
The indolizine core is present in many molecules that display a wide range of pharmacological properties.[1] Moreover, some interesting organic fluorophores possess the indolizine core as the key structural unit.[2] Here we present a multicomponent approach to novel *N*,*N*-disubstituted 2-(indolizin-3-yl)acetamide derivatives with fluorescent properties starting from simple and readily available building blocks [2-(pyridin-2-yl)pent-4-yn-1-carbonyl compounds, CO, amines, and oxygen] through a sequential PdI_2/KI-catalyzed oxidative aminocarbonylation[3] – cyclization – aromatization process (Scheme 1).



Scheme 1

As shown in Figure 1, the tested indolizine absorb (λ_{abs}) in the UV region (374.5–386.0 nm), and emit (λ_{em}) in the visible or blue region (442–448.6 nm).

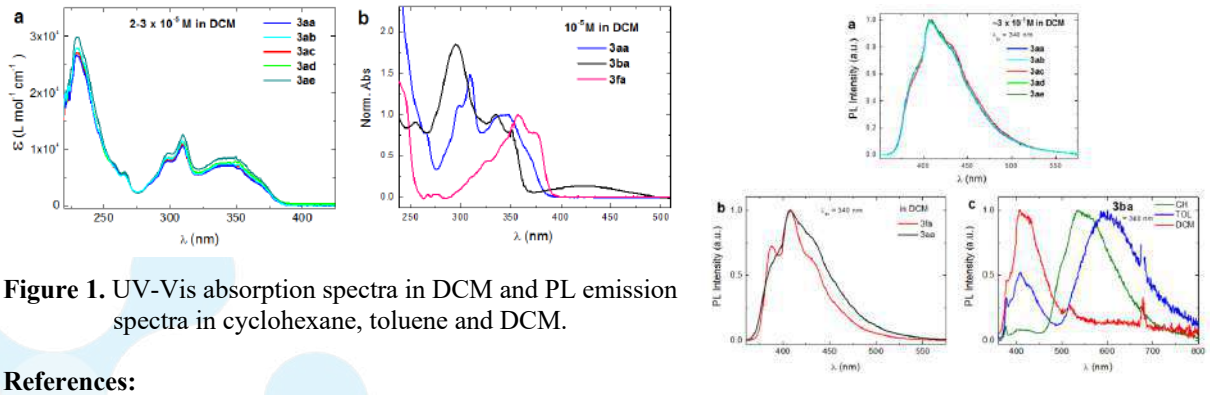


Figure 1. UV-Vis absorption spectra in DCM and PL emission spectra in cyclohexane, toluene and DCM.

References:

[1] K. M. Dawood, A. A. Abbas, *Expert Opin. Ther. Patents* **2020**, *30*, 695-714.
[2] E. Kim, Y. Lee, S. Lee, S. B. Park, *Acc. Chem. Res.* **2015**, *48*, 538-547.
[3] B. Gabriele (Ed.), *Carbon Monoxide in Organic Synthesis – Carbonylation Chemistry*, Wiley-VCH, **2022**.

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ORG-PO-164

One-pot applications of 1-phenylsulphonyl-1-cyano epoxides for the asymmetric synthesis of heterocycles and building blocks

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The enantioselective synthesis of epoxides is of considerable interest, as these compounds are used as highly versatile intermediates to obtain bioactive compounds useful in medicinal chemistry.[1] Recently, a new class of molecules, 1-phenylsulfonyl-1-cyano epoxides, has been disclosed and employed for the synthesis of enantioenriched dihydroquinazolinones, via a one-pot Knoevenagel/epoxidation/*DROC* (*Domino Ring Opening Cyclization*) reaction sequence, using a quinine-based organocatalyst and commercially available reagents.[2] In this contribution, an additional application of this one-pot sequence is reported, employing 2-aminobenzylamine in the *DROC* step to obtain the corresponding 7-membered cyclic products, 1,4-benzodiazepinones, privileged scaffolds in medicinal chemistry (Figure 1).
Further iteration of this one-pot strategy afforded α-aryl glycines,[3] through the epoxides opening according to a *DROE* (*Domino Ring Opening Esterification*) mechanism, employing two different nucleophiles such as aromatic amines and methanol. Similarly, enantioenriched mandelic acids, which represent important building blocks to obtain drugs such as *S*-Clopidogrel and Cyclandelate, have been prepared using water as a nucleophile in the final *DROH* (*Domino Ring Opening Hydrolysis*) step (Figure 1).

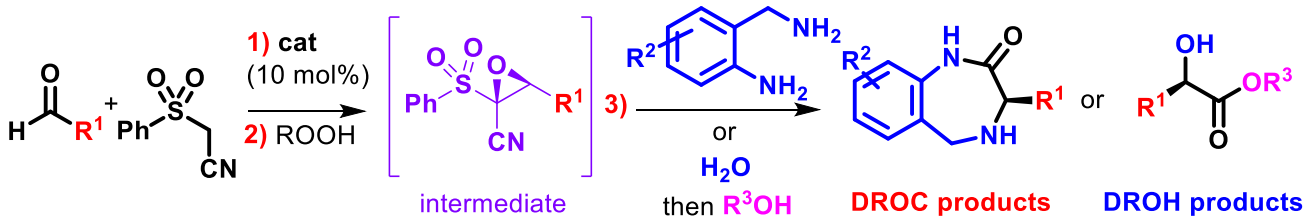

Figure 1: One-pot catalytic approach for the enantioselective synthesis of 1,4 benzodiazepinones and mandelic acids esters.

References:
[1] S. Meninno, A. Lattanzi, ACS Org. Inorg. Au 2022, 2, 289 – 305.
[2] C. Volpe, S. Meninno, C. Crescenzi, M. Mancinelli, A. Mazzanti, A. Lattanzi, Angew. Chem. Int. Ed. 2021, 60, 23819 – 23826.
[3] V. Battaglia, S. Meninno, A. Pellegrini, A. Mazzanti, A. Lattanzi, Org. Lett 2023, 25, 5038 – 5043.

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ORG-PO-165

Mechanochemical N-alkylation of amines with alcohols: A green and sustainable approach

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N-alkylation of amines is a crucial transformation for pharmaceutical and fine chemical industries.[1] The general synthetic procedures for N-alkylation of amines involve harsh reaction conditions such as high temperature and inert atmosphere, harmful reagents like alkyl halides, and prolonged reaction times. These processes also use large quantities of solvents for the reactions. Borrowing hydrogenation (BH) strategies to obtain N-alkylated amines using alcohols has gained significant attention due to its intrinsic atom economy and selectivity. Although it is a significant step to avoid alkyl halides, borrowing hydrogenation strategies often comes with the same drawbacks of harsh reaction conditions, longer reaction times, and use of solvents.[2]

Mechanochemistry, a field that offers tools to perform reactions without the involvement of solvents and sometimes uses a very low amount of liquid for enhancing the milling procedures, has been instrumental in our innovative approach.[3] Thus, in this project, we describe an efficient methodology for borrowing hydrogenation for N-alkylation of amines using mechanochemistry at solvent-free, room temperature, under normal atmosphere, and low catalyst loading conditions. Our procedure offers significant reduction in time and energy along with propounding a greener and more sustainable pathway for the accessibility to N-alkylamines.

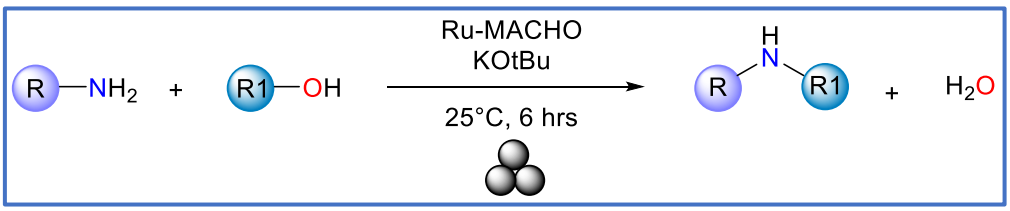

Figure 1: Condition for mechanochemical N-alkylation of amines using alcohols.

References:

[1] S. A. Lawrence, *Amines: Synthesis Properties, and Applications*, Cambridge University Press, **2004**

[2] B. G. Reed-Berendt, D. E. Latham, M. B. Dambatta, L. C. Morrill, *ACS Central Science*,**2021**, *7*(4), 570-585.

[3] F. Basoccu, F. Cuccu, P. Caboni, L. De Luca, A. Porcheddu, *Molecules* **2023**, *28*(5), 2239.

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Novel Strategies for CO_2 Fixation in Organic Scaffolds: Electro-, Nickel- and Carbo-catalyzed Processes.

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An overview of the latest strategies developed by our group for the valorization of CO_2 through fixation into organic scaffolds is presented, employing three different approaches. Initially, we have devised Ni-catalyzed methodologies to effect carbonylation reactions using CO_2 as a CO surrogate, facilitated by the presence of $AlCl_3$ as an oxygen scavenger, thereby addressing the formation of cyclic ketones[1a] and amides.[1b] Subsequently, leveraging electrochemistry as a tool for generating reactive nucleophilic species capable of capture CO_2, we are presently advancing carboxylation processes of olefins, including Morita-Baylis-Hillman acetates[2a] and electron-deficient allenes,[2b] in a metal- and additive-free fashion. Lastly, we are investigating the use of Graphene-Oxide (GO) functionalized with natural amino acids, such as arginine, for the realization of "smart" materials capable of executing CO_2-Capture and Utilization (CCU) strategies.[3]

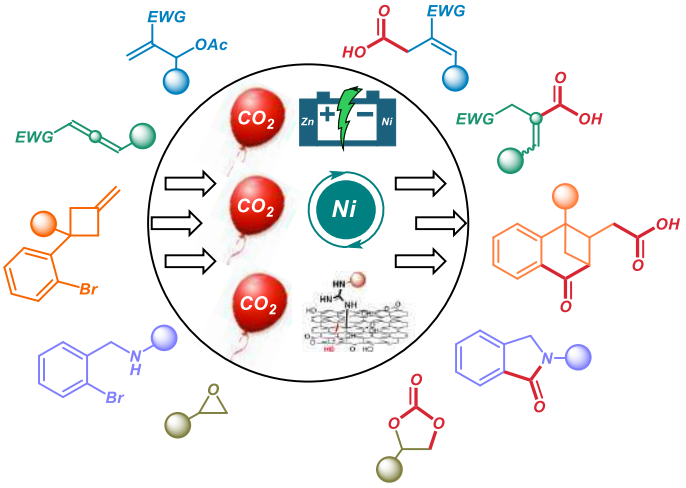

Figure 1. Multiple approaches for the valorization of CO_2.

References:

[1] a) R. Giovanelli, G. Bertuzzi, M. Bandini *et al. Org. Lett.* **2023**, *25*, 6969; b) R. Giovanelli, G. Bertuzzi, M. Bandini *et al. Manuscript in preparation.*

[2] a) A. Brunetti, G. Bertuzzi, M. Bandini *et al. Synthesis* **2024**, *55*, 3047; b) A. Brunetti, G. Bertuzzi, M. Bandini *et al. Manuscript in preparation*.

[3] a) A. Pintus, G. Bertuzzi, M. Bandini *et al. Chem. Eur. J.* **2023**, *29*, e202202440; b) S. Mantovani, G. Bertuzzi, M. Bandini *et al. ChemSusChem* **2024**, *17*, e202301673.

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ORG-PO-167

Structure-property correlations in polyhalogenated Thiele hydrocarbons

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Molecules with open-shell electronic configurations are crucial in modern molecular material science. Singlet diradicaloids (SDs) belong to this category. They are molecular compounds with two unpaired electrons that are coupled antiferromagnetically, resulting in a singlet spin state. Their significance in organic chemistry stems from their unique electronic properties, which can lead to intriguing magnetic, optical, and conducting behaviors. One prominent group of SDs is represented by para-quinodimethanes (pQDMs). By utilizing polychlorination as a synthetic tool, we successfully stabilized the Thiele hydrocarbon.[1] This new species, named TTH (Figure 1), exhibited intense photoluminescence (with a quantum yield of 0.84 in toluene), a red-shifted emission (Stokes' shift of 193 nm in cyclohexane), and solvatochromic properties. Through transient spectroscopic techniques and supported by multireference quantum-chemical calculations, we demonstrated that this emission arises from a zwitterionic doubly excited state, typically found at low excitation energies in SDs. This state gains dipole moment and intensity through state mixing *via* twisting around the strongly elongated exocyclic CC bonds of the excited pQDM core, akin to sudden polarization in olefins. While previous studies focused on the influence of para-halogens on the electro-optical properties of Thiele fluorocarbons,[2] our current work delves into the effects induced by structural variations. We synthesized new polyhalogenated Thiele hydrocarbons with different halogenation patterns to showcase the relevance of molecular geometry on the photophysical properties of these derivatives, thereby providing fresh insights into the molecular design of SDs.

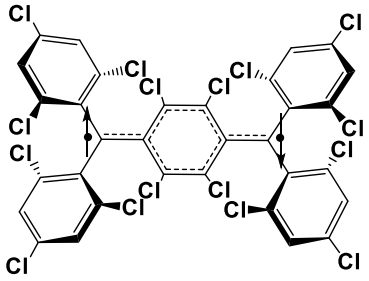

Figure 1: molecular structure of TTH

References:

[1] A. Punzi, Y. Dai, C. N. Dibenedetto, E. Mesto, E. Schingaro, T. Ullrich, M. Striccoli, D. M. Guldi, F. Negri, G. M. Farinola and D. Blasi, *J. Am. Chem. Soc.*, 2023, **145**, 20229–20241.

[2] C. Liu, Z. He, C. Ruchlin, Y. Che, K. Somers and F. Dmytro, *J. Am. Chem. Soc.*, 2023, **145**, 15702–15707.

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N-lactam radicals in light-promoted reactions

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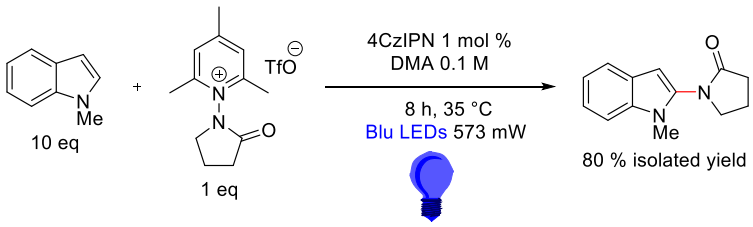
Nitrogen-containing structures are ubiquitous in natural and in synthetic organic compounds, such as pharmaceutical and agrochemicals products. The development of new synthetic methodologies to build C-N bonds in a mild, sustainable, and possibly stereoselective manner is a topic of great interest for synthetic organic chemists. In the last two decades, photoredox catalysis emerged as a powerful tool for the generation of radical species under such conditions. Among the different radical species, we focused on amidyl radicals, which are electrophilic nitrogen radical species where the single electron is in a p orbital. [1]

Our research group has studied the formation of amidyl radicals through the homolytic cleavage promoted by light of N-O[2] and N-N bonds and the reactivity of these radicals with nucleophiles like enamines and heteroarenes. We also managed to successfully form and react the γ, δ and ε-*N*-lactam radicals, which are not known in literature. For these transformations, we have done an extensive reaction conditions screening by changing the light source, the photocatalyst, the stoichiometry and the solvents; in Scheme 1 the best conditions are summarized. [3]



Scheme 1: General reaction scheme for the reaction under study.

With the best conditions in hand, we have studied the addition of these *N* lactam radicals to different arenes and heteroarenes, collecting 19 different substrates with isolated yields up to 95 %. Gladly, we were also able to directly functionalize *N*-Boc-OMe-L-tryptophan obtaining the addition product in 50 % yield. Then, we performed a wide mechanistic investigation comprehensive of Cyclovoltammetry, X ray analysis, Stern-Volmer and Life-Time studies, Quantum Yield measurements, kinetic analysis and DFT calculations. In the end, we succeeded to run the photocatalytic radical addition of γ-*N* lactam radical in water in 44 % yield, opening the pathway to possible biological applications.

References:

[1] J. Davies, S.P. Morcillo, J.J. Douglas, D. Leonori; *Chem. Eur. J*. **2018,** *24*, 12154–12163.
[2] M. F. Boselli, N. Intini, A. Puglisi, L. Raimondi, S. Rossi, M. Benaglia, *Chem. Eur. J*, **2023**, 26, e20220130.
[3] Unpublished results.

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Porphycenes networks, chemosensing properties of 2D and 3D thin films

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Photoactive organic-based molecular materials hold a great deal of potentials in many technological and biomedical fields. Porphycenes (H_2Po), tetrapyrrole 18π electron conjugated chromophore macrocycles constitutional isomers of porphyrins,[1] are an intriguing class of molecular materials which can serve as multipurpose scaffolds. They have two H atoms in the inner cavity which are subject to fast tautomerism while, as tetradentate ligands, they can also host almost all the metal ions. Being chemically and thermally stable, their periphery (*meso* and *β* positions) can be functionalized for specific scopes and applications. The different pattern of connection of the four pyrrole rings with respect to porphyrins, reflects in H_2Po different molecular symmetry and inner core size which favours optical behaviour suitable for ultrafast responsive material.

We previously reported the first study on vacuum deposited H_2Po continuous and compact 2D/3D thin films[2,3] *via* a combination of UV-Vis-NIR optical spectroscopies (absorption, emission, surface differential reflectivity-SDR and reflectance anisotropy spectroscopy-RAS) and surface microscopies (i.e. AFM). We demonstrate a spectacular chromatic change when the film is exposed to acid and we verified the fast reversibility of the process. We now further investigate this behaviour in porphycenes functionalised with alkyl and aryls substituents in both the β pyrrole and *meso* positions as those reported in Figure 1.

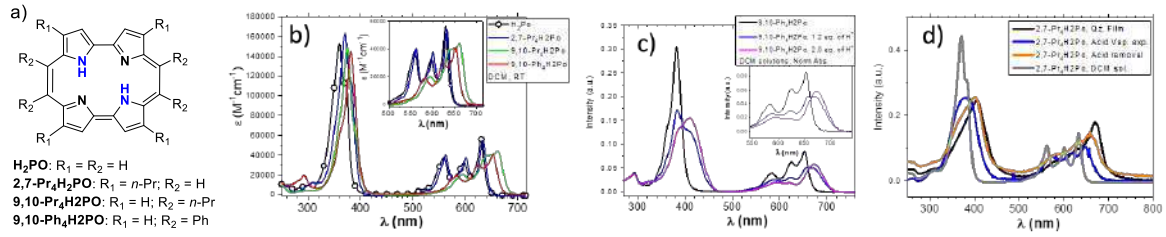

Figure 1: a) Chemical structures of the studied porphycenes; b) comparisons of the optical absorptivities of the studied porphycenes in DCM solutions; c) changes in optical absorptions of 9,10-Ph_4H_2Po upon addition of 1 and 2 equivalent of H^+ (in the form of TFA); d) absorption changes of a 20nm thin film of 2,7-Pr_4H_2Po when exposed to HCl vapours.

References:

[1] E. Vogel, M. Köcher, H. Schmickler, J. Lex, *Angew. Chem. Int. Ed. Engl*. **1986**, 25, 257. [2] A. Bossi, J. Waluk, R. Yivlialin, M. Penconi, M. Campione, G. Bussetti, *ChemPhotoChem,* **2020**, 4, 5264. [3] M. Penconi, L. Ferraro, J. Waluk, L. Duò, F. Ciccacci, A. Bossi, M. Campione, G. Bussetti, *Proceedings* **2020**, 56(1), 44.

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N-Rich Chemical Platforms: Continuous Flow Synthesis via Sustainable Ru-Supported Hydrochar-waste derived

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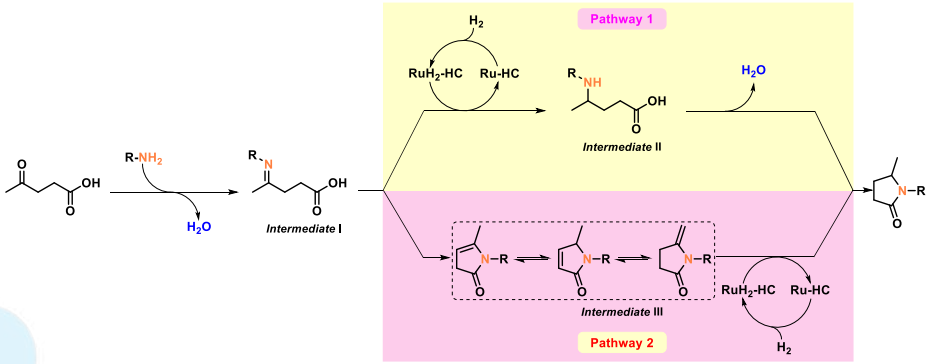
The utilization of biomass waste for a catalytic approach and the subsequent synthesis of valuable products through catalytic reactions are pivotal endeavours addressing pressing energy and environmental concerns. In line with sustainability objectives, this study explores the application of hydrochar derived from hydrothermal treatment of brewing industry waste as a support for a Ru-based catalyst (Ru-HC) in the improvement of reductive amination processes. Employing an efficient continuous flow method, alongside a hydrogen source, has yielded remarkable results, achieving up to 99% conversion in the hydrogenation of biomass-derived molecules such as levulinic acid (LA) and n-butylamine into pyrrolidones compounds. The catalytic ability of Ru-HC extends to a wide array of substrates, including various carbonyl-containing compounds and amines, encompassing green molecules such as furfural, 5-hydroxymethylfurfural, and furfurylamine, leading to the production of valuable N-containing products. Mechanistic insights are elucidated through intermediate formation and recyclability studies, demonstrating the stability and reusability of Ru-HC. The selection of solvents and optimization of key parameters, such as flow rate, temperature, and pressure, significantly influence selectivity.



Adopting a continuous process not only reduces reaction times but also eliminates the requirement for hazardous gaseous hydrogen, ensuring enhanced selectivity while minimizing environmental impact. This research underscores an eco-friendly approach to the production of high-value compounds from biomass, contributing to sustainable amine synthesis through the utilization of biomass-based catalysts.

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New Electrochemical Manipulations of Tropones: Selective Alkylation Strategies

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Tropones are seven-membered-ring ketones belonging to the class of non-benzenoid aromatic molecules, that can be encountered in a variety of naturally occurring compounds and constitute a unique platform in the total synthesis of complex scaffolds.[1] Despite this undoubted interest, direct and site-selective protocols for the tropone skeleton decoration are still rare and scattered in scope.

Herein, as part of our ongoing interest on electrochemical organic transformations,[2] we present two different innovative electrochemical strategies for the direct functionalization of tropones. Firstly, we have developed a ***general α-alkylation of tropones*** via a "radical approach", utilizing a metal-free C(sp^2)-C(sp^3) cross coupling manifold. This process relies on an activated form of tropolone undergoing the addition of nucleophilic radicals, generated by the electrochemical reduction of *N*-hydroxyphthalimide esters.[3a] Secondly, we are currently pursuing an ***α-benzylation of tropones*** through a Ni-catalyzed electrochemical cross-electrophile coupling between aldehydes and substituted tropones.[3b]

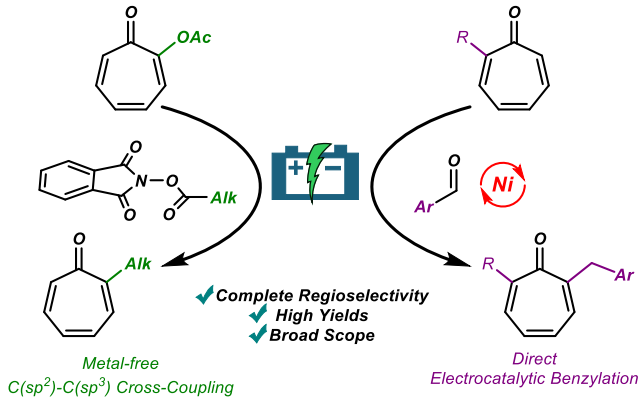

Figure 1. New Electrochemical Functionalizations of Tropones.

References:

[1] K. C: Nicolau, R. Yu, Z. Lu, F. G. Alvarez, *J. Am. Chem. Soc.* **2022**, *144*, 5190.

[2] For the most recent examples see: a) L. Rapisarda, A. Fermi, P. Ceroni, R. Giovanelli, G. Bertuzzi, M. Bandini, *Chem. Commun.* **2023**, *59*, 2664; b) M. Garbini, A. Brunetti, R. Pedrazzani, M. Monari, M. Marcaccio, G. Bertuzzi, M. Bandini, *Chem. Commun.* **2024**, *60*, 404.

[3] a) A. Brunetti, M. Garbini, N. G. Kub, M. Monari, R. Pedrazzani, C. Zanardi, G. Bertuzzi, M. Bandini *Adv. Synth. Catal.* **2024**, *e202400050;* b) A. Brunetti, M. Garbini, M. Monari, C. Zanardi, G. Bertuzzi, M. Bandini, *Unpublished.*

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Chemical decoration of phages for the development of viral-based theranostic platforms

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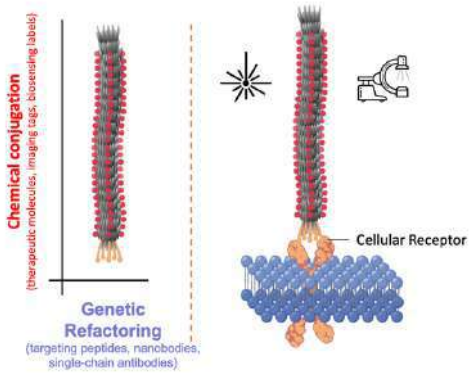
Viral capsid can be considered as a chemically addressable structure, providing a synthetic way to decorate the external surface of a virus with molecules of interest. Phages are ubiquitous viruses that infect bacteria but are inactive against eukaryotic cells.

We developed an orthogonal nanoarchitectonics approach (genetic/chemical) to engineer the M13 phages as innovative theranostic platforms.[1] M13 phages were genetically refactored to display on their tip a peptide, a nanobody or a single chain antibody, retargeting them to any type of cell. Using an orthogonal approach to the genetic display, the refactored phages were then chemically modified, conjugating hundreds of imaging tags/therapeutic molecules/biosensing labels on the capsid surface.[1-4] Natural amines present on the surface of the protein capsid allow the direct functionalization of the virus[1-4] or the introduction of abiotic chemical functionalities for "click chemistry" or "supramolecular chemistry". The M13 phage platform can be conjugated with hundreds of molecules without impinging upon the targeting moiety.[1-3] Thereby, many more molecules can be delivered to the cellular target per binding event as compared to one/few molecules for antibodies. In principle, any kind of molecules can be attached to the surface of the phage.



Using this strategy, we developed phototheranostic platforms able to simultaneously detect, image and kill selectively cancer cells at picomolar concentration of the phage vector.[1-3] These platforms are active in photodynamic(PDT) and sonodynamic (SDT) therapy of cancer[1-3] and in antimicrobial PDT/SDT.[4] We also demonstrated the ability to use these bioconjugated viral platforms as receptor-targeted delivery system or for the analytical sensing of pathogens, replacing antibodies with an improvement in the therapeutic/imaging/sensing efficacy of two-order of magnitude.

References:

[1] L. Ulfo, A. Cantelli et al. Nanoscale, 2022,14, 632-641.
[2] B. Bortot, M. Apollonio et al. Free Radic. Biol. Med. 2022, 179, 242-251.
[3] E. Turrini, L. Ulfo et al. Cell. Mol. Life Sci. 2024, 81, 144.
[4] A. Petrosino, R. Saporetti et al. iScience 2023, 26, 108032.

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Sulfonated pine needles derived biochar as efficient heterogeneous catalyst for alkyl levulinates synthesis

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The exploitation of lignocellulosic urban waste represents nowadays an alternative and innovative way toward the constitution of a circular and residues-free economy. In particular, in certain Mediterranean areas such as the Italian coastal zone, Pine needles pose a serious issue being among the major responsible for forest fires contributing to greenhouse gases in the atmosphere. This lignocellulosic material, in addition to its use as a source of value-added products (cellulose, bioethanol, bio-oils, etc), can be also converted into biochar, whose further functionalization can provide a series of heterogeneous catalysts.

In the present work, we aim to highlight the most significant results obtained in the esterification reaction of levulinic acid with a plethora of alcohols, exploiting a homemade sulfonated pine needle-derived biochar as an acidic heterogeneous catalyst, named Pine-SO3H.

Our study wants to demonstrate that green chemistry and modern technologies can give access, exploiting biobased derived starting materials, to a series of valuable and atoxic products such as alkyl levulinates, useful as fuel additives, solvents, and fragrances.

This work has been funded by the European Union – NextGenerationEU under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 – VITALITY. We acknowledge Università degli Studi di Perugia and MUR for support within the project Vitality. The University of Perugia is acknowledged for financial support to the university project “Fondo Ricerca di Ateneo, edizione 2022”

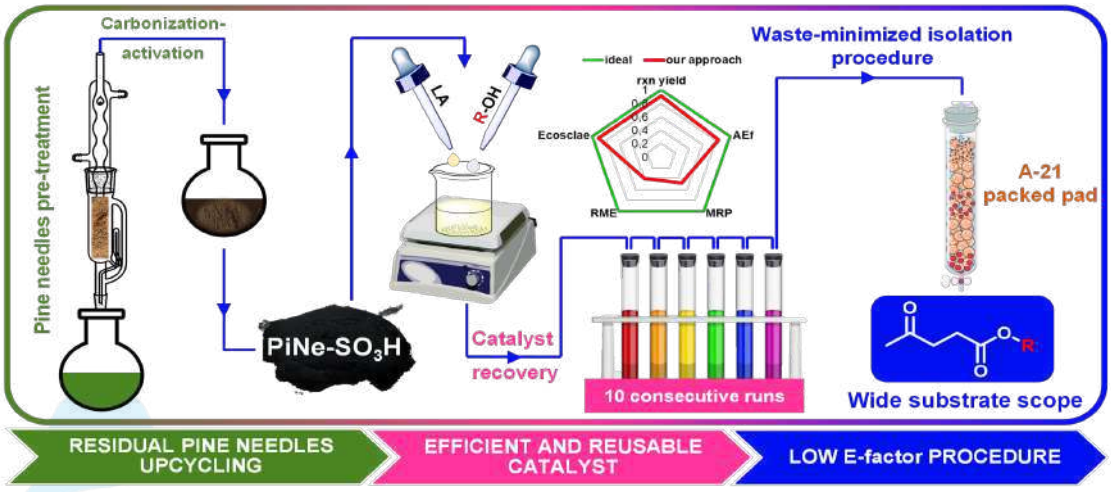

Figure 1: Levulinic acid valorization to alkyl levulinates.

References:

[1] F. Campana, F. Valentini, A. Marrocchi, L. Vaccaro, Biofuel Res. J., 2023, 40, 1989–1998.

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Asymmetric reduction of cyclic imines by Imine Reductase enzymes in non-conventional solvents

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Biocatalysis became a powerful tool for the synthesis of relevant high-added value molecules with excellent chemo-, stereo- enantioselectivities but also allow to perform greener chemical transformations. However, the low solubility of many organic substrates or products in aqueous solutions, commonly used in enzymatic reactions, often hampered the application of enzymes in synthesis, mainly because of substrate concentration restrictions. In this context, non-conventional solvents are acquiring increasingly relevance and, in recent publications, they were demonstrated to improve the yield and selectivity of enzymatic reactions in an economical, health-safe, and environmentally-friendly manner.[1] In this field, Deep Eutectic Solvents (DESs) have rapidly emerged as a promising class of green reaction media as a promising class of green reaction media due to their unique properties.[2] In these work we report a successful example of non-conventional solvents used for the synthesis of cyclic chiral amines by bio-reduction of the starting cyclic imines.[3] The transformation was realized by means of a novel class of NADPH-dependant enzymes, namely Imine Reductases (IREDs). We performed the reduction of cyclic imines in a mixture of phosphate buffer/glycerol (50% v/v). Pyrrolidines, piperidines, and azepines were produced in good yields and excellent S-enantioselectivities (up to >99% *ee*). Also, the use of non-conventional solvents allows to increase the concentration of the starting material up to 100 mM. It is worth mentioning that applying a fed-batch strategy, we were able to work at mmol scale with 80% yield and excellent *ee*, which formally corresponds to a seven-fold use of the same enzyme. Our findings in terms of enantioselectivity, substrate scope and scalability will be presented.

References:

[1] M. Panić, M. Cvjetko Bubalo, I. Radojčić Redovniković, *Journal of Chemical Technology & Biotechnology*, 2021, 96.1: 14-30.
[2] E. L. Smith, A. P. Abbott, K. S. Ryder, *Chem. Rev*. 2014, 114, 11060−11082.
[3] D. Arnodo, F. De Nardi, S. Parisotto, E. De Nardo, S. Cananà, F. Salvatico, E. De Marchi, D. Scarpi, M. Blangetti, E.G. Occhiato, C. Prandi, *ChemSusChem*, 2023, e202301243.

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Emissive nucleobases in PNA chemistry

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Peptide nucleic acids (PNA) are key candidates in chemical biology. They are synthetic oligonucleotide mimetics which are capable of interacting with DNA and RNA due to common nucleobase alphabet, although presenting a pseudopeptide backbone.[1,2] They have been already studied in antisense and antigene therapies, gene editing, nucleic acid sensing and imaging.[2] The substitution of natural occurring nucleobases with fluorescent isomorphic analogues into PNA is a unique strategy to impart intrinsic luminescence while maintaining efficient paring, aiming to overcome structural limitations of fluorophores' tagging.[3] Isomorphic fluorescent bases have shown significant emissive read-outs upon variation of pH and polarity and in the imaging of biological relevant events like duplex formation.[3,4] In this work we have prepared and investigated thieno[3,4-d]pyrimidine nucleobases and their incorporation into PNA (Figure 1).

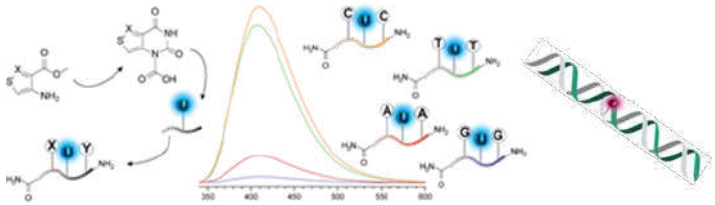

Figure 1: Emissive nucleobases incorporated into PNA.

Our studies confirm how the synthesized bases are compatible for insertion along PNA sequences of different length to deeply understand the emissive traits and to evaluate the ability to form stable heteroduplex with complementary DNAs. These preliminary results highlight that these fluorescent analogues can be easily used for PNA synthesis while conferring significant modular luminescence.

References:

[1] P.E. Nielsen, Account of Chemical Research 1999, 32, 624–630.
[2] J. Saarbach, P.M. Sabale, N. Winssinger, Current Opinion in Chemical Biology 2019, 52, 112 – 124.
[3] R.W. Sinkeldam, N. Greco, Y. Tor, Chemical Reviews 2010, 110, 2579 – 2619.
[4] A. Rovira, A. Fin, Y. Tor, Chemical Science 2017, 8, 2983 – 2993.

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ORG-PO-176

New natural-based hybrids as tyrosinase inhibitors

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In mammals, tyrosinase is responsible for melanin biosynthesis, which can protect the skin cells against the harmful effects of ultraviolet (UV) irradiation, oxidative stress, and DNA damage. However, melanin overproduction can cause several aesthetic problems and even severe diseases related to hyperpigmentation and malignant melanoma onset. Consequently, tyrosinase inhibitors can effectively inhibit excessive melanin formation and be employed as whitening agents in cosmetics, which have a broad space for market prospects, as well as for hyperpigmentation diseases and malignant melanoma, which is a promising therapeutic strategy.

In the design of new tyrosinase inhibitors, many research groups have employed bioactive natural products as scaffolds to achieve more effective inhibitors.[1] In doing that, molecular hybridization can be an efficient way to include two pharmacophore moieties into a new molecular species with specific and selective activity, and/or less toxicity, and/or improved bioavailability.

The synthesis of new hybrid molecules based on natural tyrosinase inhibitors such as resveratrol, azelaic acid, and others is reported herein (Figure 1), keeping the *m*-hydroxyphenol moiety unchanged, as SAR studies revealed this portion to have significant influence on the inhibitory activity of tyrosinase.[2]The new hybrids will be in-vitro evaluated as tyrosinase inhibitors.

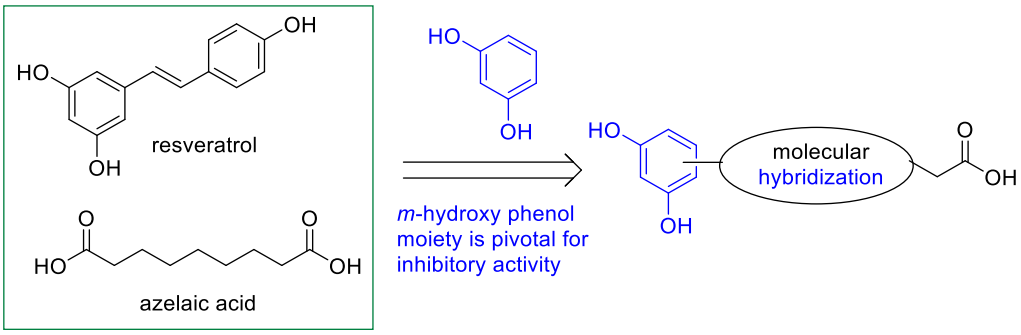

Figure 1: Scope of the work: synthesis of natural-based hybrids as tyrosinase inhibitors.

Acknowledgement: This work was financed by MUR ITALY PRIN 2022 PNRR (Project No. P2022MWY3P).

References:

[1] J. Li, L. Feng, L. Liu, F. Wang, L. Ouyang, L. Zhang, Z. Hu, G. Wang, European Journal of Medicinal Chemistry 2021, 224, 113744.
[2] Q. Li, H. Yang, J. Mo, Y. Chen, Y. Wu, C. Kang, Y. Sun, H. Sun, PeerJ 2018, 6, e4206.

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ORG-PO-177

Lewis acid-catalyzed synthesis of *B,B',B"*-substituted borazines under microwave irradiation

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Borazine, valence isomer of inorganic benzene, is nowadays a well-known precursor for ceramic materials. Since its first synthesis in 1926 by Stock and Pohland[1] much progress has been made both in the synthesis and application field[2] of this substrate owning to its features that differ from those of benzene. While borazine is isoelectronic with benzene, it is less aromatic and has a higher HOMO-LUMO bang gap (6.2 eV vs 6.0 eV for benzene). Despite the progress made to date, borazine synthesis remains a challenge for scientists. Regarding *B*-aryl substituted borazines, only few synthetic protocols are available. In 2005 Nöth and Troll[3] afforded to synthesize 2,4,6-Triphenylborazine in 98% yield after a 10-day reaction between $PhBCl_2$ and HMDS at 55°C. Successively, Engels and Helten[4] attempted the synthesis of *B,B',B"*-trimesityl-*N,N',N"*-trimethyl borazine but they could obtain the product only in traces after 14 days.

Keeping in mind these challenges, we developed a new synthetic protocol to access *B,B',B"*-substituted borazines. In this context greener, easier to handle and more accessible boronic esters are used instead of harmful boron halides. Moreover, by combining the Lewis acid-catalysed protocol with the known advantages of Microwave Assisted Organic Synthesis, we could synthesize a variety of *B*-substituted borazines in higher yields in 1h while reducing the quantity of waste generated.

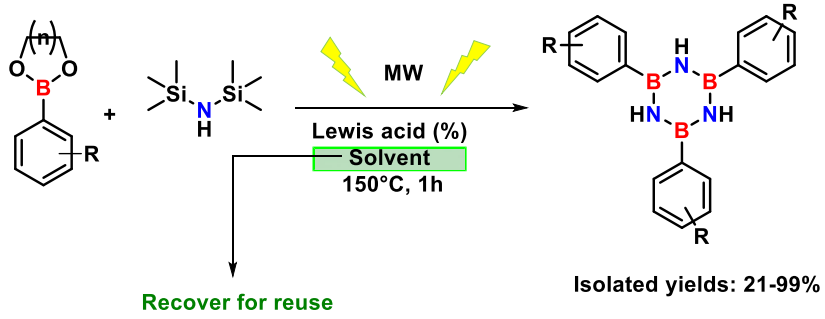

Figure 1: Microwave assisted synthesis of *B*-substituted borazines.

References:

[1] A. Stock, E. Pohland, Ber. *Dtsch. Chem. Ges. (A and B Series)* **1926**, *59*, 2210.
[2] D. Marchionni, S. Basak, A. N. Khodadadi, A. Marrocchi, L. Vaccaro, *Adv. Funct. Mater*. **2023**, *2303635*
[3] H. Nöth, A. Troll, Eur. *J. Inorg. Chem.* **2005** *(17),* 3524–3535
[4] M. Maier, J. Klopf, C. Glasmacher, F. Fantuzzi, J. Bachmann, O. Ayhan, A. Koner, B. Engels, H. Helten, *Chem. Commun.* **2022**, *58 (28)*, 4464–4467

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Enhanced Adsorption of Water Contaminants on Chemically Functionalized Multi-Walled Carbon Nanotubes

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Carbon nanomaterials are promising adsorbents for the removal of organic pollutants from wastewater due to their nanometer size, high surface-to-volume ratio as well as possible chemical modification of the surface.[1] The introduction of selected functional groups through surface functionalization can in principle allow the dispersion in water and establish specific interactions with the pollutant, thus enhancing the adsorption rate and enabling a regeneration strategy. Here we report on a derivative of multi-walled carbon nanotubes (MWCNT) bearing benzenesulfonate groups (MWCNT-S) for the adsorption of methylene blue dye (MB).[2]

MWCNT-S was synthesized through diazotization reaction and characterized with IR, TGA, TEM, XPS and DLS measurements. The obtained material demonstrated to have more than double adsorption capacity and significantly higher adsorption rate than that of the pristine insoluble MWCNT. Surface functionalization ensured the dispersibility of the derivative in water, providing more available surface area, and the possibility of electrostatic interactions between the cationic MB and the anionic sulfonate groups (Figure 1).

Additionally, the reversibility of ionic interactions disclosed the possibility to release the adsorbed cationic pollutant through competition with salts, not only regenerating the adsorbent, but also recovering the dye.

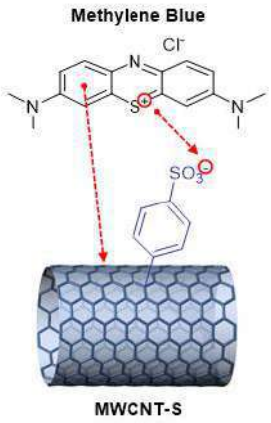

Figure 1: Schematic representation of interactions between MWCNT-S and MB during adsorption.

References:

[1] L. Y. Jun, N. M. Mubarak, M. J. Yee, L. S. Yon, C. H. Bing, M. Khalid, E. C. Abdullah, Journal of Industrial and Engineering Chemistry 2018, 67, 175-186

[2] L. Ceroni, S. Benazzato, S. Pressi, L. Calvillo, E. Marotta, E. Menna, Nanomaterials 2024, 14, 522.

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ORG-PO-179

ALLENAMIDES: A POWERFUL SUBSTRATE FOR THE VISIBLE- LIGHT DEAROMATIZATION OF SIMPLE AROMATICS

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The extreme development of reactions between sp2 carbons has generated a bias in modern chemistry: the dependence of flatness[1]. In this scenario, dearomatization reactions are extremely useful[2].

We found out that allenamides can be sensitized in presence of visible light[3]. When **R** is a **benzyl** or **naphthyl**, we achieved a dearomative 1,4 para-cycloaddition obtaining a [2.2.2] bicyclooctene(diene)[4]. By tuning the **R** group, we developed two intermolecular dearomatizations[5]. If the amide is substituted with an **alkyl** moiety, a para-cycloaddition on naphthalene occurs. On the contrary, when **R** is an **allyl** group, we got a very complex product with the formation of four new C-C bonds in one step.

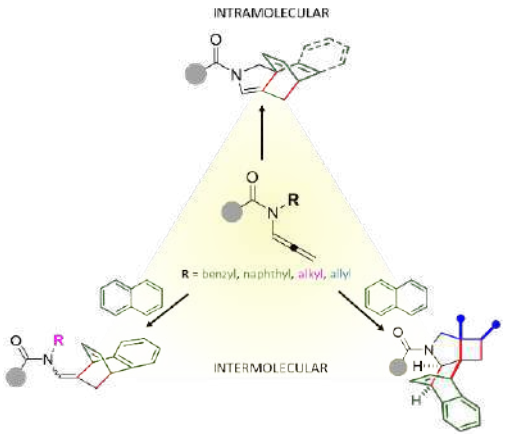

Figure 1: dearomatizations unlocked with allenamides.

Allenamides have therefore proven to be an excellent substrate to allow challenging synthetic transformations, with extremely mild conditions, cheap setups and complete atom economy.

References:

[1] F. Lovering, J. Bikker, C. Humblet, J. Med. Chem., 2009, 52, 6752 – 6756.
[2] W. C. Wertjes, E. H. Southgate, D. Sarlah, Chem. Soc. Rev., 2018, 47, 7996 – 8017.
[3] A. Serafino, M. Chiminelli, D. Balestri, L. Marchiò, F. Bigi, R. Maggi, M. Malacria, G. Maestri, Chem. Sci., 2022, 13, 2632 – 2639.
[4] M. Chiminelli, A. Serafino, D. Ruggeri, L. Marchiò, F. Bigi, R. Maggi, M. Malacria, G. Maestri, Angew. Chem. Int. Ed., 2023, 62: e202216817.
[5] M. Chiminelli, G. Scarica, D. Balestri, L. Marchiò, N. Della Ca', G. Maestri, Tetrahedron Chem, 2023, 8: 100053.

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ORG-PO-180

SUSTAINABLE SYNTHESIS OF TACRINE AND ANALOGUES FOR ALZHEIMER'S DISEASE IN DEEP EUTECTIC SOLVENTS: A GREEN APPROACH

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N-heterocyclic compounds exhibit diverse pharmacological properties and serve as constituents of many biologically important molecules, including vitamins, nucleic acids, pharmaceuticals, antibiotics, and agrochemicals.[1] Traditionally, the preparation of *N*-heterocyclic compounds relies on energy-intensive conditions with long reaction times (16–48 h), toxic volatile organic compounds (e.g., $POCl_3$, toluene), and laborious work-up procedures based on volatile organic compounds (VOCs) (e.g., $CHCl_3$, Et_2O, MeOH).[2] Unfortunately, these solvents significantly contribute to the environmental impact of chemical industries and laboratories, resulting in substantial waste generation.[3] A promising solution to address these sustainability concerns lies in the adoption of Deep Eutectic Solvents (DESs), a new class of environmentally friendly solvents.[4] Over the last decade, we have explored valuable sustainable methodologies for the synthesis of heterocycles with anti-inflammatory or antiproliferative properties, such as functionalized triazoles,[5] pyrimidines, imidazoles,[6] and tetrahydropyran derivatives.[7]

In this communication, we introduce a green synthetic protocol for the synthesis of tacrine and analogues, which are utilized in the treatment of neurological disorders, achieving yields of 90–95%. We employ Type I and IV Lewis Acid Lewis Acid DESs (LADESs) as solvent and catalyst (**Figure 1**). Quantitative metrics confirm the eco-friendliness of these novel approaches.[8]

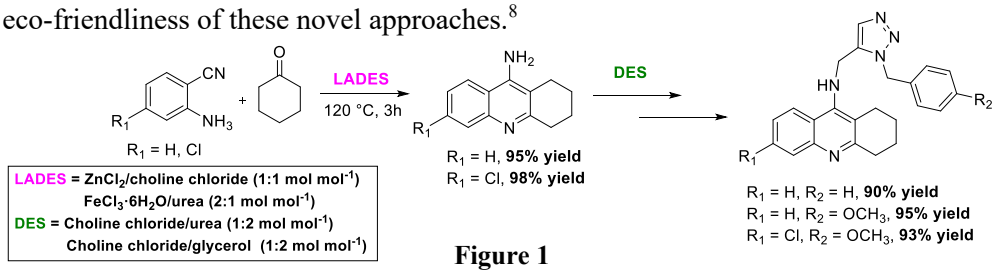

Figure 1

References:

[1] N. Kerru, S. Maddila, S. B. Jonnalagadda S.B. *Curr. Org. Chem.* **2019**, *23*, 3156–3192.
[2] J. Broichhagen, I. Jurastow, K. Iwan, W. Kummer, D. Trauner, *Angew. Chem. Int. Ed.* **2014**, *53*, 7657–7660.
[3] R. A. Sheldon, I. W. C. E., U. Arends Hanefeld, *Green Chemistry and Catalysis*, Wiley VCH, Weinheim, **2007**.
[4] F. M. Perna, P. Vitale, V. Capriati, *Curr. Opin. Green Sustain. Chem*., **2020**, *21*, 27.
[5] L. Cicco, F. M. Perna, A. Falcicchio, A. Altomare, F. Messa, A. Salomone, V. Capriati, P. Vitale, *Eur. J. Org. Chem.* **2022**, *36*, e202200843.
[6] P. Vitale, L. Cicco, I. Cellamare, F. M. Perna, A. Salomone, V. Capriati, *Beilstein J. Org. Chem.* **2020**, *16*, 1915–1923.
[7] G. Dilauro, L. Cicco, P. Vitale, F. M. Perna, V. Capriati, *Eur. J. Org. Chem.* **2023**, *26*, e202200814.
[8] L. Cicco, F. M. Perna, V. Capriati, P. Vitale, *Molecules*, **2024**, *29*, 1399.

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Photoredox Hydroxyalkylation of Unsaturated Partners in Batch and Continuous Flow: An Opportunity to Overcome Polarity Mismatch

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Approximately 37% of marketed drugs contain at least one hydroxyl group in their structure. The introduction of a single hydroxyl group can dramatically influence the drug−receptor binding affinity through the creation of an extensive hydrogen bond network.[1] Moreover, the -OH group can serve as a handle for further derivatizations. In the polar domain, hydroxyalkylations can be accomplished via different reaction pathways. However, retrosynthetically, the possibility to obtain γ-hydroxy substituted derivatives is precluded from polar mechanisms due to a polarity mismatch. α-hydroxyalkyl radicals have emerged as suitable intermediates to promote radical hydroxyalkylations.[2] Despite extensive research into the chemistry of ketyl radicals, we hypothesised that a more direct approach to accessing these intermediates was feasible using readily available feedstocks. In this context, the prospect of utilizing α-hydroxy acids (AHAs) as readily available linchpins for radical hydroxyalkylations seemed particularly promising. In this communication, we demonstrate AHAs can serve as a platform to deliver ketyl radicals via visible light-mediated oxidative CO_2-extrusion. In particular, we developed a photoredox-based γ-hydroxyalkylation via the coupling of α-hydroxy radicals with unsaturated acceptors. Furthermore, flow technology facilitates the scaling of this photochemical methodology.[3,4]

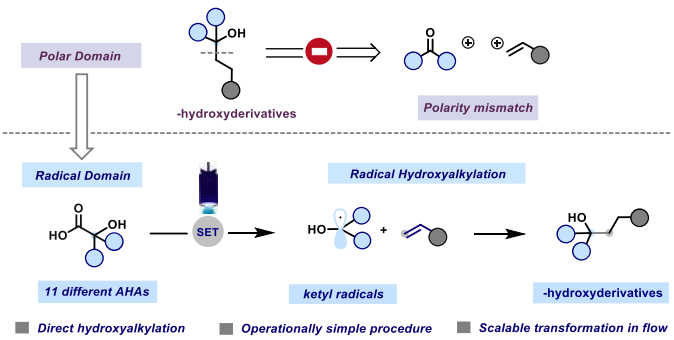

Figure 1: Photoredox hydroxyalkylation leveraging ketyl radicals generated from AHAs.

References:

[1] J. Cramer, C. P. Sager, B. Ernst, J. Med. Chem., 2019, 62, 8915-8930.
[2] Á. Péter, S. Agasti, O. Knowles, E. Pye, D. J. Procter, Chem. Soc. Rev. 2021, 50, 5349-5365.
[3] S. D. A. Zondag, D. Mazzarella, T. Noël, Annu. Rev. Chem. Biomol. Eng., 2023, 14, 283-300.
[4] M. Colella, Y. Gelato, M. Andresini, E. Graziano, G. Vilé, L. Degennaro, R. Luisi. Eur. J. Org. Chem. 2023, 26, e202300413.

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ORG-PO-183

Novel organic dyes for indoor dye-sensitized solar cells: a machine learning and density functional theory study

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Recently, dye-sensitized solar cells (DSSCs) have emerged as the technology of choice for indoor applications and Internet of Things (IoT) devices.[1,2] In this context, extensive research has been carried out to design novel organic dyes whose absorption properties match a variety of artificial light emissions at different intensities.[3,4] Nevertheless, this process is often costly and time-consuming. To address this issue, we have combined Machine Learning (ML) and Density Functional Theory (DFT) methods to accelerate the discovery of potentially novel organic dyes with D-π-A architecture for indoor DSSCs. In particular, a two-stage screening approach has been developed by predicting the power conversion efficiency (PCE) of the dye candidates under different light sources and intensities. Additionally, the evaluation of the synthetic accessibility (SAscore) of the dye candidates has been assessed. Our findings demonstrate that the integration of ML and DFT methods offers an effective way to accelerate the discovery of organic dyes for indoor DSSCs, helping to address the growing demand for sustainable power sources for IoT devices.

References:

[1] H. Michaels, I. Benesperi, M. Freitag, Chem. Sci. 2021, 12, 5002-5015.
[2] A. Aslam, U. Mehmood, M. H. Arshad, A. Ishfaq, J. Zaheer, A. Ul Haq Khan, M. Sufyan, Solar Energy 2020, 207, 874-892.
[3] M. A. Saeed, K. Yoo, H. C. Kang, J. W. Shim, J.-J. Lee, Dyes and Pigments 2021, 194, 109626.
[4] D. Devadiga, M. Selvakumar, P.A Shetty, M.S. Santosh, Journal of Electronic Materials 2021, 50, 3187-3206.

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ORG-PO-184

C(sp^3) -C(sp^3) heterocyclic alpha-alkylation via organometal/metalloid reagents: a robust strategy to exploit the molecular three-dimensional space

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In 2022, the FDA and EMA have approved 37 and 41 New Chemical Entities (NCE), respectively. Among them, small molecules are still apical representing more than 50% of the recently approved entities.[1] Typically, small molecule drugs are constructed around aromatic core architectures even if it is well established how the three-dimensional topology provided by aliphatic motifs is strongly associated with improved pharmacological properties.[2] In this scenario, heterocycles are one of the most widespread moieties within pharmaceutical small molecule structures and the interest in the functionalization with C(sp^3)−C(sp^3) bond is even more prominent.[3] In the last decades, few new methodologies have been introduced for the α-alkyl functionalization of heterocycles, which are often characterized by the use of particular conditions and/or reagents.[4] For this reason, we developed a simple and strong methodology using easily accessible alkyl-M reagents for the α-functionalization of bulky heterocycles. Starting from a common motif based on a cyclic α-amino acid structure through an oxidation step an aminoacetal intermediate is obtained and converted to the corresponding α-alkyl heterocycle.

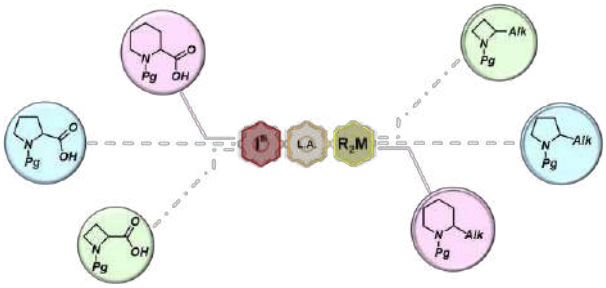

Figure 1: Schematic representation of the α-alkyl heterocyclic functionalization.

References:
[1] A. Mullard, Nature Reviews Drug Discovery 2022, 22, 83–88.
[2] F. Lovering, J. Bikker, C. Humblet, J. Med. Chem. 2009, 52, 6752−6756.
[3] D. F. Fernández, M. González-Esguevillas, S. Keess, F. Schäfer, J. Mohr, A. Shavnya, T. Knauber, D. C. Blakemore, D. W. C. MacMillan, Org. Lett. 2024, 26, 2702
[4] C. P. Johnston, R. T. Smith, S. Allmendiger, D. W. C. MacMillan, Nature, 2016, 536, 322–325; C. J. Cordier, R. J. Lundgren, G. C. Fu, JACS, 2013, 135, 10946–10949

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ORG-PO-185

Aminocatalytic enantioselective [2 + 2] dearomative photocycloaddition for the synthesis of indoline polycyclic scaffolds

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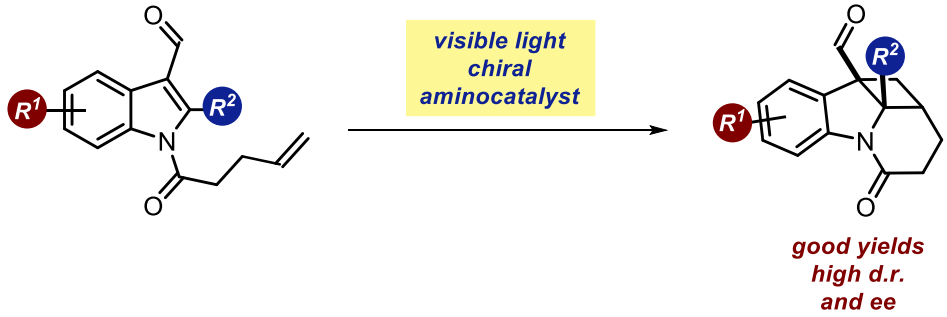
The direct transformation of readily available aromatic feedstocks into structurally diverse three-dimensional molecules makes catalytic asymmetric dearomatization (CADA) reactions of broad interest.[1] Indeed, they provide a sustainable and straightforward route to medicinally relevant archetypes. However, the inherent difficulty of the disruption of aromaticity demands a large energy input during the dearomatization process, which could be incompatible with the typical conditions required by asymmetric catalysis. One promising approach to overcome this issue is the investigation of the excited-state reactivity of (hetero)arenes, which may display different reactivity patterns compared to the original ground-state ones.



Scheme 1: Aminocatalytic enantioselective [2 + 2] dearomative photocycloaddition of indole derivatives.

In this contribution, the successful combination of asymmetric aminocatalysis[2] with the direct activation of visible light (or the use of a photocatalyst)[3] to develop an interesting catalytic asymmetric [2 + 2] dearomative photocycloaddition of the indole core[4] is presented. This methodology relies on the excited state reactivity of transiently generated organocatalytic intermediates, thus enabling the construction of optically active polycyclic products in high levels of yield and stereoselectivity.

References:

[1] a) C.-X. Zhuo, W. Zhang, S.-L. You, *Angew. Chem. Int. Ed.* **2012**, *51*, 12662 – 12686. b) C. Zheng, S.-L. You, *ACS Cent. Sci.* **2021**, *7*, 432 – 444.
[2] D. W. C. MacMillan, *Nature* **2008**, *455*, 304 – 308.
[3] J. Twilton, C. Le, P. Zhang, M. H. Shaw, R. W. Evans, D. W. C. MacMillan, *Nat Rev Chem* **2017**, *1*, 0052.
[4] a) J. Mateos, A. Vega-Peñaloza, P. Franceschi, F. Rigodanza, P. Andreetta, X. Companyó, G. Pelosi, M. Bonchio, L. Dell'Amico *Chem. Sci.* **2020**, *11*, 6532 – 6538. P. Franceschi, S. Cuadros, G. Goti, L. Dell'Amico *Angew. Chem. Int. Ed.* **2023**, *62*, e202217210.

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ORG-PO-186

Green production of Biofuel from Organic Fraction of Municipal Solid Wastes

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The Organic Fraction of Municipal Solid Wastes (OFMSW) can play a key role in the frame of Circular Economy, having great potential as a renewable energy source of biofuel. OFMSW is mainly composed of carbohydrates (50%) and lipids (13%) that are both valuable for the production of bioethanol and biodiesel, respectively.[1] Biofuels have recently gained attention as a sustainable alternative to fossil fuels, allowing to overcome the current environmental issue related to the depletion of raw materials.[2] Moreover, biofuels have higher biodegradation rates, low toxicity and no sulphur content with respect to fossil fuels.[3] Their production from OFMSW can also overcome the problem related to soil and water consumption due to the cultivation of vegetable biofuel sources. Moreover, it can contribute to reduce municipal waste disposal, favouring recycling processes.[4] Indeed, the largest part of OFMSW is disposed at landfills causing environmental and human issues.[5] Here we report an innovative method of biofuel production from OFMSW, based on the use of supercritical carbon dioxide (sc-CO_2) as a green solvent for lipid oils extraction and subsequent conversion into fatty acid methyl esters (FAMEs), suitable as biodiesel. A systematic study, via Central Composite Design (CCD) of Response Surface Methodology (RSM), was performed to identify the optimal operating conditions leading to maximum extraction yields. In particular, the effects of extraction temperature, pressure and supercritical CO_2 flow rate were investigated in the ranges 40-70°C, 150-450 bar and 5-10 l/min, respectively. The obtained FAME mixtures are mainly composed of saturated and unsaturated C10-C18 alkyl chains, being promising for applications as biodiesel.

References:

[1] E.M. Barampouti, S. Mai, D. Malamis, et al., 2019, 298-314
[2] Z. Zhang, IM. O'Hara, S. Munree, 2016, 38:97-105
[3] C.K. Westbrook, 2013, 201-219
[4] I.K. Kiniry, L. Lynd, N. Greene, et al., 2008, 17-30
[5] U. Gustafsson, W. Willis, A. Draper, 2011, 385-93

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Double green strategy for the oxidative functionalization of privileged natural scaffolds

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There is an increasing need for ecologically friendly procedures in the chemical and pharmaceutical industries. In this context, photocatalytic generated singlet oxygen ($^1O_2$) has attracted a great interest. Singlet oxygen is a potent and green oxidant for the functionalization of natural organic compounds in order to obtain potentially active derivatives. Here we report a double green strategy for the oxidative functionalization of estrogens[1], stilbenes and coumarins[2] in a two-liquid-phase system composed by buffer and eco-certified 2-methyltetrahydrofuran (2-MeTHF) in the presence of meso-tetraphenyl porphyrin (meso-TPP) as photosensitizer. Depending on the experimental conditions, $^1O_2$ can directly functionalize the selected substrate by [2+2] and [4+2] cycloaddition with high efficiency and rate constants, or in alternative, it can contribute to the activation of horseradish peroxidase (HRP) by selective formation of the hydroperoxide of 2-MeTHF. In this latter case, the selective insertion of $^1O_2$ in the 2-MeTHF tertiary C-H bond was operative, avoiding enzyme inactivation due to excess of H_2O_2, as well as the formation of undesirable and low selective radical species[2,3]. These procedures were effective for the chemical space analysis and scaffold morphing of estrogens, stilbenes and coumarins, yielding bioactive compounds such as natural bicoumarins identified from pharmacologically active extracts of *Erycibe obtusifolia Benth* (Convolvulaceae)[4].

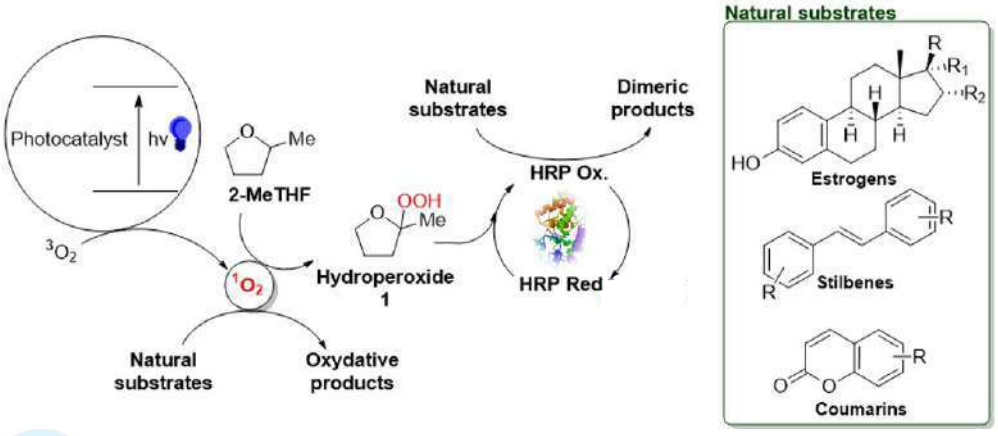

Figure 1: general scheme of the double green strategy for the oxidative functionalization of privileged natural scaffolds.

References:

[1] E. De Marchi, L. Botta, B. M. Bizzarri, R. Saladino, Molecules 2022, 27(24), 8961 – 8973.
[2] C. Zippilli, B. M. Bizzarri, S. Gabellone, L. Botta, R. Saladino, ChemCatChem 2021, 13(19), 4151 – 4158.
[3] C. Zippilli, M.J. Bartolome, T. Hilberath, L. Botta, F. Hollmann, R. Saladino, Chembiochem. 2022, 23, e202200367.
[4] J. Liu, Z. Feng, J. Xu, Y. Wang, P. Zhang, Phytochemistry 2007, 68, 1775-1780.

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Exploring the potential of NADPH-dependent Imine Reductases in non-conventional solvents for enantioselective biocatalysis

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Biocatalysis has seen a growing adoption in both academic and industrial domains in recent years. Enzymes offer the possibility to obtain high ratios of chemo-, stereo- and enantioselectivities in chemical transformations using mild reaction conditions and without the use of polluting reagents and solvents.[1] Moreover, they can be easily produced by means of a microbial host, also in large quantities. Chiral amines are key intermediates in the synthesis of several biological active compounds and biocatalysis has emerged as an efficient method for their preparation. In this report, we propose the use of NADPH-dependent Imine Reductases (IREDs)[2] from different organisms to perform the enantioselective reduction of cyclic imines and the reductive amination of simple ketones and amines. These enzymes were selected and produced in the form of lyophilized cell extracts, avoiding expensive enzyme purifications. We are also interested on the use of non-conventional solvents applied to chemical transformation and biocatalysis.[3] Indeed, we envisaged the possibility of using the produced IREDs in non-conventional systems consisting of glycerol and Deep Eutectic Solvents (DES) as additives. Our findings in terms of enantioselectivity, substrate scope and applicability will be presented.

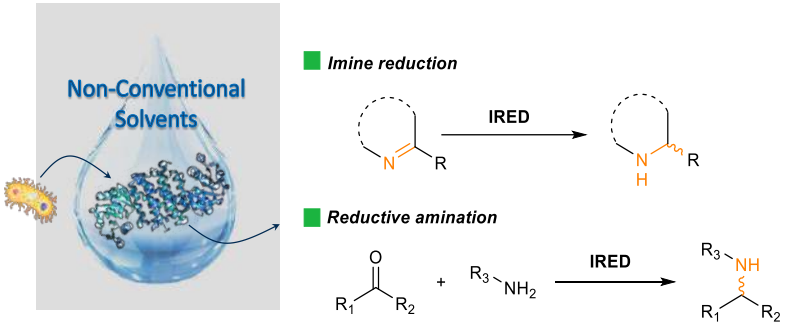

Figure 1: Chiral amines synthesis by means of Imine Reductases in non-conventional solvents.

References:

[1] A. R. Alcántara, P. Domínguez de María, J. A. Littlechild, M. Schürmann, R. A. Sheldon, R. Wohlgemuth, *ChemSusChem* 2022, 15, e202102709

[2] J. Mangas-Sanchez, S. P France, S. L Montgomery, G. A. Aleku, H. Man, M. Sharma, J. I. Ramsden, G. Grogan, N. J. Turner *Curr. Opin. Chem. Biol.* 2017, 37, 19 – 25.

[3] D. Arnodo, F. De Nardi, S. Parisotto, E. De Nardo, S. Cananà, F. Salvatico, E. De Marchi, D. Scarpi, M. Blangetti, E. G. Occhiato, C. Prandi, *ChemSusChem.* **2024**, 17, e2023012.

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Divergent self-deoxyfluorination of bromodifluoromethyl alcohols enabling the synthesis of fluoroamides and acylfluorides

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The introduction of fluorine atoms into organic molecules often induces significant changes in their chemical and biological properties. Consequently, organofluorine compounds have gained widespread methods for their synthesis and new applications in pharmaceuticals, agrochemicals, and advanced materials.[1] Compared to direct C–F bond formation or nucleophilic introduction of a fluoroalkyl unit,[2,3] the selective activation and/or functionalization of the chemically robust C–F bond have emerged as intriguing methods for manipulating fluorine-containing compounds.[4] Recently, we have identified that a pre-installed bromodifluoromethyl group can function as a C1 and F1 synthon through selective multiple cleavages and atom recombination under basic conditions and in the presence of amines, facilitating the synthesis of a diverse range of valuable N-containing compounds such as α-fluoroamides and acylfluorides. This discovery introduces an innovative and promising platform for the transformation of halodifluoromethyl compounds.

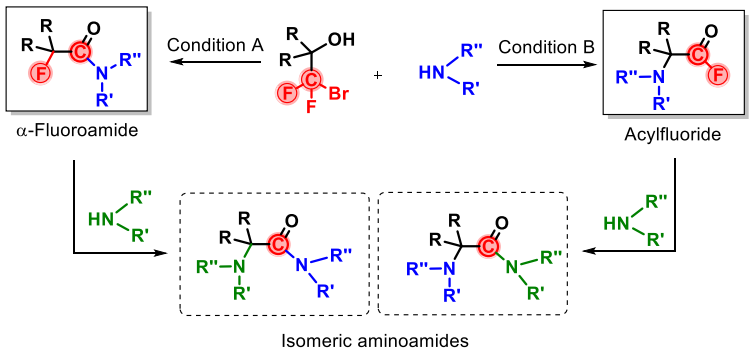

Figure 1: Synthetic platform for the synthesis of fluoroamides and acylfluorides

References:
[1] S. Purser, P. R. Moore, S. Swallow, V. Gouverneur, **Chem. Soc. Rev**., **2008**, 37, 320–330.
[2] G. Parisi; M. Colella; S. Monticelli; G. Romanazzi; W. Holzer; T. Langer; L. Degennaro; V. Pace; R. Luisi, **J. Am. Chem. Soc**. **2017**, 139, 39, 13648–13651.
[3] M. Spennacchio; M. Colella; M. Andresini; R. S. Dibenedetto; E. Graziano; A. Aramini; L. Degennaro; R. Luisi, **Chem. Commun.**, **2023**, *59*, 1373–1376.
[4] X. Ma, Q. Song, **Chem. Soc. Rev.**, **2020**, 49, 9197-9219.

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Modular and Regioselective C–H Functionalization of Electron-rich Azole Nuclei

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Heterocyclic compounds are key structural frameworks whose variety covers applications in disparate fields of modern organic, medicinal, crop and material chemistry.[1] In recent years, many efforts were oriented on the late-Stage Functionalization (LSF) of five-membered electron-rich azoles, aiming for the introduction of a desired moiety in a selective fashion, possibly *via* single step, at the end of a synthetic process.[2] In this context, radical chemistry and transition-metal catalyzed C–H activation played a pivotal role in the rising arena of LSF.[3] Within the framework of our research program on the C–H functionalization of electron-rich nuclei,[4] we report on a series of transition-metal catalyzed, mediated and radical transformations for the selective alkylation and arylation of pharmaceutically relevant imidazole-based scaffolds.[5-7] The methodologies include newly established radical pathways (Minisci-type reaction)[4] as well as transition-metal catalyzed C–H activation and transition-metal mediated direct and selective arylation of electron-rich azole nuclei for the modular LSF of key structures with applications in medicinal[6] and material chemistry (Organic Room Temperature Phosphorescent structures)[7] (Figure 1).

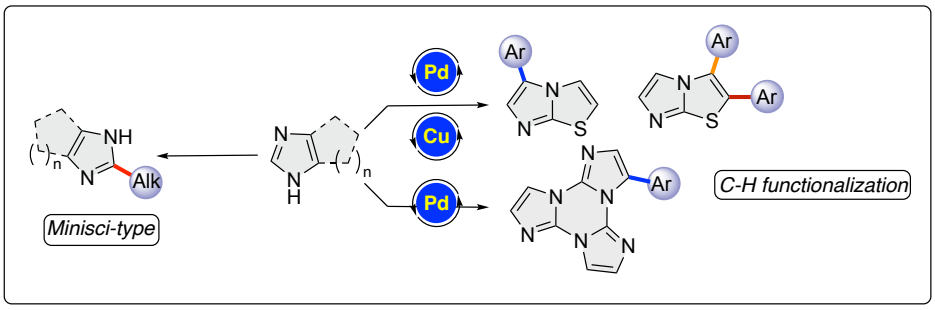

Figure 1: LSF of electron-rich azole nuclei: radical *vs* transition-metal catalyzed and mediated reactions.

References

[1] T. Eicher, S. Hauptmann, A. Speicher, The Chemistry of Heterocycles : Structure, Reactions, Syntheses, and Applications, Wiley-VCH Verlag GmbH & Co. KGaA, 2003.

[2] J. Börgel, T. Ritter, Chem, 2020, 6, 1877–1887.

[3] L. Guillemard, N. Kaplaneris, L. Ackermann, M. J. Johnasson, Nat Rev Chem, 2021, 5, 522–545.

[4] R. Rossi, F. Bellina, M. Lessi, C. Manzini, Adv. Synth. Catal. 2014, 356, 17–117

[5] E. Rosadoni, E. Bombonato, A. Del Vecchio, S. Guariento, P. Ronchi, F. Bellina, J. Org. Chem. 2023, 88, 19, 14236–14241.

[6] A. Del Vecchio, E. Rosadoni, L. Ballerini, A. R. Cuzzola, F. Lipparini P. Ronchi, M. Biagetti, S. Guariento; M. Lessi, F. Bellina, *Manuscript submitted.*

[7] E. Rosadoni, L. Ballerini, A. Del Vecchio, F. Bellina, *Manuscript submitted.*

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Hydrodeoxygenation of phenols *via* hydrazone chemistry: a valuable solution to arene derivatives

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Throughout the years, phenols have been considered a byproduct of biomass processing due to the difficulty of oxygen removal. Crude biomass-oil, mainly composed of lignin components, contains a large amount of oxygenated compounds, which make it non compatible with the actual oil industry.[1] Efforts exploiting molecular hydrogen have been made to remove hydroxyl group in lignin-derived phenolic compounds to make them appealing for the chemical industry.[2] However, these processes rely on high pressures, elevated temperatures, and expensive catalysts, presenting challenges in terms of safety, hydrogen storage, and cost-effectiveness. This highlights the urgent demand for sustainable alternatives with safer and more accessible reaction conditions.

Our long-time interest in Green Chemistry played a key role in driving us to the formulation of a more sustainable protocol for the hydrodeoxygenation of phenols to arene derivatives that does not involve molecular hydrogen. To pursue this objective, we initiated our research from the work on the conversion of phenols to primary anilines *via* hydrazone chemistry.[3] Instead of promoting the reductive cleavage of the N–N bond of the hydrazone to form the C(Ar)–NH_2 bond, we focused on promoting a C–N bond cleavage to form the C(Ar)–H bond. To do this, we employed an acid additive (trifluoroacetic acid), hydrazine and heterogeneous Pd/C. This innovative method aims to convert phenols into valuable aromatic products while bypassing the challenges associated with hydrogen gas, such as safety risks and storage issues.

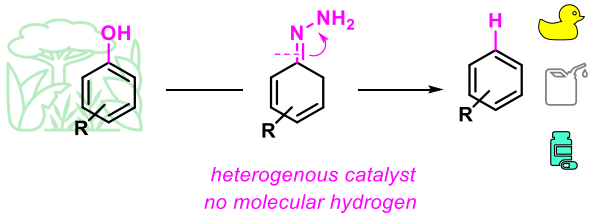

Figure 1: Hydrodeoxygenation of phenols to arene derivatives without molecular hydrogen.

References:

[1] C. Zhang, X. Shen, Y. Jin, J. Cheng, C. Cai, F. Wang, Chem. Rev. 2023, 123, 4510−4601
[2] M. Lang, H. Li, ACS Sustainable Chem. Eng. 2022, 10, 13208−13243
[3] Z. Qiu, L. Lv, J. Li, C.-C. Li, C.-J. Li, Chem. Sci. 2019, 10, 4775–4781

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Recoverable and recyclable heterogeneous $Y(OTf)_3$ for Michael and Diels-Alder additions

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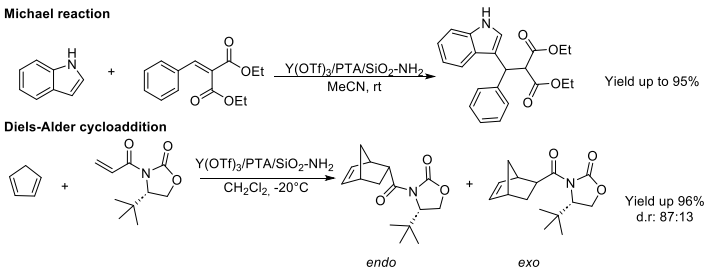
Heterogeneous catalysts have many advantages over homogeneous ones, such as easier catalyst separation, recovery, regeneration, and reuse, even though the latter have higher selectivity and active sites accessibility.

In the present study the attention was focused on $Y(OTf)_3$. Yttrium is a Rare Earth Element (REE), and its triflate functions as a Lewis acid in promoting a variety of reactions including Michael addition[1,2] and Diels-Alder cycloaddition[1,2]. In this work we decided to immobilize $Y(OTf)_3$ through a noncovalent interaction between $Y(OTf)_3$ and phosphotungstic acid (PTA) that is anchored onto amine functionalized silica nanoparticles. The PTA was found to be crucial for the preparation and the activity of the catalysts[3].

Figure 1: Design and general procedure for silica-supported yttrium catalyst.

We developed an example of supported Yttrium catalyst, which demonstrated excellent activity in the Michael addition between different benzylidene malonates and indoles[1] but also in the Diels-Alder cycloaddition between cyclopentadiene and (4*S*)-3-acryloyl-4-tert-butiloxazolidin-2-one[1,2]. The catalyst was tested in batch and in flow conditions.



Scheme 1: Michael addition and Diels-Alder cycloaddition.

Moreover, Y_2O_3 recovered from E-waste, such as fluorescent lamps, was supported, converted in triflate salt and successfully used as catalyst in the Michael and Diels-Alder cycloaddition.

References:

[1] E. Donato , F. Medici , V. Chiroli , S. Rossi , A. Puglisi, Tetrahedron Green Chem, 2023, 2, 100032.
[2] E. Donato , V. Chiroli , A. Puglisi, M. Benaglia, Adv. Synth.Catal. 2024,366, 1001–1006.
[3] Y. Saito, S. Kobayashi, Angew. Chem. Int. Ed. 2021, 60, 26566 –26570

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The Black-Box: Investigating the Key Pathways for the Reduction of Pd^{II} to Pd^{0}

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Palladium cross-coupling reactions represent among the most versatile and useful tools in organic synthesis for the carbon-carbon (C-C) bond formation.[1] Although the general mechanism of palladium cross-coupling reactions is well known, the first step, the formation of Pd^{0} active catalyst from Pd^{II} pre-catalyst, is still a matter of investigation for several research groups.[2]

A rapid and complete pre-catalyst reduction is critical for an efficient process. Understanding exactly the mechanisms allows the possibility to lower the amount of catalyst and avoid an excess of phosphine to be used. In addition, it enhances the overall efficiency of the process, leading to higher yields of the desired product and reducing the formation of unwanted by-products.[3,4]

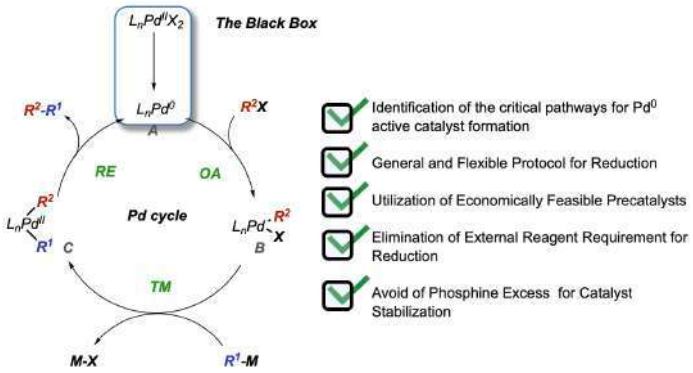

Figure 1: The Palladium Reduction Black Box

To clarify the reduction mechanism, stoichiometric and catalytic reactions were carried out and monitored by $^{31}P/^{1}H$ NMR spectroscopy. We have studied the reduction starting from the most common and cost-effective pre-catalysts such as $PdCl_2$ and $Pd(OAc)_2$, employing various types of ligands. Our focus has been on identifying the most efficient reduction mechanisms utilizing bases, phosphines, and solvents, enabling us to create a versatile library of pre-catalysts and phosphines for tailored reactions. This approach not only ensures superior performance but also avoids the use of expensive Pd^{0} or palladacycles, thereby enhancing the flexibility and cost-effectiveness of the processes.

References:

[1] Fantoni et al, *Catal.Today*, 2022, 397, 265-271
[2] Johansson Seechurn and Colacot et al, *J. Am. Chem. Soc.* 2017, 139, 14, 5194–5200
[3] Palladino and Fantoni et al, *ACS Sustainable Chem. Eng*. 2023, 11, 15994−16004
[4] Palladino and Fantoni et al, *ACS Catal. 2023*, 13, 12048−12061.

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Development of Reusable Electrolytes for the Waste-Minimized Synthesis of 2-arylbenzoxazoles

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Using a current of electrons to replace redox reagents presents a promising route for sustainable organic synthesis.[1] However, many sustainability challenges persist in this sector, and the effectiveness of electrosynthesis depends on the quantities of electrolytes used, influencing, for example, electron transfer and current density.[2] Equimolar amounts of supporting electrolytes are needed, leading to a significant generation of waste. These electrolytes, typically non-recoverable, require separation from the final reaction mixture, further increasing waste production.[3]

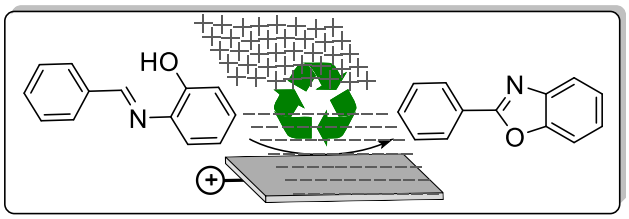

Figure 1: Reusable electrolytes in the synthesis of 2-arylbenzoxazoles.

To find a solution to this critical sustainability challenge for electrosynthesis, we report here our commitment to developing an easily recoverable supporting electrolyte. We representatively applied our study to the synthesis of 2-arylbenzoxazoles under batch and flow conditions. Importantly, the electrochemical flow cell also allowed us to improve current efficiency and overall performance. With a comprehensive analysis of green parameters, one can also quantify how our strategy is very promising and a valuable approach to minimize the quantity and quality of waste produced in organic electrosynthesis.

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References:

[1] C. Yan, X. Jiang, J. Yu, Z. Ding, L. Ma, T. Su, Y. Wang, C. Wang, G. Huang and S. Xu, *Green Chem.*, 2023, **25**, 3816–3846

[2] O. Y. Gutierrez, K. Grubel, J. Kothandaraman, J. A. Lopez-Ruiz, K. P. Brooks, M. E. Bowden, T. Autrey, *Green Chem.*, 2023, **25**, 4222–4233

[3] C. Stang and F. Harnisch, *ChemSusChem*, 2016, **9**, 50–60

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Chemically modified and immobilized diatom microalgae for bioremediation from persistent pollutants

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In the last century, intensive human activities changed the equilibria of our planet, mainly by the increase of CO_2 concentration and by the introduction of persistent pollutants in natural environments. Among all the available remediation technologies, bioremediation seems to be the most attractive, thanks to its eco-compatibility and efficacy. Several organisms (or parts of them, such as enzymes) could be involved in bioremediation activities. In this context, diatoms, a class of eukaryotic microalgae, are gaining increasing interest, thanks to their presence in quite all aqueous habitat and their adaptability to extreme conditions. Their main feature is the ability to produce a nanostructured biosilica shell, named frustule. Frustules, together with the exopolysaccharides (EPS) external matrix, represent physical and chemical structures for the interaction and sequestration of pollutants in natural environments[1]. Our research group has recently investigated the ability of living diatoms to bioremediate contaminated seawater from heavy metals[2] and persistent organic pollutants[3]. We tested both the intrinsic bioremediation property of the microalgae towards pollutants and the possibility of enhancing this ability via the direct synthesis of a biocompatible coating of polydopamine (PDA) around living cells. Our studies, focused on the diatom model organism *Phaeodactylum tricornutum*, showed bioremediation activities in seawater model solutions against As, Cr, Pb, Cu, Zn and Sn, and a remediation activity against several biphenyls up to 47% for bare *P. tricornutum* and up to 97% for PDA-coated microalgae.

References:

[1] Marella, T.K., Saxena, A., Tiwari, A. Bioresource Technology 2020, 305, 123068.
[2] Vona, D.; Cicco, S. R.; Labarile, R.; Flemma, A.; Garcia, C. V.; Giangregorio, M. M.; Cotugno, P.; Ragni, R. ChemBioChem 2023, e202300284.
[3] Flemma, A.; Vicente-Garcia, C.; Rizzo, G.; Cotugno, P.; Cicco, S. R.; Falciator, A.; Farinola, G. M.; Vona, D.; Ragni, R. In 2022 IEEE International Workshop on Metrology for the Sea; Learning to Measure Sea Health Parameters (MetroSea); IEEE: Milazzo, Italy, 2022; pp 101–105.

ORG-PO-197

Efficient Synthesis of 1,4,7-Triazamacrocycle Derivatives for Functionalized Polymers

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Synthetic chemists, inspired by polyazamacrocycles present in nature (such as porphyrin and corrine), have worked on the development of numerous organic molecules able to chelate a wide variety of metal ions as natural analogues make.[1] The presence of nitrogen atoms in the structure of these compounds makes them very incline to associate with metal cations, forming very high stable complexes due to thermodynamic and kinetic effects.[2.]

In particular, 1,4,7-triazacyclononane (TACN) and its derivatives, that are isoelectronic to cyclopentadiene, compose an essential class of aza-macrocycles since they can stabilize high oxidation states of different metal cores.[3] Our research group, starting from the results obtained on the synthesis of 1,4,7-trimethyl-1,4,7-triazacyclonane, used as hardener of alkyd emulsion for painting, has focused their effort to synthesize a 1,4,7-triazacyclononane functionalized with a long aliphatic chain with a terminal diol. These vital structure features will lead to the possible development of a new class of functionalized polymer[4] that could be able to chelate metal present in wastewaters and/or develop a new class of heterogeneous catalyst.

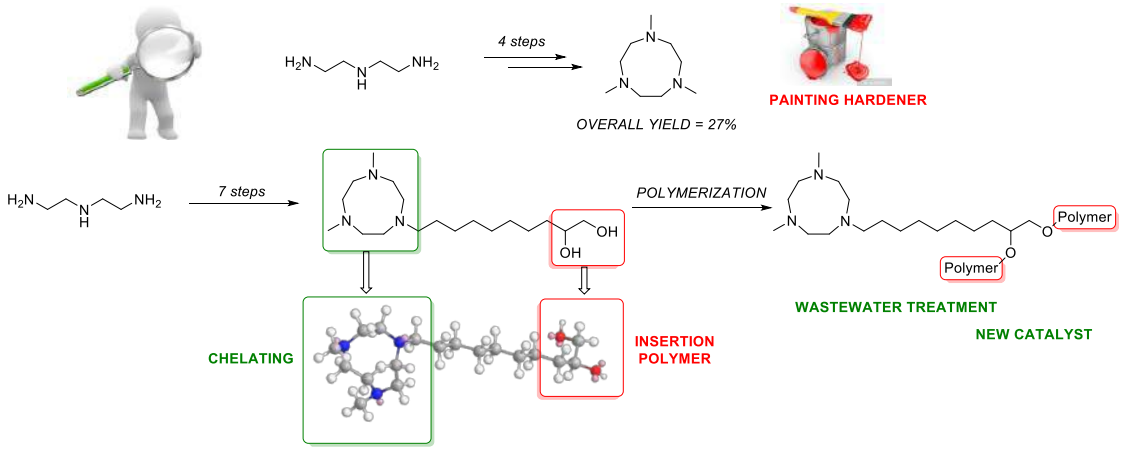

Figure 1

References:

[1] Timmons J.C., Hubin, T.J., Coordin. Chem. Rev. 2010, 254, 1661 – 1685.
[2] Hubin T.J., Coordin. Chem. Rev. 2003, 241, 27 - 46.
[3] Désogère P., Rousselin Y., Poty S., Bernhard C., Goze C., Boschetti F., Denat F., Eur. J. Org. Chem. 2014, 7831 – 7838.
[4] G. Lupidi, G. Pastore, E. Marcantoni, S. Gabrielli, Molecules 2023, 28, 2009.

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ORG-PO-198

Ultrashort Peptides-based Hydrogels Exposing Thiol Groups Forming Complexes with Peptide Nucleic Acid as Potential Tools for Smart Drug Release

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Ultrashort aromatic peptide-based multicomponent hydrogels (HGs) have been used as biocompatible matrix for tissue engineering, drug delivery, and biosensor production. One of the most explored hydrogelators is the low molecular-weight Fmoc-FF (N^{α}-fluorenylmethoxycarbonyl-diphenylalanine) homodimer because of its ability to gel under physiological conditions such as of pH and ionic strength.[1] Additional molecules, such as proteins, chemical compounds, or different peptide sequences, can be included into the Fmoc-FF hydrogel to create unique hydrogels with enhanced mechanical and functional characteristics. From this standpoint, a collection of unique multicomponent hydrogels based on Fmoc-FF that were doped with a range of concentrations of the tripeptide Fmoc-FFX, where X can be Cys, Ser, or Thr have been examined.[2] Among these tripeptides, Fmoc-FFC was chosen as it generates hydrogels functionalized with thiol groups, which can be post-derived chemically with desirable bioactive compounds, such as biosensing, therapeutic or diagnostic agents. One of the most valuable nucleic acid mimetics is Peptide Nucleic Acid (PNA).[3] Hybrid hydrogels are non-toxic and can serve as scaffolds for various applications in biotechnology, such as for controlled drug release in the presence of a reducing environment, such as the tumour microenvironment.[4] In this regard, the functionalization of mixed (Cys)HG at different molar ratios compared to Fmoc-FF (1/5, 1/10 and 1/20, respectively) with (Cys)PNA molecules *via* specific and non-specific interactions is shown here, followed by the supramolecular characterization through several techniques, such as HPLC, MS, CD, FT-IR, NMR and microscopy.

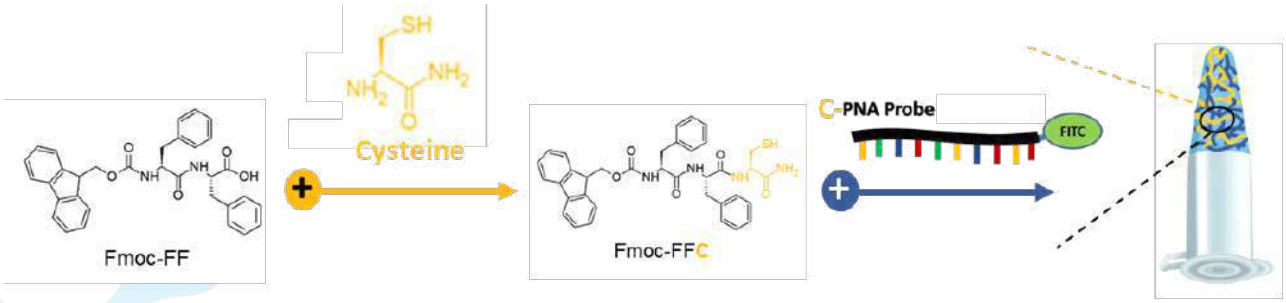

Figure 1: Schematic representation of Fmoc-FFC and C-PNA-FITC probe forming supramolecular hydrogels.

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ORG-PO-199

Peptide Amphiphiles From Functionalized L-Dopa: Correlating Structure And Self-Assembly Properties

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Low-Molecular-Weight Gelators (LMWGs) are a versatile class of compounds able to self-assemble into supramolecular materials thanks to non-covalent interactions. Peptide derivatives, especially those containing aromatic amino acids, such as Phenylalanine and Tyrosine, are ideal candidates as LMWGs because they are biocompatible, biodegradable, and promote the assembly in a variety of conditions.[1]

In our group, we focused our attention on L-Dopa (3,4-dihydroxyphenylalanine), which can be functionalized also on the catechol moiety. We reported a robust gelator, Boc-L-Dopa(Bn)$_2$-OH, able to form strong gels under several conditions and to trap different materials, such as crystals, fragrances and antioxidants. We have recently designed a small library of amphiphilic Dopa-based gelators, substituting the Boc group with long chain fatty acids (lauric, palmitic and azelaic acid) to introduce additional Van der Waals interactions, contributing to the self-assembly process.[2] The structure of the new gelators resembles that of surfactants and allows self-assembly also in basic aqueous solutions, a property which highly affects the outcome and features of the final gel, obtained by lowering the pH. The relationship between the gelator structure, the self-assembly and the gel properties was deeply investigated by means of EDC, FT-IR, XRD, SEM and rheology, demonstrating that the propensity of these compounds to form β-sheets is correlated to the final properties of the gels.

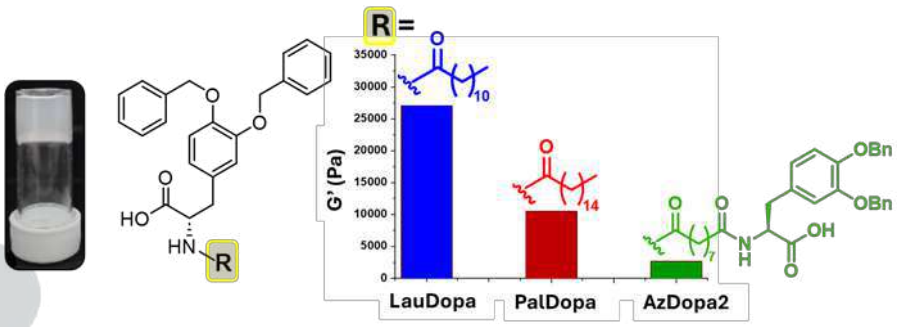

Figure 1: Schematic representation of the work, with the structures and stiffness of the gelators studied.

References:

[1] T. Das, M. Häring, D. Haldar, D. Díaz Díaz, Biomater. Sci. 2018, 6, 38-59.
[2] F. Cenciarelli, S. Pieraccini, S. Masiero, G. Falini, D. Giuri, C. Tomasini, Mater. Chem. Front. 2023 (submitted).

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ORG-PO-200

Engineering Photocatalytic Protocells for Artificial Photosynthesis

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Wireless artificial photosynthetic systems, a technology at the edge of the academic research in solar fuels, envision a machinery that mimic Nature to exploit sunlight energy to convert abundant resources, such as water and carbon dioxide, into high-added value products like H_2 or carbon derivatives (formic acid, methane) and O_2 without any external bias or circuitry.[1,2] In particular, in the design of a bio-inspired molecular-based photocatalytic artificial system, four fundamental components need to be considered: a photosensitiser (PS), a catalyst, an electron relay (ER) and a vesicle forming the reactor.[3]

PLANKT-ON project, part of the initiatives of the program of the European Innovation Council as Pathfinder Open 2022, inserts in this framework proposing coacervate vesicles as micro-compartmentalised protocells for artificial photosynthesis.[4]

Herein, we present the synthesis and characterization of protocells functionalized by the encapsulation of the artificial analogue of the natural Photosystem II (PSII), namely the artificial quantasome (QS).[5-7] Artificial quantasomes are an emerging class of supramolecular systems designed for photocatalytic water oxidation reaction. QS are based on the self-assembly of bis-cationic perylene bisimide derivatives, acting as antenna, and tetra-ruthenium deca-anionic polyoxometalate, being the water oxidation catalyst.[5-9] These two components readily self-assemble in water, exploiting the complementary electrostatic interactions, forming a hierarchical supramolecular system.[5-7] In this work, we focused on the functionalization of innovative photocatalytic reactors to design a photoactive protocell specifically engineered to achieve the light-induced water oxidation reaction.

References:

[1] P. Zhou, I.A. Navid, Y. Ma et al., Nature 2023, 613, 66–70
[2] J. R. McKone, N. S. Lewis, H. B. Gray, Chem. Mater. 2014, 26, 1, 407–414
[3] L. Velasco-Garcia, C. Casadevall, Commun. Chem. 2023, 6, 263
[4] P. Gobbo, M. Bonchio, S. Mann, et al. Nat. Commun. 2020, 11, 41
[5] M. Bonchio, F. Rigodanza, M. Prato, et al. Nature Chem. 2019, 11, 146–153
[6] T. Gobbato, F. Rigodanza, M. Bonchio, M. Prato et al. J. Am. Chem. Soc. 2022, 144, 31, 14021–14025
[7] F. Rigodanza, T. Gobbato, I. Crea, M. Bonchio, et al. Chem. Eur. J. 2024, e202303784
[8] F. Rigodanza, M. Prato et al. Chem. Phys. Lett. 2017, 683, 454– 458
[9] A. Sartorel, M. Bonchio et al. J. Am. Chem. Soc. 2008, 130 (15), 5006– 5007

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ORG-PO-201

Towards a Circular Future: Sustainable Strategies for Agri-Food Waste Valorization

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Minimization of waste stands as a cardinal principle within the Circular Economy framework, striving to repurpose end-of-life products into valuable resources, thus fostering closed-loop systems within industrial systems. The proliferation of sustainability consciousness underscores an escalating focus on waste reduction and pollution mitigation. In particular, processing operations within the agri-food sector often yield by-products still rich in bioactive compounds, boasting significant nutritional benefits for human health and commercial value. Those enormous volumes of residues can serve as a source of high added-value molecules that can find applications in several fields, including functional foods, nutraceuticals, and cosmetics.[1] Innovative green methodologies typically entail reduced timeframes, energy expenditure, and solvent volumes compared to traditional processes. In recent years, attention has gravitated towards those pioneering extraction methodologies geared as an answer to the sustainability issues. Microwave-Assisted Extraction (MAE) stands out among such innovations, presenting process advantages together with enhanced extraction efficiencies and yields.[2]

The presented study investigates MAE in water to recover metabolites from Pomegranate Peels (PP), refining extraction parameters and energy consumption.[3] The total phenolics, anthocyanins, flavonoids, and tannin contents of the extract have been determined, alongside their antioxidant activity (356.35 mgGAE/gextr., 303.97 µgCy3G/gextr., 37.28 mgQE/gextr., 56.48 mgGAE/gextr., and 1.43 µmolTE/gextr., respectively). The research explores water recycling through nanofiltration (approx. 75% of water reuse), simultaneously achieving product concentration and significant energy savings. The overall sustainability of the protocol is assessed evaluating energy consumption (20.92 W/mgGAE) and main Green Metrics. Finally, the antimicrobial features of the PP extracts have been evaluated against Gram-positive and Gram-negative bacteria, as well as their antiproliferative activity towards human cancer cells (HeLa).

The collected information supports the proposed valorisation protocol as a green and sustainable approach to upcycle PP, achieving a final product with interesting biological features.

References:

[1] F. Chemat, M. Abert-Vian, G. Cravotto, Green Extraction of Natural Products: Concept and Principles. Int. J. Mol. Sci. 2012, 13, 8615–8627.
[2] F. Chemat, M. Abert-Vian, A.S. Fabiano-Tixier, J. Strube, L. Uhlenbrock, V. Gunjevic, G. Cravotto, Trends Anal. Chem. 2019, 118, 248–263.
[3] G. Grillo, G. Capaldi, K. Radoševic, Ž. Jakopovic, K. Markov, M. Brncic, L. Gallina, E. Calcio Gaudino, G. Cravotto, Antioxidants 2023, 12, 1796.

ORG-PO-202

Tailor-made heterogenous catalyst for biomass upgrading and green hydrogen production

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Although hydrogen is widely recognized for its promising improvements in clean energy applications, its still predominant supply from fossil fuels presents environmental challenges, also associated with H_2 storage and distribution issues. In light of this, there is a pressing need for efficient and sustainable hydrogen production, storage and use alternatives. Liquid organic hydrogen carriers (LOHCs) are emerging as promising candidates. Among them, formic acid stands out as a green hydrogen source derived from renewable feedstocks. In addition to serving as an energy carrier, biomass-derived formic acid has potential as a "on-demand" hydrogen source in chemical hydrogen transfer reactions (figure 1).[1,2] Additionally, hydrogenation processes in biomass upgrading, leading to high-value added products, have gained increased importance. Biomass, being natural, abundant, renewable, and carbon-neutral, offers a promising approach to replace fossil feedstock in producing chemicals, fuels, materials, and energy.[3,4] The design of high-performance durable and reusable catalysts is one of the key challenges in hydrogenation and dehydrogenation of FA. Here, we present a tailor-made water-tolerant heterogeneous catalytic system for advancing green hydrogen production and hydrogen transfer processes in aqueous medium.

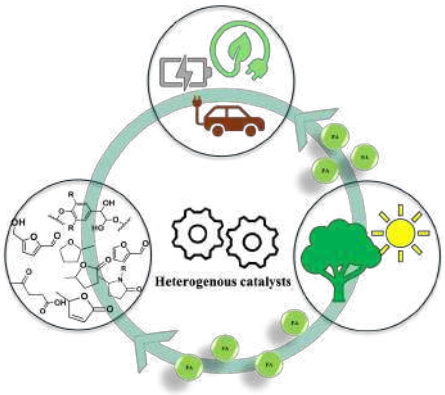

Figure 1: LOHCs in biomass upgrading and energy production

Acknowledgements
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m grant ECS00000041 – VITALITY. We acknowledge Università degli Studi di Perugia and MUR for support within the project Vitality. The University of Perugia is acknowledged for financial support to the university project "Fondo Ricerca di Ateneo, edizione 2022".

References

[1] F. Valentini, A. Marrocchi, L. Vaccaro, Adv. Energy Mater. **2022**, 12, 2103362 – 2103391.
[2] F.Ferlin, F.Valentini, A. Marrocchi, L. Vaccaro. ACS Sustainable Chem. Eng. **2021**, 9, 9604−9624
[3] V. Trombettoni, F. Ferlin, F. Valentini, F. Campana, M. Silvetti, L. Vaccaro, Molecular Catalysis, **2021**, 509, 111613 – 111622.
[4] F.Campana, F.Valentini, A. Marrocchi, L. Vaccaro. Biofuel research journal, **2023**, 49, 1989-1998.

ORG-PO-203

Visible-light generation of aryl radicals from C-halogen bond in cross-coupling reactions

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The generation of aryl radicals has been widely investigated during the last century for their synthetic utility. The typical generation methods involve the combination of aryl halides and an excess of radical initiator, such as AIBN or Bu_3SnH, or diazonium salts with strong metal-based reductants. These strategies have several problems related to low efficiency and vast by-product formation, and, for this reason, aryl radicals found low applicability in organic synthesis[1].

In the last decade, the development of photoredox catalysis led to a renaissance of aryl radicals, since using an efficient catalytic system it is possible to generate aryl radicals under mild conditions. Seminal papers reported the use of diazonium and iodonium salts as aryl radical precursors[1]. Aryl radicals find synthetic applications in two main classes of reactions: atom transfer (XAT) and radical addition[2].

In this work, we propose an innovative, more general and efficient photochemical method to perform cross-coupling reactions with an electronrich aromatic compound.

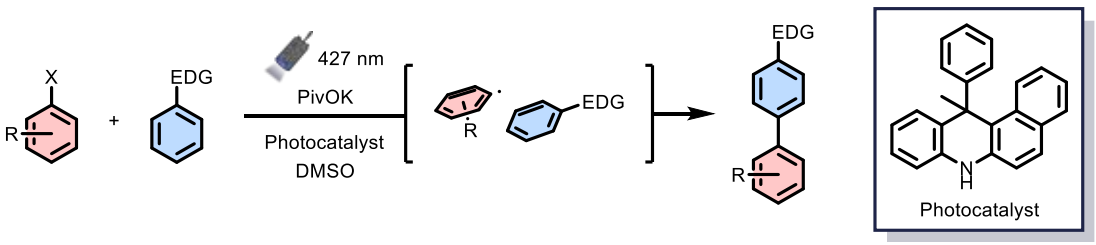

Figure 1: General scheme of the reaction.

Cross-coupling reactions are one of the most common classes of chemical transformations. The general approach to perform this reaction is well described in the literature and, generally, it requires the use of metals such as Copper, Nickel, or, more commonly, Palladium[3].

The reaction consists of the generation of an aryl radical by the reduction of a C-X bond by an organic photocatalyst in its excited state. This radical can then react with an electronrich species to form a new C-C bond.

References:

[1] N. Kvasovs, & V. Gevorgyan, *Chem. Rev.* 2021, 50, 2244–2259.
[2] J. Lan, R. Chen, F. Duo, M. Hu, & X. Lu, *Molecules* 2022, 27, 5364-5381.
[3] X. Chen, K. M. Engle, D. H. Wang & Y. Jin-Quan, *Angew. Chem. Int. Ed.* 2009, 48, 5094–5115.

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ORG-PO-204

CO_2 capture and conversion on Graphene Oxide-Arginine composite: *in situ* investigation by using X-Ray Photoelectron Spectroscopy

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The "on-demand" capture and utilization of CO_2 is effectively realized with a readily accessible dual function organic composite. The covalent and controlled derivatization of graphene oxide (GO) surface with naturally occurring arginine led to a "smart" material capable of capturing (chemisorption) CO_2 from high-purity flue-gas as well as low-concentration streams (i. e. direct air capture) and concomitant chemical activation toward the incorporation into cyclic carbonates. The overall integrated CO_2 capture and conversion (ICCC) strategy has been fully elucidated mechanistically via dedicated computational, spectroscopic and thermal analyses.

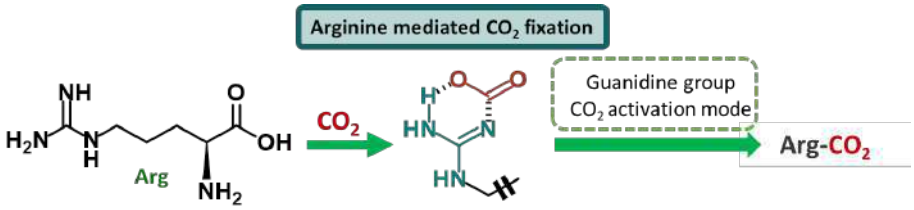

Figure 1: caption.

The in situ investigation of CO_2 chemisorption or physisorption on functionalized graphene oxide – or on a heterogeneous catalyst - usually requires the low temperature Solid State Nuclear Magnetic Resonance (ssNMR)[1], while in present work we were able to observe the chemical environment of chemisorbed CO_2 by using the Hi-Resolution X-Ray Photoelectron Spectroscopy via analysis of C 1s, N 1s and O 1s signals. The presence of guanidine group was fundamental for further development of Quantum Mechanics/Molecular Mechanics calculation on the reaction mechanism[2]. The role of XPS in heterogeneous catalysis on GO and functionalized GO is not limited to study the in situ chemistry of the reaction, but may also support the understanding of limits and issues present in carbocatalysis as a complementary technique to ssNMR[3].

References:

[1] J. Cai, J. Chen, et al., Chem. Mater. 2019, 31, 3729−3735
[2] S. Mantovani, A. Pintus, et al., ChemSusChem (2024) e202301673
[3] S. Caputo, A. Kovtun, et al., RSC Advances, 12 (2022) 15834

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ORG-PO-205

Synthesis of Tetra-*ortho*-Methoxylated Azobenzene Photoswitches via Sequential Catalytic C−H Activation and Methoxylation

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In recent years, particular attention has been paid to the development of new strategies to counteract antibiotic resistance. One of these consists in limiting the release of active antibiotics into the environment: visible light can be used as a tool to modulate the activity of drugs.[1] Recently, Just Baringo et al. have demonstrated how the introduction of a photoswitch, the amino acid tetra-*ortho*-chloro-diethylene-azobenzene (CEBA), can allow control over the activity of tyrocidine A analogues using visible light. In particular, upon isomerization under red light, the *cis* form would become the major isomer and re-establish the biologically active secondary structure of the natural product whereas, upon exposure to other visible light wavelengths, the activity quickly turn-off.[2] Nevertheless, due to the electrophilic nature of the C-Cl bond, CEBA needs to be introduced at the end of the growing peptide in order to avoid the use of strongly nucleophilic bases used during solid-phase peptide synthesis (SPPS). For this reason, methoxy-azobenzenes represent a much more appealing alternative for SPPS as they can be isomerized at 650 nm (red light), like chlorine derivatives, but are not sensitive to SNAr. However, the synthesis is highly limited. The methods reported in the literature had extremely low yields and limitations in functionalization.[3,4] To overcome these restrictions, the aim of this research is to develop a new strategy for the methoxylation of azobenzenes that allows a wide range of functionalization and good yields. This objective was achieved through a two-step procedure: 1) synthesis of tetra-ortho-bromo-azobenzenes by C-H activation 2) cross-coupling of the brominated derivatives with methanol (Figure 1).

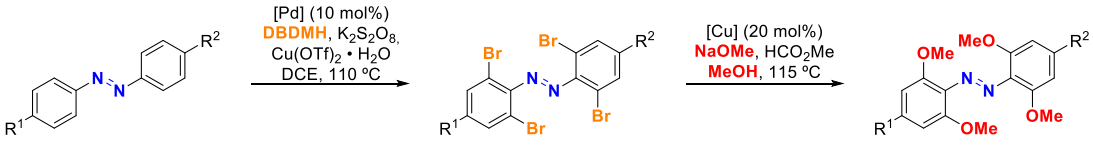

Figure 1: Synthesis of tetra-*ortho*-methoxyazobenzenes.

References:

[1] W.A. Velema, W. Szymanski, B.L. Feringa, J. Am. Chem. Soc., 2014, 136 (6), 2178–2191.
[2] X. Just-Baringo, A. Yeste-Vázquez, J. Moreno-Morales, C. Ballesté-Delpierre, J. Vila, E. Giralt, Chem. – Eur. J., 2021, 27 (51), 12987-12991.
[3] A. Müller-Deku, O. Thorn-Seshold, J. Org. Chem., 2022, 87 (24), 16526–16531
[4] M. J. Hansen, M. M. Lerch, W. Szymanski, B. L. Feringa, Angew. Chem. Int. Ed., 2016, 55 (43), 13514–13518.

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ORG-PO-206

Theoretical study of the reaction mechanism and solvent effect in the reaction between $LiCH_2SiMe$ and N-benzoylpirrolydine

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A theoretical investigation was conducted in conjunction with the department's organic chemistry laboratory to explore the conversion of non-activated amides to α,β-unsaturated ketones using $LiCH_2SiMe_3$.[1] This study employed two different solvents, THF and CPME, resulting in the formation of distinct products exhibiting high stereoselectivity (Figure 1). The primary objective of this study is to elucidate the reaction mechanism occurring in these solvents using Density Functional Theory calculations (M06-2X/def2-TZVP//M06-2X/def2-SVP). Given the propensity of lithium to form aggregates in solution[2], various model scenarios have been explored to represent the reagent, ranging from monomeric to dimeric structures, to capture the solvation effect on the complex. Dimeric structures were investigated using the two-layer ONIOM method. In addition to examining the reaction in THF and CPME, studies were carried out in water, as the reaction was experimentally quenched with water. This study underscores the significance of explicitly incorporating the solvent into calculations: substantial alterations in the topology of the potential energy and energetics were detected in the dimeric system (Figure 2) and when explicit solvent only (PCM) was used.

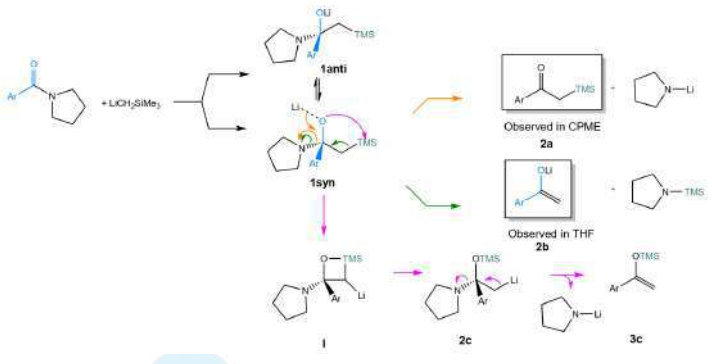

Figure 1: Reaction pathways for acyl nucleophilic substitution initiated by $LiCH_2SiMe_3$.

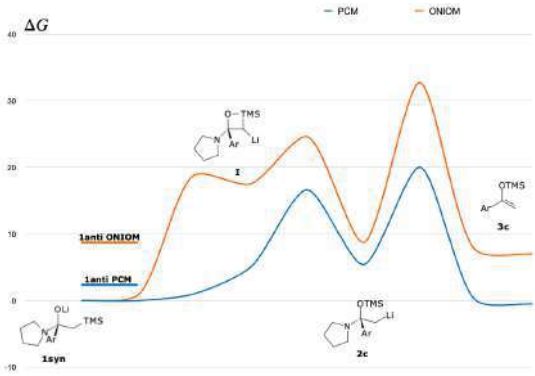

Figure 2: Differences in Gibbs free energy profiles for the same reaction pathway with two types of solvent simulations, expressed in kcal mol^{-1}.

References:

[1] S. Ghinato; C. Meazzo; F. De Nardi; A. Maranzana; M. Blangetti; C. Prandi, Organic Letters, 2023, 25, 3904−3909.
[2] R. E. Mulvey, Chemical Society Reviews 1991, 20, 167–209.

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ORG-PO-207

Electrochemical approach for cyclization/bromination of unactivated alkenes

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Various combinations of functional groups have been installed on alkenes through either intra/intra- or intra/intermolecular processes, resulting in differently functionalized heterocyclic systems. In organic synthesis, the electrosynthesis has emerged as a powerful and green tool to construct complex molecules without the use of stoichiometric amounts of hazardous oxidants or reductants.[1] Indeed, *in-situ* electro-generation of highly reactive species allows the use of safe reactants and provides a simplified approach. The development of sustainable electrochemical cascade reactions as efficient method to synthesize added-value molecules, possibly involving the formation of heterocyclic rings, is extremely intriguing. Our research group has been involved in the vicinal difunctionalization of multiple C-C bonds[2] and recently we undertook the study of electrochemical cascade cyclization/bromination reactions, focusing on the synthesis of directly functionalized heterocyclic systems by intra/intermolecular processes.

Pursuing the search for a new class of homonucleoside derivatives, an electrochemical palladium-catalyzed alkoxybromination was developed to access 2-bromomethyl morpholines (Figure 1, path A). Some examples of electrochemical alkoxybromination reactions are reported in the literature,[3] but analogous aminobromination procedures have been much less developed. In this context, due to the broad possibilities in brominated heterocycles functionalization, we planned palladium-catalyzed amination/bromination procedures in the presence of TBAB as electrolyte and bromine source (Figure 1, path B).

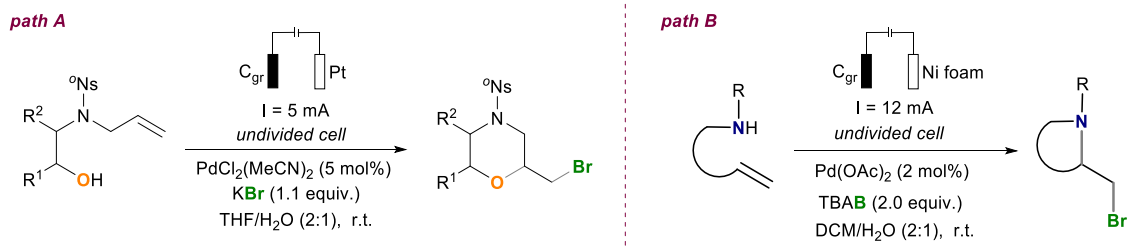

Figure 1: Electrosynthesis of bromomethyl-substituted heterocycles.

Optimization, scope, and mechanistic aspects will be discussed in the communication.

References:

[1] T. H. Meyer, I. Choi, C. Tian L. Ackermann, *Chem* **2020**, *6*, 2484-2496
[2] C. Loro, M. Papis, F. Foschi, G. Broggini, G. Poli, J. Oble, *J. Org. Chem.* **2023**, *88*, 13995-14003
[3] L. G. Gombos, S. R. Waldvogel, *Sustain. Chem.* **2022**, *3*, 430-454

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Design, synthesis and characterization of maytansinol-based PROTACs targeting tubulin

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Targeted Protein Degradation (TPD) is a revolutionary therapeutic concept that exploits cellular protein regulation systems to control protein degradation. In this context, PROteolysis TArgeting Chimeras (PROTACs) are heterobifunctional molecules able to interact with an over-expressed or misfolded Protein of Interest (POI) and an E3 ligase. Such constructs bind to both their targets and form a ternary POI-PROTAC-E3 ligase complex, where the POI is polyubiquitinated, freed from the ternary complex and driven to the proteasome for degradation.[1]

Our idea is to develop PROTACs targeting tubulin, an essential dimeric protein with a key role in cancer development and neurodegeneration.[2] The known tubulin binder maytansinol was selected as a POI ligand to build PROTAC-type molecules, as it is located on an exposed pocket of β-tubulin offering wider design possibilities. It has been rationally functionalized and coupled via click chemistry to chosen linkers bearing cereblon (CRBN)- or VHL- ligand as E3 ligase recruiters (Figure 1).

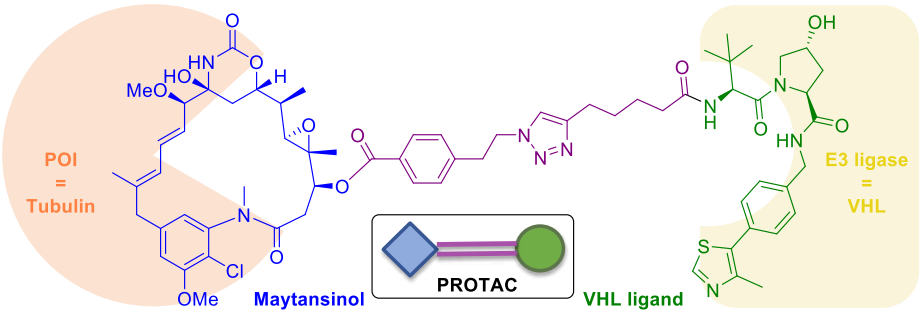

Figure 1. Chemical structure of maytansinol-based PROTAC targeting tubulin and VHL ligase.

The biophysical and structural characterization of four synthesized compounds was carried out, proving that such PROTACs can bind and recruit tubulin with high-resolution crystal structures. Additionally, it was confirmed that the compounds can bind to VHL and CRBN, respectively, with a crystal structure obtained in the case of VHL. The most significant achievement was the discovery of the capability of the four PROTACs to form the desired ternary complexes tubulin-PROTAC-E3 ligase, which is a groundbreaking discovery in chemically driving the conjugation of tubulin with a ligase.

References:

[1] M. Bekes, D. Langley, and C. M. Crews, Nat. Rev. Drug Discov. 2022, 21, 181-200
[2] A. Kanakkanthara, J. H. Miller, BBA Rev. Cancer. 2021, 1876, 188607.

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ORG-PO-209

Synthesis and Characterization of Small Molecule-Drug Conjugates for Targeted Drug Delivery

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Over the past ten years, the conjugation of bioactive substances to biocompatible carriers has proven to be a successful approach for the targeted delivery and controlled release of drugs. This strategy encompasses the covalent linkage of drugs to biological macromolecules thereby enhancing their solubility, stability, and pharmacokinetics while lowering toxicity and side effects.[1] Several biologically active molecules, including lipids, carbohydrates, aptamers, and antibodies, have been used as effective carriers to create novel molecular constructs for the treatment of various diseases. The drug of interest, also termed payload, can be directly linked to the carrier or it can be spaced by a properly designed linker. In both cases, once the bioconjugate has selectively engaged with its target, specific chemical or enzymatic stimuli induce the release of the payload, which is free to exert its pharmacological activity. In this context, we investigated the possibility for cholic acid (CA) and folic acid (FA) to function as carriers for different cytotoxic agents, thus obtaining small molecule-drug conjugate as selective anticancer agents. CA is a primary bile acid whose trafficking in the liver is finely regulated by intracellular lipid-binding proteins (ILBPs).[2] This acid has been directly linked to Mirin, an inhibitor of the DNA damage response processes, endowed with anticancer activity along with chemo- and radio-sensitising properties.[3] This new conjugate has been evaluated for its ability to bind ILBPs, and potentially to accumulate in the liver where, upon release of Mirin, it exerts its antitumor activity. Similarly, FA has been used for the creation of a novel prodrug involving an inhibitor of histone deacetylases (HDAC) as the payload. Folate receptors are frequently overexpressed in different forms of solid tumours,[4] hence FA could selectively shuttle the payload on tumour cells, limiting the off-target toxicity on healthy ones. The HDAC inhibitor has been loaded on FA via a specifically designed self-immolative spacer. This latter is based on a 5-nitropyrrole scaffold that allows the release of the payload via an electron push−pull mechanism activated by the reduction of the nitro group to the corresponding electron-donating amine. For the synthesis of the FA-prodrug, both in-solution and solid-phase synthetic techniques have been exploited.

References:

[1] F. Li, R. I. Mahato, Mol Pharm, 2017, 14, 1321–1324.
[2] H. L. Monaco, Biopolymers, 2009, 91, 1196–1202.
[3] A. Dupré *et al*. Nat. Chem. Biol., 2008, 4, 119–125.
[4] M. Fernández, F. Javaid, V. Chudasama, Chem. Sci., 2018, 9, 790–810.

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ORG-PO-210

An eco-friendly treatment of landfill leachate to reduce the Chemical Oxygen Demand

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Landfills represent the most common routes to solid wastes disposal, and provide two main kinds of products related to wastes degradation, *i. e.* leachates and biogas.[1] Landfill leachates derive from water percolation through waste deposits: they are toxic and have a negative impact on environment. They are composed of highly concentrated organic and inorganic contaminants that require severe treatment protocols for degradation to comply with environmental legislation[2]. The parameter used to evaluate the level of contamination in landfill leachate is the Chemical Oxygen Demand (COD), *i.e.* the amount (mg) of oxygen required to oxidize organic and inorganic chemicals present in 1 liter of aqueous sample[3]. The protocol used for COD determination is provided by the EPA Method 410.4 (Revision 2.0: "Determination of chemical oxygen demand by semiautomated colorimetry"), and it is based on the use of $K_2Cr_2O_7$ and H_2O_2 as the oxidants and potassium hydrogen phthalate as the standard. Here we provide a method of COD reduction that includes a preliminary reverse osmosis step of the landfill leachate and further acid-oxidative steps that lead to a COD value closely matching the limit required by legislation for disposal.

References:

[1] S. Renou, J.G. Givaudan , S. Poulain , F. Dirassouyan , P. Moulin,2008, 150(3) ,468-493
[2] E. Suárez García, S. A. Cardona-Gallo,2013, 80(178), 37-43
[3] Z. Hu, D. Grasso, 2005, (Second Edition), 325-330

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ORG-PO-211

Resolving the structural complexity of antibody-epitope interaction in *Neisseria gonorrhoeae* strains: Insights into antibody recognition

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Neisseria gonorrhoeae infection remains a prevalent sexually transmitted disease, with 82.4 million new cases reported globally in 2020. Its consequences, including pelvic inflammatory disease (PID), infertility, and adverse pregnancy outcomes, underscore the urgent need for effective treatments. In the context of increasing antibiotic resistance, the World Health Organisation (WHO) aims to reduce the impact of gonorrhoea by 90% by 2030. Therefore, alternative therapies are being explored. Monoclonal antibodies represent an alternative strategy as they offer targeted action against bacterial pathogens, minimising side effects and hospitalisation. Understanding the complex relationship between antibodies and bacterial epitopes is essential for developing effective treatments[1]. In this context, this study focuses on the chemical and structural characterization of the lipooligosaccharide (LOS) of *N. Gonorrhoeae* strain associated with disseminated infections[2]. The Core oligosaccharide (OS) was purified from cells in stationary phase and the exact mass was determined by Matrix-Assisted Laser Desorption/Ionization Time-of-Flight mass spectrometry (MALDI-TOF). We used NMR approaches to identify the conformation of the oligosaccharide in the free-state and compared it with the bioactive conformation obtained in the bound-state using a specific monoclonal antibody (mAb 2C7) directed against the lipooligosaccharide using STD-NMR and tr-NOESY techniques[3]. The experimental results were confirmed by computational techniques such as Docking and Molecular Dynamics simulations.

References:

[1] Rice P.A., Shafer W.M., Ram S., Jerse A.E. *Neisseria gonorrhoeae*: Drug Resistance, Mouse Models, and Vaccine Development. Annu Rev Microbiol. 2017 Sep 8;71:665-686

[2] Erwin A.L., Haynes P.A., Rice P.A., Gotschlich E.C. Conservation of the lipooligosaccharide synthesis locus lgt among strains of *Neisseria gonorrhoeae*: requirement for lgtE in synthesis of the 2C7 epitope and of the beta chain of strain 15253. J Exp Med. 1996 Oct 1;184(4):1233-41.

[3] Di Carluccio C., Forgione M.C., Martini S., Berti F., Molinaro A., Marchetti R., Silipo A. Investigation of protein-ligand complexes by ligand-based NMR methods. Carbohydrate Research, Volume 503,2021

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ORG-PO-212

Synthesis of chiral amines by a chemoenzymatic one-pot tandem protocol

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Multistep one-pot synthetic protocols are an emerging and attractive field in organic chemistry, since the development of these synthetic strategies allows to produce chemicals in compliance with criteria of more sustainable and green processes.[1] One-pot and/or tandem reactions are a strategic tool when it is not possible to isolate highly reactive or transient species. In this context, the combination of chemical and biocatalytic transformations represents a valuable alternative to traditional approaches. In this context, our preliminary investigations revealed the possibility to synthesize chiral amines by means of a chemoenzymatic tandem protocol which combines the reactivity of organolithium reagents with the enzymatic asymmetric reduction of cyclic imines, generated in situ in the first step of the reaction (Figure 1). Compared to the previously reported operating conditions,[2] promising results have been obtained performing the addition of PhLi to 5-bromovaleronitrile under sustainable conditions, using a greener solvent such as cyclopentyl methyl ether (CPME), at room temperature and under air, within a short reaction time. The bioenzymatic transformation is then realized by means of a novel class of NADPH-dependant enzymes, namely Imine Reductases (IREDs), which have been recently employed for the asymmetric reduction of chiral imines under sustainable conditions.[3] Preliminary results will be discussed.

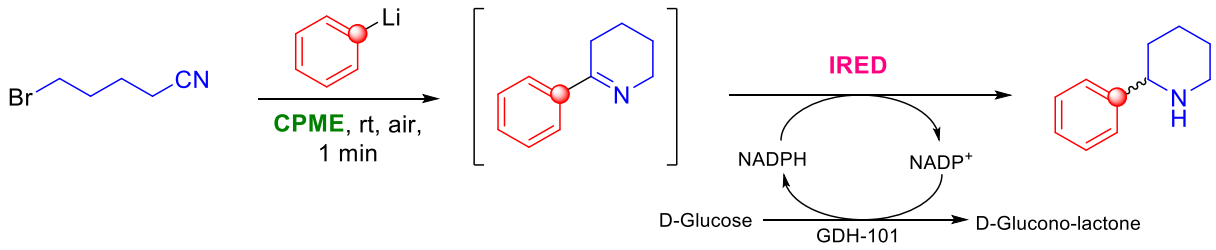

Figure 1: Chemoenzymatic tandem protocol to synthesize chiral amines.

References:
[1] Y. Hayashi, *Acc. Chem. Res*. **2021**, 54, 1385–1398.
[2] E. J. Cochrane, D. Leonori, L. A. Hassall, I. Coldham, *Chem. Commun*. **2014**, 50, 9910-9913.
[3] D. Arnodo, F. De Nardi, S. Parisotto, E. De Nardo, S. Cananà, F. Salvatico, E. De Marchi, D. Scarpi, M. Blangetti, E. G. Occhiato, C. Prandi, *ChemSusChem* **2023**, e202301243

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Solid state excimer emitting polychlorinated trityl radicals

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Polychlorinated trityl radicals are considered inert carbon-centered free-radicals thanks to their high chemical and thermal stability both in solution and in solid state.[1] Organic nanoparticles (ONPs) and polymeric films of tris(2,4,6-trichlorophenyl)methyl radical (**1** in **Figure 1**) form excimers from stable and persistent supramolecular radical-pairs.[1] It is reported that these ONPs present a two-photon excitation and emission in the biological transparency window and can be used to monitor temperature changes with an excellent thermal absolute sensitivity of 0.6-3.7% K^{-1} in the temperature range of 278-328 K.[2,3] Here, we report the synthesis and the characterization of two new polychlorinated trityl radicals (**2** and **3** in **Figure 1**) that can form excimers at the solid state. In $CHCl_3$ solution, monoradical **3**[4] shows a Fluorescence Quantum Yield (QY) of 9.5 %, a value markedly higher than that measured for **2** and for other trityl radicals reported in literature (QY < 1%).[5] Similarly, radical **3** shows an increased QY compared to **2** at the solid state (94% *vs* 83% for films containing a 2% of radical in the matrix).

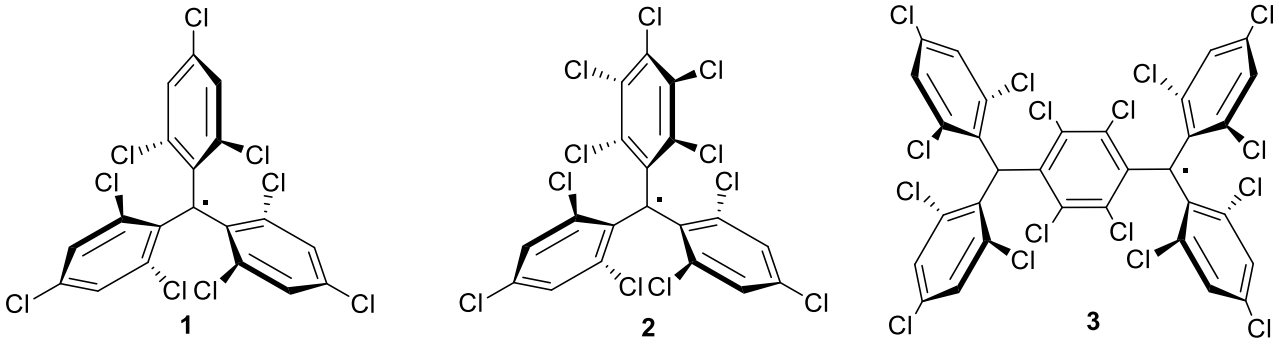

Figure 1: Molecular structure of radicals **1**, **2** and **3**.

References:
[1] D. Blasi, D.M. Nikolaidou, F. Terenziani, I. Ratera, J. Veciana, Phys. Chem. Chem. Phys. 2017, 19, 9313–9319.
[2] D. Blasi, I. Ratera, J. Veciana, Small 2023, 19, 1 – 11.
[3] N. Gonzalez-Pato, I. Ratera, J. Veciana, Small Methods 2023, 2301060, 1 – 8.
[4] A. Punzi, D.M. Guldi, F. Negri, G.M. Farinola, D. Blasi, JACS 2022, 1021, 1 – 8.
[5] D. Mesto, Y. Dai, C. N. Dibenedetto, A.Punzi, J. Krajkovic, M. Striccoli, F. Negri, D. Blasi, EurJoc 2022, 26, 1 – 10.

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Multivalent calix[4]arene-based mannosylated dendrons as new FimH ligands and inhibitors

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FimH is a mannose-specific adhesin that mediates the adhesion of uropathogenic *Escherichia coli* (UPEC) to urothelial cells and can be targeted thanks to the glycoside cluster effect given by carbohydrate-lectin interactions.[1]

Among the different synthetic scaffolds used to build multivalent glycoconjugates,[2] calixarenes show peculiar properties dependent on the different valences of the scaffold and on the stereochemical disposition of the saccharide units. Thus, we inserted two trivalent mannosylated dendrons onto the upper rim of a calix[4]arene scaffold, obtaining hexavalent glycocalixarenes (Figure 1). The antiadhesive properties of compounds **5a-b** was then assessed by an assay based on yeast cell agglutination to UPEC, a highly conserved FimH-dependent binding property among isolated *E. coli* strains. On-cell STD NMR experiments, acquired in the presence of UPEC living cells, confirmed the specific binding of calixarenes functionalized with Man units (**5a-b**) to FimH proteins at the cell surface.[3] Mannosylated calixarenes **5a-b** are thus promising hit compounds for the development of novel antiadhesive therapies aimed at fighting urinary tract infections caused by UPEC.

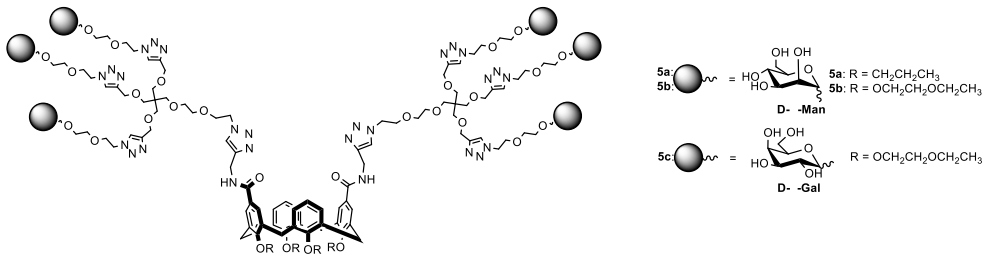

Figure 1: compounds **5a**, **5b** and **5c**

Funders: MIUR PRIN 2017 - BacHounds: Supramolecular nanostructures for bacteria detection; PNRR per la Missione 4, componente 2 Investimento 1.1- Avviso 104/2022 | Self-assembly of bacteria-targeting materials across the mesoscale

References:

[1] S. N. Abraham, D. Sun, J. B. Dale, E. H. Beachey, Nature 1988, 336, 682 – 684.
[2] A. Palmioli, P. Sperandeo, S. Bertuzzi, A. Polissi, C. Airoldi, Bioorg. Chem. 2021, 112.
[3] A. Palmioli, L. Moretti, C. A. Vezzoni, L. Legnani, P. Sperandeo, L. Baldini, F. Sansone, C. Airoldi, A. Casnati, Bioorg. Chem. 2023, 138.

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Chemoselective S_N2' Homologation of Allylic Platforms with Zinc Carbenoids

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Homologation chemsitry has been subject of considerable attention in the last decade, leading to a lot of studies and publications investigation the possible combination of homologating agent and substrates.[1] Most of the known procedures foresee the employment of a nucleophilic species as the medium of the chain enlargement; among the several nucleophiles, lithium and magnesium carbenoids have been largely exploited for the exploration of this kind of chemistry.[2] A exception relies in zinc carbenoids, mostly known for their electrophilic behavior which made possible the Simmons-Smith cyclopropanation reaction of alkenes by iodomethylzinc iodide[3] and ethyl(iodomethyl)zinc.[4] Still, zinc carbenoid chemistry is not as explored as other metals one. Herein we present the homologation of allylic halides (X: Br, Cl) to homoallylic iodides derived from a iodomethylene unit S_N2' type transfer mediated by iodomethylzinc iodide. More than 30 examples were synthesized achieving remarkable scope and chemoselectivity thanks to the neutral nature of zinc carbenoids toward electrophilic site sas amides, esters, ketones and aldehydes.

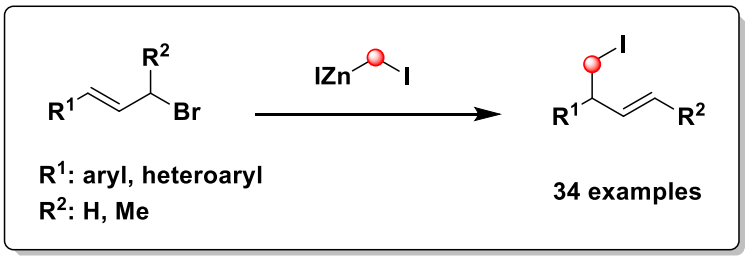

Figure 1: Zinc carbenoid homologation of allylic halides.

References:

[1] Pace, V. *Homologation Reactions: Reagents, Applications and Mechanisms.* Wiley-VCH: Weinheim, 2023.
[2] a) L. Ielo et al., *Synlett*, **2020**, *32*; b) V. Pace, L. Castoldi, W. Holzer, *Adv. Synth Cat.* **2014**, 1761–1766; c) V. Pace et al. *Angew. Chem.*, **2017**, *129.41*, 12851– 12856. i) V. Pace; *Australian Journal of Chemistry*, **2014**, *67*, 311–313
[3] a) H. E. Simmons; R. D. Smith; *J. Am. Chem. Soc*.; **1958**, *80*, 5323. b) H. E. Simmons; R. D. Smith; *J. Am. Chem. Soc*.; **1959**, *81*, 4256
[4] J. Furukawa; N. Kawabata, *Adv. Organomet. Chem*.; **1974**, *12*, 83.

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Artificial fluorescent proteins as sustainable downshifters for bio-hybrid LEDs: tailoring the emission through modifications of a non-native fluorophore

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LED lighting plays a fundamental role in the energy transition, due to its superior energy efficiency, compared to traditional light sources. For this reason, LEDs have now become the standard for indoor and outdoor applications, but their production and disposal still poses concerns in terms of sustainability, due to the need of employing rare-earth based colour down-converting filters. In the search for alternative solutions, fluorescent proteins (FPs), in which an organic fluorophore is embedded into a peptide scaffold, have been proposed as bio-based emitters for sustainable downshifter materials.[1] An ideal FP emitter should display high fluorescence quantum yield values and good photo- and thermal stability, to ensure long lifetime, compatible with the required applications. To achieve such features, we studied several classes of fluorescent organic compounds, in order to cover the whole range of the visible light spectrum, by tailoring the absorption and emission properties. In this regard, we selected a well-known fluorescent core based on a photostable thiadiazole molecule as a flexible molecular platform, whose emission wavelength can be extensively modulated from green-yellow to orange-red, with relatively low synthetic effort, through conjugation with different (hetero)aryl moieties.[2] Through synthetic modification of the fluorophore scaffold, we investigated the possibility to adapt it for efficient interaction with a properly designed protein scaffold. Finally, we revised the whole synthetic route to improve the overall sustainability of the process.

References:

[1] V. Fernández-Luna, P. B. Coto, R. D. Costa, Angew. Chem. Int. Ed., 2018, 57, 8826 – 8836; S. Ferrara, S. H. Mejias, M. Liutkus, G. Renno, F. Stella, I. Kociolek, J. P. Fuenzalida-Werner, C. Barolo, P. B. Coto, A. L. Cortajarena, R. D. Costa, Adv. Funct. Mater., 2022, 32, 2111381
[2] B. A. D. Neto, J. R. Correa, J. Spencer, Chem. Eur. J., 2022, 28, e202103262.

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ORG-PO-217

Transition-metal free one-pot synthesis of *N*-aryl-1,2,4-triazoles via arylazo sulfones under visible light irradiation

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The 1,2,4-triazole core is present in several bioactive molecules and therapeutically significant drugs including alprazolam and fluconazole. The growing interest for this scaffold and the drawbacks of traditional approaches have raised the demand for mild and sustainable synthetic routes.[1] Photochemical approaches utilizing visible light to achieve this target remain underexplored. In the view of this, we exploited arylazo sulfones as photoactive substrates for the synthesis of the 1,2,4-triazole ring. The dyed auxiliary group (N_2SO_2R) in arylazo sulfones is responsible for visible light absorption and photoreactivity, allowing the formation of radical species.[2] Indeed they have been recently employed as photoactive reagents in the visible-light-mediated metal and (photo)catalyst-free preparation of α-sulfonyl arylhydrazones.[3]

We present herein a one-pot, 100% atom economy, mild and transition-metal-free photochemical route to *N*-aryl-1,2,4-triazoles, by irradiation of variously substituted arylazo sulfones **1** in the presence of different *N*-alkenyl amides **2** (Figure 1). The desired products **3** have been isolated in moderate to satisfactory yields via cyclization of the key intermediate **I** and the developed protocol showed an excellent group tolerance. Post-transformations on compounds **3** and their preparation under flow conditions have been also performed.

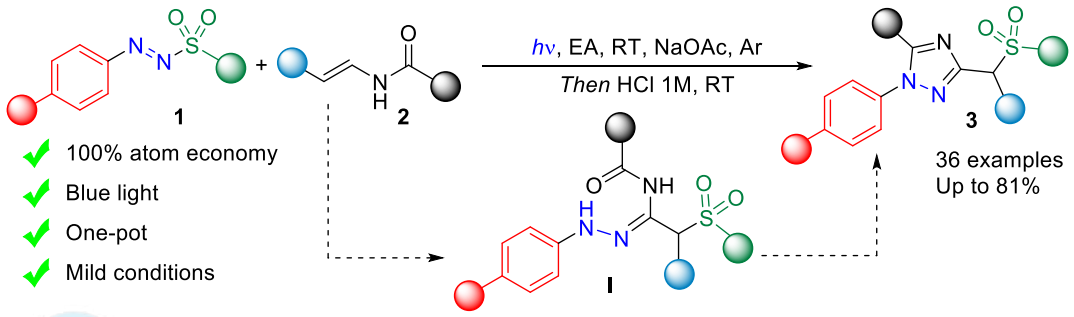

Figure 1: General scheme of the proposed photochemical approach to 1-aryl-1,2,4-triazoles.

References:

[1] L. Gonnet, M. Baron, M. Baltas, Molecules 2021, 26, 5667-5693.
[2] D. Qiu, C. Lian, J. Mao, M. Fagnoni, S. Protti, J. Org. Chem. 2020, 85, 12813-12822.
[3] L. Di Terlizzi, L. Nicchio, C. Callegari, S. Scaringi, L. Neuville, M. Fagnoni, S. Protti, G. Masson, Org. Lett. 2023, 25, 9047-9052.

ORG-PO-218

New bioorganic materials

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This study delves into Porous Silicon Nanoparticles (PSiNPs), with a specific focus on their potential surface passivation with bioorganic molecules for therapeutic applications1. Porous Silicon (PSi) is a nanostructured material renowned for its optical properties and sponge-like morphology, characterized by a substantial surface area that renders it highly suitable for biomolecule decoration. The optical properties of PSi stem from voids within its network, which can be controlled by adjusting various process parameters (crystalline silicon doping, attack time, electrolyte concentration, etc.), yielding diverse photonic structures (Fabry-Perot Bragg mirror, optical microcavity, aperiodic multilayer sequence, etc).2 3 4

The primary challenge associated with employing PSi lies in its chemical instability when exposed to air or aqueous environments. In such conditions, the native Si-H bonds undergo replacement with Si-O-Si bonds, resulting in the formation of a surface oxide layer. This chemical transformation is thermodynamically driven and compromises the stability of PSi. To overcome this hurdle and ensure the stability of PSiNPs, a crucial passivation process for their surface is imperative.4 In this study, PSiNPs have been effectively passivated using carbohydrates to enhance their suitability for drug delivery applications.

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Copper-Catalyzed Synthesis of Chiral γ-Amino Alcohols from Alkynyl Oxetanes

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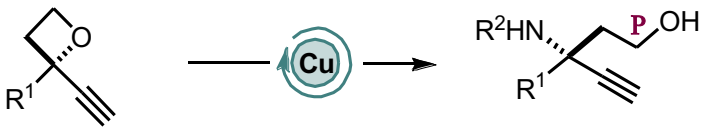
The synthesis of compounds featuring quaternary stereocenters represents one of the most demanding tasks in organic synthesis due to the large steric repulsion present in congested carbon centers.[1] Although ɣ -amino alcohol fragments are present in a multitude of pharmaceutical and intermediates for natural product synthesis (e.g. benzo[1,4]oxazepines and benzo[1,4]diazepines), enantioselective approaches for the preparation of such targets comprising quaternary stereocenters has remained largely unexplored.[2,3]



- high atom-economy
- functionalized g-amino-alcohols
- versatile enantio-enriched BBs

Here, we present a simple, scalable, and attractive method for the enantioselective synthesis of ɣ -amino alcohols having quaternary stereocenters. Enantioselective Cu-catalyzed ring-opening amination of oxetanes is demonstrated to provide access to these compounds in high yields. These functional propargylic compounds are illustrated to be suitable and versatile synthons for the preparation of a series of biological importance intermediates such as ß -unnatural amino acids.

References:

[1] J. Feng, M. Holmes, M. J. Krische, Chem. Rev. 2017, 117, 12564.
[2] V. A. Palchykov, A. A. Gaponov, Advances in Heterocyclic Chemistry, Elsevier, 2020, pp. 285.
[3] K. W. Quasdorf, L. E. Overman, Nature 2014, 516, 181.

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ORG-PO-220

Sustainable-by-design metallophthalocyanines: a multidisciplinary approach for sensing application

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In recent years, driven by the increasing environmental awareness, the development of alternative and greener strategies for the synthesis of organic molecules has experienced a growing interest in the scientific scene. In this sense, step economy stands as an important concept in the synthetic design and strategic implementation of chemical reactions from an environmental, economical and practical point of view[1]. In this contribution, a new one-pot procedure for the synthesis of substituted metallophthalocyanines is reported, assessing its environmental sustainability through green chemistry metrics.

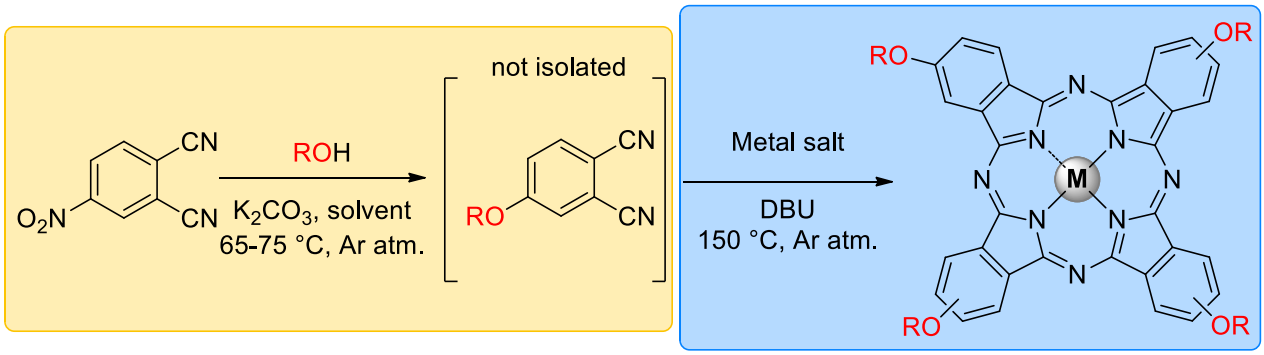

Figure 1: Scheme of the one-pot procedure for the synthesis of substituted metallophthalocyanines.

Furthermore, the noteworthy photophysical properties of such prepared sustainable-by-design metallophthalocyanines can be used for sensing application. Through a multidisciplinary approach the electrospray deposition technique (ESD), used in previous works of my group to immobilize enzymes[2] onto suitable supports to fabricate biosensors, has been now explored to immobilize metallophthalocyanines.

References:

[1] Y. Hayashi, Chem. Sci., 2016, 7, 866 – 880.
[2] M. C. Castrovilli, V. Scognamiglio, E. Tempesta, J. Chiarinelli, M. Parracino, V. Frisulli, M. T. Giardi, L. Avaldi, D. Rossi, A. Cartoni, Green Chem., 2023, 25, 5257 – 5266.

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ORG-PO-221

The important role of GPC/SEC system in molecular structure identification of polymers and characterization of their functionality

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Gel permeation chromatography (GPC/SEC) is the most widely used technique for determining the molecular weight distribution of polymers. It is employed not only for their characterization but also for the separation of the polymer matrix from oligomers, additives, degradation products, and residual monomer. The chemical structure of both synthetic and natural polymers (polysaccharides, proteins) can be investigated by GPC/SEC using organic or aqueous solvents.[1] Furthermore, multi-detector options (multiple detection with viscometry, concentration and static light scattering detectors) allow accurate molecular weight values and to study structural properties, such as the number of branches on the polymer backbone. We employed this technique to control the polymerization reaction of polyester and polyurethane.[2] We performed, in particular, an optimization of reaction conditions taking into account the molecular weight and the percentage of monomer conversion. The formation of linear polymer with a very low percentage of ramification was observed.[3] The molecular structure of natural and synthetic polymers was also studied to verify the goodness of recycling process and functionalization.

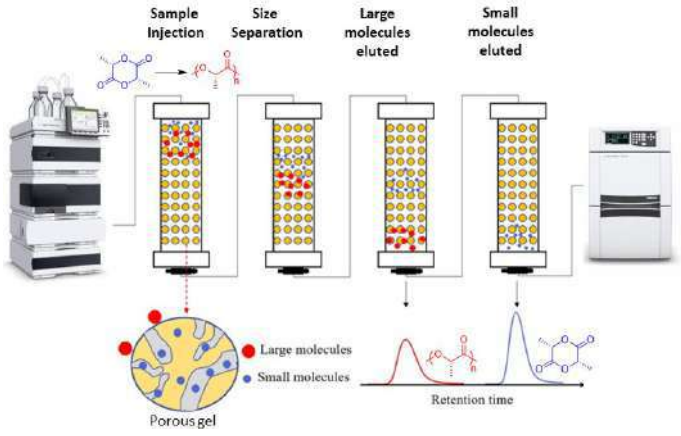

Figure 1: Principle of separating molecules by GPC/SEC.

References:

[1] T. Williams, J. Mater. Sci. 1970, 5, 811–820.

[2] G. Pastore, S. Gabrielli, R. Giacomantonio, G. Lupidi, S. Capodaglio, F. Stella, E. Leone, T. Compagnucci, Results Mater. 2022, 15, 100294.

[3] G. Pastore, S. Gabrielli, T. Cecchi, A. Giuliani, C. Cimarelli, A. Menchi, E. Marcantoni, RSC Adv. 2021, 11, 10592–10598.

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Electrocatalytic Cobalt Catalyzed CO_2 Reduction: Mechanistic Investigation via the Parasite Hydrogen Evolution Reaction

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The mechanistic investigation of homogeneous electrocatalytic CO_2 reduction is crucial for the development of new and increasingly high-performance catalysts.[1] Tris(2-pyridylmethyl)amine **TPMA** cobalt complexes have been reported as promising species able to catalyzes the CO_2 reduction.[2] Despite several mechanism have been proposed, an overall understanding is still missing and the selectivity of CO_2RR vs HER still remains an opened issue.

Here we report a novel strategy to investigate the reaction mechanism based on the evolution of CO2RR vs HER selectivity during the controlled-potential electrolysis experiments.

A decrease in the production of CO vs H_2 was found during the CPE experiments suggesting the intermediate formed during the electrolysis shift the selectivity towards H_2 production. Through a deep computational study, it was found that the stable Co(I)-CO intermediate formed during the electrolysis is the key intermediate responsible for this experimental trend. Moreover, the presence of the intermediate was experimentally confirmed though in-situ IR-SEC experiments.

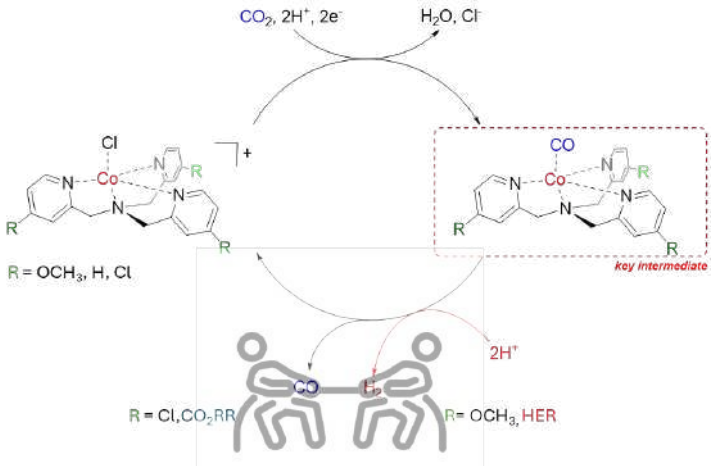

Figure 1: Simplified mechanism for CO_2RR and HER catalysed by Co**TPMA** complexes.

References:

[1] K. Elouarzaki, V. Kannan, V. Jose, H. S. Sabharwal, J. M. Lee, *Adv. Energy Mater.* **2019**, *9*, 1–33.
[2] S. L. F. Chan, T. L. Lam, C. Yang, S. C. Yan, N. M. Cheng, *Chem. Commun.* **2015**, *51*, 7799–7801.

ORG-PO-224

Study of the interaction between Graphene Oxide and cholesterol using liposomes as artificial membrane model

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The growing use of Graphene Oxide (GO) as biomaterial brings to light many important questions regarding its possible toxicity to organs, tissues and cells. One of the most interesting fields of study would be the characterization of the GO exposure effect on reproductive functions. In a recent study,[1] it has been demonstrated that GO at low concentrations can promote an increase of membrane fluidity of the apical membrane of mammalian spermatozoa and a reduction of cholesterol/phospholipidic ratio in a dose/dependent manner. As a result, it was found that GO improved the spermatozoa fertilizing ability in an *in vitro* fertilization model (IVF) by extracting cholesterol from membranes, without affecting sperm membrane integrity.

Starting from this evidence, the aim of this work was to investigate whether the ability of GO to promote membrane remodelling was reproducible even in the presence of an artificial phospholipid membrane. The effect of GO was studied on liposomes consisting of cholesterol and 1,2-dioleoyl-*sn*-glycero-3-phosphocoline (DOPC), by using two different fluorescent probes, such as 5(6)-carboxyfluorescein and Filipin III. The former dye was embedded into the aqueous core of liposomes and its rate of leakage was monitored to evaluate the kinetic stability of the membranes in presence and absence of GO. Filipin III marker is known to form complexes with cholesterol and the analysis of its excitation spectra has been used to suggest either cholesterol extraction or membrane remodelling induced by GO. Liposomes treated with GO were also characterized in terms of dimension, morphology and phase transition temperature by DLS, AFM and DSC analyses. In addition, Raman spectroscopy analysis of the liposomes was performed in order to evaluate the phospholipid chain packing, and therefore the variation of fluidity of liposomes membrane treated with GO. The obtained data may offer a better insight into GO interaction with lipidic membranes and open the way to new potential engineering of sperm membrane for improving assisted reproduction technologies outcomes.

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References:

[1] N. Bernabò, J. Machado-Simoes, L. Valbonetti, M. Ramal-Sanchez, G. Capacchietti, A. Fontana, R. Zappacosta, P. Palestini, L. Botto, M. Marchisio, P. Lanuti, M. Ciulla, A. Di Stefano, E. Fioroni, M. Spina, B. Barboni, Sci. Rep. 2019, 9, 8155:1-13.

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Improving Selective Filtration in Polymeric Hollow Fibers through Chemical Modification of Graphene Oxide

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Hollow fiber membranes play a pivotal role in advanced filtration technologies, finding applications in various fields such as biomedical treatments and water purification. The inherent chemical inertness of the polymers constituting these membranes poses a significant challenge for functionalization.[1] Thus, this study addresses the challenge of enhancing selective filtration in polymeric membranes by introducing graphene oxide (GO), a two-dimensional material that serves as an ideal platform for post-functionalization due to the presence of oxygenated groups on its surface.[2, 3] The incorporation of GO was achieved through a systematic approach, involving the coating of polyethersulfone (PES) fibers.[4] This procedure featured a novel post-functionalization strategy designed to obtain a chemically modified GO-polymeric membrane. Lysine (Lys) was selected as a case study, and successful GO covalent modification was confirmed through SEM, XPS, and contact angle measurements. Adsorption experiments conducted with both pristine PES-GO and modified PES-GO-Lys fibers revealed improved removal of carbamazepine pollutants after Lysine-modification. Several examples of chemical modification and applications of resulting composite membranes for water treatment will also be discussed.

Figure 1: Post-functionalization of GO-modified hollow fiber membranes.

References:
[1] I. Sadeghi, P. Kaner, A. Asatekin, *Chem. Mater.* **2018**, 30, 21, 7328–7354.
[2] M. Zambianchi, S. Khaliha, A. Bianchi, et al., *J. Membr. Sci*. **2022**, 658, 120707;
[3] S. Mantovani, S. Khaliha, A. Pintus, et al., *Environ. Sci.:Water Res. Technol.* **2023**.
[4] A. Kovtun, A. Bianchi, M. Zambianchi, et al*., Faraday Discuss*. **2021**, 227, 274-290.

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ORG-PO-226

Chemo-enzymatic synthesis of the HDAC inhibitor vorinostat

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Thanks to its ability to chelate metal ions, hydroxamic acid is one of the most interesting functional groups in medicinal chemistry, especially in the context of metalloenzyme inhibition. Vorinostat, also known as suberoylaniline hydroxamic acid (SAHA), is a pan HDAC inhibitor approved by the FDA in 2006 for the treatment of relapsed/refractory cutaneous T cell NHL, inhibiting cell proliferation and selectively inducing apoptosis in hematologic and solid tumor malignancies.[1] Its large-scale preparation has been widely studied and essentially consists of the cyclic suberic anhydride opening by aniline, followed by acid activation with highly reactive chloroformates and condensation with hydroxylamine. Herein, we report the design of a new chemoenzymatic pathway for the synthesis of vorinostat. The preparation of the suberoylaniline acid was performed in water, in presence of *Mycobacterium smegmatis* acyl transferase (MsAcT),[2] and further functionalized with an *O*-protected hydroxylamine, *via* lipase-catalyzed condensation. Final deprotection in presence of acidic cationic resins afforded pure vorinostat in 60% total yield. In order to improve the productivity of the process, all the steps were performed testing several solvent mixtures, based on the most recent guidelines about solvent sustainability. In the best case, pure vorinostat was obtained in a 3-step-5-hour synthesis of in 79% overall yield. Finally, the entire procedure was further optimized and transferred to a continuous flow system, where the final product was obtained in a time-saving automated way, large scale, high yield and high purity, paving the way for a more sustainable preparation of pharmacologically active hydroxamic acid derivatives.

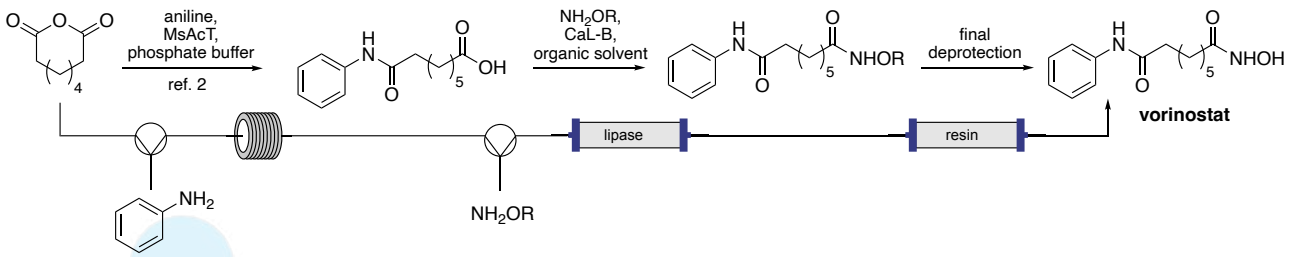

Figure 1: Schematic chemoenzymatic preparation of vorinostat

References:

[1] K. Xue, J.J. Gu, Q. Zhang, *et al. J Cancer Res Clin Oncol* **2006**, *142*, 379–387.
[2] M.S. Christodoulou, M.L. Contente, S. Dallavalle, A. Pinto *Green Chem* **2022**, *24*, 4432.

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Functionalized clay minerals for optical detection of environmental pollutants

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Anthropogenic activities cause the release of harmful compounds in air and water (e.g. VOCs and PAHs), posing a serious risk to overall ecosystem. Thus, the development of reliable technologies capable to detect pollutants at low concentration high efficiency, portability and low cost, is highly desiderable.[1]

In this context, the use of luminescent probes anchored to natural and eco-compatible nanomaterials is emerging as promising strategy to obtain sensing and remediation platforms.[2-3] Clay minerals (CM) are gaining growing interest as smart nanomaterials for several applications, due to their eco-compatibility, tuneable surface chemistry and low cost.[4] In this context, new naphthylimide-based fluorescent probes were synthesised and functionalised to be anchored to clay minerals, obtaining naphthylimide-CM nanomaterials. The physical-chemical characterization of the obtained materials was carried out by several techniques, and optical properties were investigated as well. The sensing performance towards the selected pollutants was evaluated both in solution and solid phase, observing an easy detectable signal after the recognition.

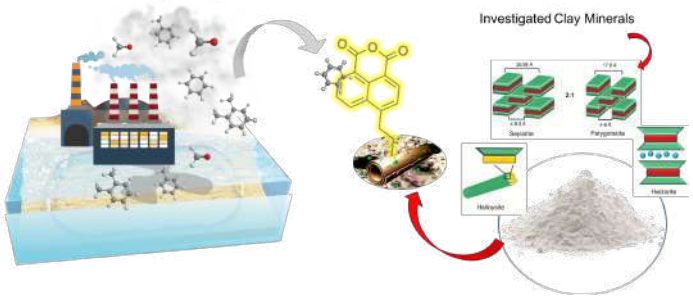

Figure 1: Example of some clay minerals that can be used for environmental remediation.

References:

[1] R. S. Andre, R. C. Sanfelice, A. Pavinatto, L. H.C. Mattoso, D. S. Correa, Materials and Design, 2018, 154-166
[2] R. Puglisi, A. Pappalardo, A. Gulino, G. Trusso Sfrazzetto, ACS Omega 2019, 4, 7550−7555
[3] Y. Foelen, R. Puglisi, M. Debije, A. P. H. J. Schenning, ACS Appl. Opt. Mater. 2023, 1, 107–114
[4] M. Massaro, A. Pettignano, N. Muratore, I. Fusteș-Damoc, G. Cavallaro, G. Lazzara, P. Lo Meo, A. Mija, R. Sànchez-Espejo, C. Viseras Iborra, S. Riela Appl. Clay Sci. 2024, 250, 107271.

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ORG-PO-228

Claisen-Schmidt Synthesis of Chalcones in Micellar Solutions. The Surfactant Role and Selectivity

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Green and more sustainable synthetic approaches are urgently needed in modern Organic Chemistry. Since the pioneering works by Lipshutz,[1a-b] the micellar catalysis emerged as an attractive opportunity to reduce/eliminate organic solvents. By now, many reactions were successfully performed but just few papers were devoted to the micellar Claisen-Schmidt aldol reaction,[2,3] and a general approach to widen its scope is lacking. Here we report the successful micellar-based Claisen-Schmidt synthesis of chalcones, considering their high-interest for medicine and organic electronics,[4,5] by considerably widening the scope. Reactions in CTAB or Tween 80 solutions and with NaOH at rt for 24h gave good to excellent yields.

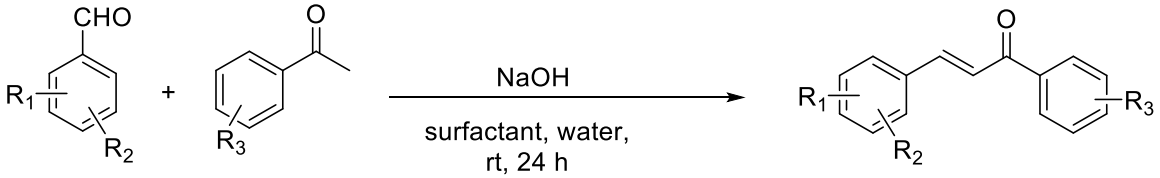

Figure 1. General scheme for the Claisen-Schmidt reaction in micellar solution.

Reactions in CTAB solution promoted also tandem/domino reactions, such as the further Michael addition, which, conversely, was suppressed by the non-ionic surfactants. Some substrates, e.g. those with free phenolic groups, reacted with higher difficulty, giving lower yields. In specific cases, protocol modifications to improve unsatisfactory yields were needed, e.g. by working at 45°C. Heterocyclic substrates reacted better in Tween 80, while the CTAB often lead to more by-products by promoting cascade reactions. Some chalcones of interest for application in medicine and organic electronics were successfully synthesized by the here presented method and the substrate-micellar binding and localization were studied to elucidate the reactions' outcome.

References:

[1] a) B. H. Lipshutz, J. Org. Chem. 2017, 82, 2806-2816; b) B. H. Lipshutz, Synlett 2021, 32, 1588-1605.
[2] C. D. Mudaliar, K. R. Nivalkar, S. H. Mashraqui, Org. Prep. Proced. Int. 1997, 29, 584-587.
[3] M. Vashishtha, M. Mishra, D. O. Shah, Appl. Catal., A 2013, 466, 38-44.
[4] C. Zhuang, W. Zhang, C. Sheng, W. Zhang, C. Xing, Z. Miao, Chem. Rev. 2017, 117, 7762-7810.
[5] M. Shkir, A. Irfan, S. AlFaify, P. Shankaragouda Patil, A. G. Al-Sehemi, Optik 2019, 199, 163354.

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Building biohybrid systems for solar energy conversion by bacterial photoenzymes and organic light harvesting antenna molecules

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Reaction Centres (RCs) of photosynthetic bacteria are enzymes employing solar energy to generate charge separated states with almost unitary conversion efficiency. This efficiency, optimized by Nature in billions of years of evolution, is very attractive in view of designing biohybrid systems for light-responsive bioelectronics.[1] Our studies have demonstrated that the covalent functionalization of the bacterial *Rhodobacter sphaeroides* RC with tailored organic light harvesting antenna molecules is an efficient route to hybrid systems that outperform the native photoenzyme in photocurrent generation.[2,3] Moreover, smart supramolecular architectures can be assembled by multiple covalent bioconjugation of both bacterial RC and Cytochrome c proteins by means of tailored organic photoactive linkers. Such systems feature an almost doubled photoactivity versus the pristine RC upon illumination at 660 nm, and ~ 10 times higher photocurrent versus an equimolar mixture of the unbound proteins, this being a promising outcome for the development of eco-sustainable systems for biophotovoltaics.[3]

The design, synthesis and photophysical properties of RC-based bioconjugated constructs, as well as their suitability as solar energy bio-photoconverters, will be herein discussed.

References:

[1] F. Milano, A. Punzi, R. Ragni, M. Trotta, G. M. Farinola. *Adv. Funct. Mater.* 2018, 1805521
[2] F. Milano F, R.R. Tangorra, O. Hassan Omar, R. Ragni, A. Operamolla, A. Agostiano, G.M. Farinola, M. Trotta, *Angew. Chem.* 2012, 51, 11019-11023
[3] S. la Gatta, F. Milano, G.M. Farinola, A. Agostiano, M. Di Donato, A. Lapini, P. Foggi, M. Trotta, R. Ragni, *BBA-Bioenergetics*, 2019, 1860, 350-359
[4] G. Buscemi, M. Trotta, D. Vona, G. M. Farinola, F. Milano, R. Ragni, *Bioconjugate Chem.* 2023, 34, 629-637

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The potential of bile acids exploitation in drug discovery: from cancer to chronic inflammation

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Bile acids (BAs) are cholesterol metabolites serving several functions in our bodies. Other than their role into digestion, BAs act as hormones regulating several metabolic processes. Many transmembrane and nuclear receptors, especially expressed along the gastrointestinal apparatus, were identified as endogenous counterparts of BAs. Over the years, the wide druggability of these receptors has been explored to address several unmet clinical conditions such as cholestatic liver diseases, metabolic syndrome, GI cancer, and inflammatory bowel disease (IBD).[1,2]

The high variability of the steroidal scaffold yielded abundant biologically active small molecules with promising pharmacological results. In such a fascinating context, our interest focused on both deepening the biological role of a vast pool of bile acids and harnessing the steroidal backbone to selectively target pathologically relevant receptors. Indeed, some BAs were identified as first endogenous antagonists of the leukemia inhibitory factor receptor (LIFR).

LIFR is a heterodimeric membrane receptor formed by LIFRβ subunit and glycoprotein (gp-130) and binds LIF protein, an IL-6 cytokine, fostering epithelial mesenchymal transition and stimulates cell growth. LIFR inhibition prompts the advancement of BA-based treatments in LIF-mediated oncogenesis.[3]

Moreover, we designed a novel class of bile acid derivatives acting as GPBAR1 agonists and RORγt inverse agonists. Both receptors are indeed attractive drug targets to develop clinically relevant small modulators as potent hybrid medicines for autoimmune diseases. We were able to identify several compounds endowed with great efficacy and potency values and excellent pharmacokinetic profiles.[4]

References:

[1] Ty. Jiao, Yd. Ma, Xz. Guo, *et al.* Acta Pharmacol Sin, 2022, 43, 1103–1119.
[2] W. Li, L. Zou, S. Huang, H. Miao, K. Liu, Y. Geng, Y. Liu, W. Wu. Frontiers in Pharmacology, 2024, 15.
[3] C. Di Giorgio, E. Morretta, A. Lupia, *et al.* Biochem Pharmacol, 2024, 15, 223, 116134.
[4] Fiorillo B, Roselli R, Finamore C, *et al.* ACS Omega, 2023, 8(6), 5983-5994, Erratum in: ACS Omega, 16, 8(47), 45163.

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Electrochemical stereoselective synthesis of biaryl scaffolds

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Biaryl scaffolds are widely spread in biologically important natural products, in numerous therapeutic agents, but they are also considered a privileged class of ligands and (organo)catalysts; therefore, the development of efficient alternative methodologies to prepare such compounds is always attracting much attention.[1] Traditional methods to achieve these structures are based on transition metal-catalysed coupling reactions, such as palladium or rhodium, and nucleophilic organometallic species, which show a notable environmentally impact. However, more recently few protocols based on an electrochemical approach have been reported.[2] In particular, in 2018, Waldvogel et al. investigated on the direct anodic cross-coupling between aryl amines and different-substituted phenols and naphthols, affording the desired products in up to 48% of yield.[3] Considering these results, we envisioned the possibility of developing an enantioselective synthesis of biaryl scaffolds (such as BINAM) using naphthylamines derivatives bearing a chiral auxiliary directly connected to the heteroatom in order to exert a stereochemical control over electrochemical-driven coupling (**Figure 1**).
Initially, an exploration of various electrochemical parameters (conductivity, electrodes, F/mol) were undertaken to optimize yield, employing a model substrate based on naphthylamine scaffold. Subsequently, different chiral auxiliaries were investigated in order to reach good level of diasteroselectivities. According to this approach, the desired biaryl products were obtained in moderate to good yields and up to 85:15 diastereomeric ratio. The two diastereoisomers were subsequently separated by chromatographic purification before the removal of the chiral auxiliary.

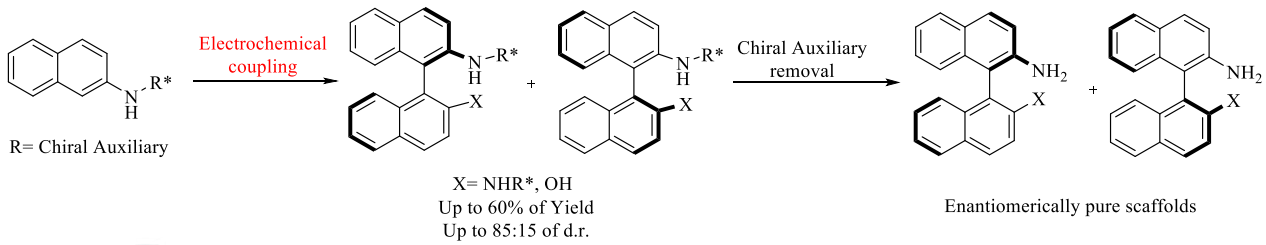

Figure 1: Electrochemical approach for the synthesis of byaril systems

References:
[1] L. J. Röckl, D. Pollok, R. Franke, and S. R. Waldvogel. Acc. Chem. Res. 2020, 53, 45−61
[2] F. Medici, S. Resta, A. Puglisi, S. Rossi, L. Raimondi and M. Benaglia, Molecules, 2021, 26, 6968-6986
[3] B. Dahms, R. Franke and S.R. Waldvogel ChemElectroChem, 2018, 5, 1249-1252

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Pd-catalyzed carbonylation reaction: process optimization and industrial scale up

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The use of palladium-catalyzed carbonylation reactions of aryl halides is increasing in the pharmaceutical chemistry due to their very high atom-efficiency, improved milder conditions and large availability of aryl halides intermediates[1].

A case study of process optimization of a reductive Pd-carbonylation of an aryl halide intermediate using silanes as hydride donor to achieve the desired aldehydic intermediate is discussed. Studies of reaction parameters like i.e. catalyst loading, temperature, CO pressure, oxygen content and concentration, including also kinetic data, helped understanding side reactions and impurities formation.

The scale up of the above carbonylation reaction was based on the gas-liquid mass transfer coefficient kLa performing down-scale optimization experiments using similar kLa value of the industrial autoclave.

All above studies allowed to achieve at industrial scale very high conversion, purity and yield

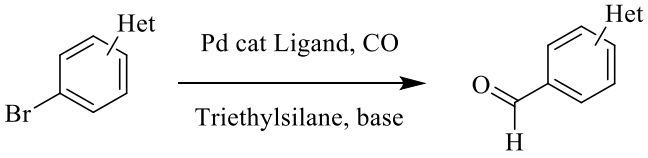

Figure 1: reductive Pd-carbonylation reaction

References:

[1] L. Ashfield, C. F. J. Barnard, Organic Process Research & Development 2007, 11, 39 – 43.
[2] C. F. J. Barnard, Organic Process Research & Development 2008, 12, 566 – 574.
[3] C. F. J. Barnard, Organometallics 2008, 27, 5402 – 5422.

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Exploring Chirality in Photo-Assisted Water Oxidation with Carbohydrate-Decorated Antenna Dyes

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Similarly to its natural counterpart, artificial photosynthesis harnesses sunlight to promote the transformation of water and carbon dioxide into energy-rich products.[1] The synthetic architectures designed for artificial photosynthesis rely on three key elements: light-harvesting chromophores, a water oxidation catalyst, and a semiconductor.[2] The "quantasome" (QS) architecture designed in our group relies on a self-assembled supramolecular aggregate generated by the hierarchical organization of perylenebisimide dyes (PBIs), the artificial antennas, on a ruthenium-based polyoxometalate (RuPOM), the reaction center for photo-assisted water oxidation.[2,3] The complex exhibits quantitative faradic efficiency and excellent performances on electrode.

A modular click chemistry approach allowed the decoration of the PBIs with different moieties to tune the properties of the aggregate. Introducing chiral carbohydrates had the double aim of generating QSs with improved water affinity and introducing optical activity into the system. The intriguing chiral assembly of the new QS allowed us to explore the effect of this property on the efficiency of the system and on the possibility of chiral-induced spin selectivity (CISS) effect in QS-mediated water oxidation.

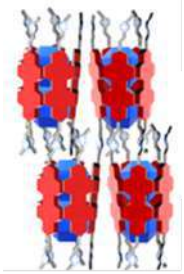

Figure 1: schematic representation of the “quantasome” architecture.

References:

[1] T. Gobbato, G. A. Volpato, A. Sartorel, M. Bonchio, Chem. Sci., 2023, 14, 12402-12429.
[2] M. Bonchio, Z. Syrgiannis, M. Burian, N. Marino, E. Pizzolato, K. Dirian, F. Rigodanza, G. A. Volpato, A. Sartorel, M. Prato, Nat Chem., 2019, 11, 2, 146–153.
[3] T. Gobbato, F. Rigodanza, E. Benazzi, P. Costa, M. Garrido, A. Sartorel, M. Prato, M. Bonchio, J Am Chem Soc., 2022, 144, 31, 14021–14025

ORG-PO-235

Discovery of a new drug prototype able to modulate the BAG3/HSP70 axis

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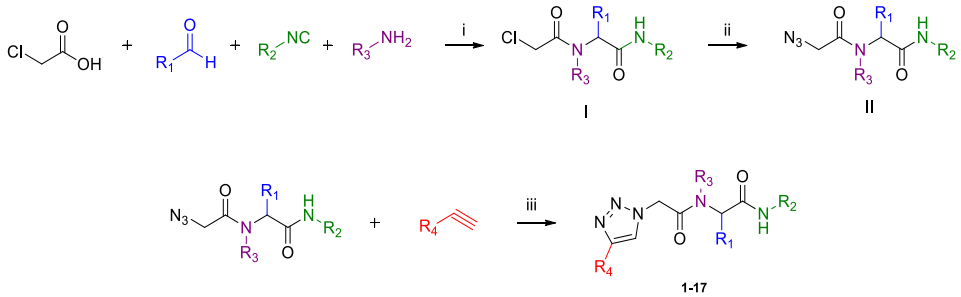
Cancer cells strategically exploit the protein quality control system to deal with the stress caused by rapid proliferation and adverse environmental conditions. The BAG3 (Bcl-2-associated athanogene 3) co-chaperone plays a crucial role in this process by interacting with HSP70 (Heat Shock Protein 70) forming an important functional module involved in cancer cell survival, apoptosis inhibition, and autophagic clearance of damaged proteins. [1] Therefore, the BAG3/HSP70 axis emerges as a focal point in various cancers, making it a promising target for drug development. However, due to the complex BAG3 biology, only a few modulators that disrupt its interaction with HSP70 are known. [2] In light of this, we decided to leverage the modular nature of multicomponent reactions to develop new chemical platforms that can interfere with the BAG3 protein. We successfully synthesized a novel class of 1,2,3-triazole-α-acylaminocarboxamides by combining the Ugi reaction with the alkyne-azide Huisgen procedure in a sequential tandem approach. [3] Our compounds underwent biophysical and biological evaluation, leading us to identify interesting molecules able to inhibit both BAG3 and HSP70 protein. These compounds, emerging as new drug prototypes, offer a therapeutic approach with enhanced efficacy against cancer. Our findings represent a significant advancement in developing effective treatments targeting the BAG3/HSP70 axis in cancer cells.



Reagents and conditions: (**i**) CH_2Cl_2, rt, 48-72 h, (60-98%); (**ii**) NaN_3, K_2CO_3, DMA, rt, 4 h, (>99%); (**iii**) $CuSO_4.5H_2O$, sod. ascorbate, DMSO/t-BuOH/H_2O, rt, 12 h, (70-98%).

Figure 1: Synthetic procedure.

References:

[1] A. Rosati, M. Ammirante, A. Gentilella, A. Basile, M. Festa, M. Pascale, L. Marzullo, M. A. Belisario, A. Tosco, S. Franceschelli, The international journal of biochemistry & cell biology 2007, 39, 1337-1342.
[2] D. Ruggiero, S. Terracciano, G. Lauro, M. Pecoraro, S. Franceschelli, G. Bifulco, I. Bruno, Molecules 2022, 27, 665.
[3] P. Pramitha, D. Bahulayan, Bioorganic & medicinal chemistry letters 2012, 22, 2598-2603.

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ORG-PO-236

AI-assisted predictive synthesis of biopolymers for the generation of colon cancer 3D tissue models

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The development of human tissue mimetics is crucial in advancing theragnostic solutions for healthcare management through the generation of in vitro organs for drug screening and cell biology studies [1]. With the advent of automated manufacturing systems like 3D printing and collaborative robot, it is now possible to control the synthesis and formulation of biomaterials, limiting the combinatorial and artisanal chemical approach that is typically used to obtain 3D in vitro tissue models with tuneable advanced biomolecular and physical properties [2,3]. In this communication, the synthesis of functional biomaterials for the generation of colorectal cancer (CRC) tissue models will be presented. Furthermore, the integration of Artificial Intelligence (AI) and Machine Learning (ML) algorithms in biomaterials synthesis and formulation, to reduce synthetic effort and predict the most efficient synthetic conditions to generate hybrid multifunctional biopolymers with selected properties and features will be included.

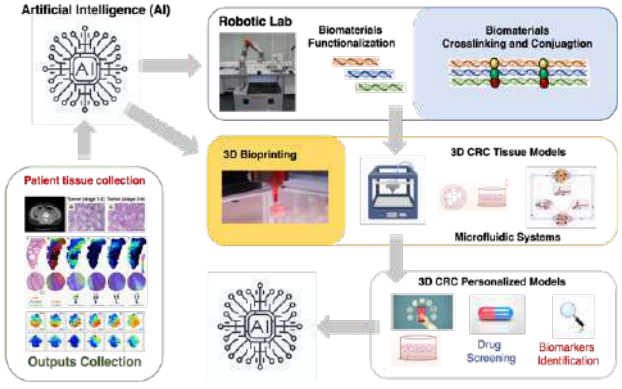

Figure 1

References

[1] Nicolas J. et al. Biomacromolecules **2020**. 21, 1968. [2] Cadamuro F. et al. Journal of Controlled Release **2023**. 354, 726.
[3] Cadamuro F. et al, Carbohydrate Polymers 2023. 302, 120395.

Acknowledgments. Financial support from**:** Iniziativa "PNC0000003 - "ANTHEM: AdvaNced Technologies for Human-centrEd Medicine". CUP BICOCCA B53C2200667000; Ministero della Salute, RF-2021-12371959 Tackling immunomodulatory properties of stromal cells to improve therapeutic strategies in lung cancer. MUR PRIN 2022, 2022MY7AZT Dynamic multifunctional hydrogels for glioblastoma therapy (DINGO).

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Synthesis of 2-(Benzofuran-2-yl)acetamides via Palladium-Catalyzed Coupling of 1-(2-(Allyloxy)phenyl)-2-yn-1-ols and Isonitriles

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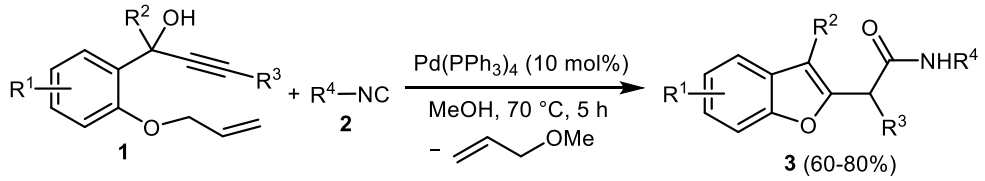
(2-(Benzofuran-2-yl)acetamides represent a class of organic compounds of particular interest, due to their significant pharmacological activities, including antifungal[1] and anticonvulsant[2,3] activities, in particular. Their structural versatility makes them promising candidates for drug discovery and development, motivating research efforts aimed at developing new methods for their synthesis as well as at understanding their biological functions and therapeutic potential.

In this contribution, a novel catalytic method is presented, which allows the synthesis of 2-(benzofuran-2-yl)acetamides **3** starting from readily available 1-(2-(allyloxy)phenyl)-2-yn-1-ols **1** and isonitriles **2** and with $Pd(PPh_3)_4$ as simple catalyst (Scheme 1). Reactions are carried out in MeOH at 70 °C for 5 h.



Scheme 1

Formation of **3** derives from a mechanistic pathway involving an ordered sequence of steps, beginning with the oxidative addition of the phenoxyallyl moiety of **1** to Pd(0) followed by the insertion of **2** to give an (allyl)(imidoyl)palladium complex. The isonitrile group, being isoelectronic with CO, in a similar manner as carbon monoxide[4] is, in fact, able to insert into the palladium-carbon bond arising from the oxidative addition of a suitable substrate to Pd(0). Water attack to the (allyl)(imidoyl)palladium complex followed by β-H elimination from the H-O-C-Pd(allyl) moiety leads to formation of an allylpalladium hydride species (allyl)PdH and a 2-(3-hydroxybenzofuran-2(3*H*)-ylidene)acetamide intermediate. Reduction of the latter by (allyl)PdH and MeOH finally affords the desired (2-(benzofuran-2-yl)acetamides.

References:

[1] C. Mahecha-Mahecha, P. Borrego-Muñoz, L.M. Pombo, D. Gamba-Sánchez, *RSC Adv.* **2023**, *13*, 25296-25304.
[2] P.K. Baruah, J. Dinsmore, A.M. King, C. Salomé, M. De Ryck, R. Kaminski, L. Provins, H. Kohn, *Bioorg. Med. Chem.* **2012**, *20*, 3551-3564.
[3] D. Choi, J.P. Stables, H. Kohn, *J. Med. Chem.* **1996**, *39*, 1907-1916.
[4] B. Gabriele (Ed.), *Carbon Monoxide in Organic Synthesis – Carbonylation Chemistry*, Wiley-VCH, **2022**.

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Puzzling Synthesis of Novel Fluorinated Bioactive Compounds

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The beneficial effects of fluorine atoms inclusion in the chemical structure of therapeutic or diagnostic drugs candidates are well established[1]: enhanced activity and selectivity, as well as improved membrane permeability, stability and pharmacokinetic properties are just few of the advantages related to the presence of one fluorine atom or a fluorinated functional group, as -CF_3. Not by chance, the list of F-containing drugs approved by the U.S. Food and Drug Administration is continuously updated[2].

As the demand for safer non-steroidal anti-inflammatory drugs (NSAIDs) has rapidly grown, a series of dual inhibitors of cyclooxygenase-2/lipoxygenase-5, enzymes involved in inflammatory processes, appeared in the literature, in the attempt to limit adverse effects typically associated with individual inhibitors[3]. Next to synthetic drugs, naturally occurring quinones, terpenoids and phenols, as eugenol or thymol, exhibited relevant bioactivity. However, targeted functionalization of natural phenols is known to further extend and enhance their effectiveness, in a wide range of biological application[4].

In this communication, an overview of our recent efforts on the synthesis of fluorinated thymol and anilines derivatives, eventually bearing -CF_3 functionalities, will be presented, together with a focus on their application as dual inhibitors of cyclooxygenase-2/lipoxygenase-5 enzymes.

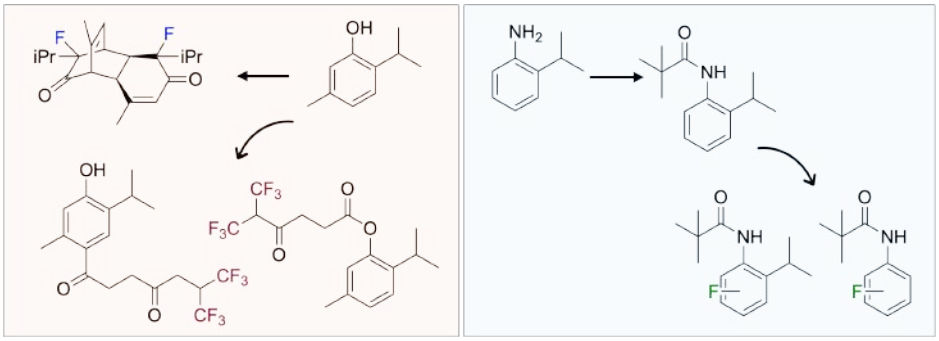

Figure 1: Structures of thymol and 2-isopropylaniline derivatives.

References:

[1] K. Müller, C. Faeh, F. Diederich Science 2007, 317, 1881 – 1886.
[2] S. Ali, J. Zhou, Eur. J. Med. Chem. 2023, 256, 115476.
[3] A. Alibadi, E. Khanniri, M. Mahboubi-Rabbani, M. Bayanati Eur. J. Med. Chem. 2023, 261, 115866.
[4] B. Floris, P. Galloni, V. Conte, F. Sabuzi, Biomolecules 2021, 11, 1325 – 1388.

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Synthesis of New Biocompatible Materials Based on Alginic Acid with Antibacterial Activity

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To replicate the exceptional performance of natural processes at a reasonable cost, scientists have often looked to nature for inspiration when creating high-performing, low-cost bio-based materials. Regarding those above, we decided to focus our recent research on alginic acid (Figure 1), a polymer extensively found in brown algae's cell walls.[1] To achieve our aim, we chose the functionalization of alginic acid with Kojic acid, a chelating agent produced by different species of fungi.[2] Due to Kojic acid's ability to chelate, the material has exhibited siderophore action and antibacterial activity against Gram-positive and Gram-negative bacteria without any cytotoxic effect. In addition, alginic acid was also functionalized with an ionic liquid.[3] The latter already had recognized antibacterial properties that were enhanced by the functionalization. This new material was further modified with another interesting chelator, tris(3-hydroxypyridin-4-one) (THP).[4] Antibacterial tests performed on this material have also shown excellent antibacterial activity.

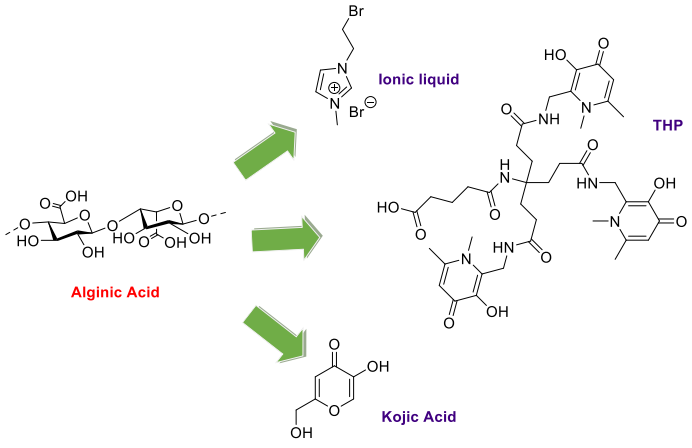

Figure 1: Synthesis of new materials based on alginic acid.

References:
[1] S.N. Pawar, Seaweed polysaccharides 2017, 111–155
[2] R. Bentley, Nat. Prod. Rep. 2006, 23, 1046–1062.
[3]P. Araque, J. Chil. Chem. Soc. 2019, 3, 64.
[4] G. Floresta, Biomedicines 2021, 9, 367.

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Point-of-care array devices based on organic fluorescent probes for human stress detection

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The development of biosensors for the quantitative detection of stress biomarkers such as dopamine, noradrenaline, epinephrine and cortisol in biological fluids such as blood, urine, saliva and sweat has a significant impact on the field of medical diagnostics.[1] Our goal is to develop a portable sensor device to detect stress biomarkers in harsh and adverse environments, such as space missions.[2] We chose to use array technology for the realisation of the sensor device because of its particular characteristics: ease of use, extreme selectivity, sensitivity and ease of implementation.[3] The array was designed with an optical/colorimetric output. In particular, we have selected and synthesised some organic fluorophores (probes) taking into account two important characteristics: *1)* the spectral properties of the transducer, in particular the absorption/emission range of the probe; *2)* the interaction with the analyte through non-covalent interactions. The interaction between each probe and the stress biomarker was previously tested in solution at different analyte concentrations, from 1 nm to 1 pM, and then the response of the array was analysed on a solid state using an optical fibre as a detector. In particular, we detected Dopamine, Cortisol and Adrenaline in real saliva samples.[4]

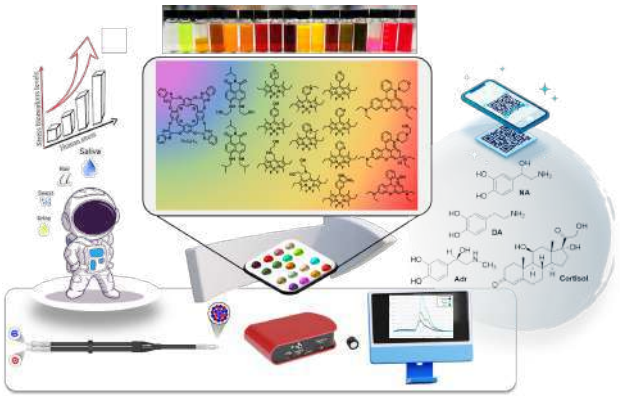

Figure 1: Real sample of the sensoristic device.

References:
[1] J. P. Ulrich-Lai, Y.M.,Herman, Nat. Rev. Neurosci. 2009, 10, 397− 409.
[2] V. Sharma, T. K. Sharm, I. Kaur, Applied Nanoscience, 2021, 11, 2577–2588.
[3] L. Zheng, K. S. Suslick; Acc. Chem. Res. 2021, 54, 950−960.
[4] R. Santonocito, N. Tuccitto, A. Pappalardo, G. Trusso Sfrazzetto, Molecules 2022, 27, 21, 7503.

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In-vitro and *in-vivo* Antifibrotic Efficacy of a Nintedanib-Containing Dual Conjugate Targeting $\alpha_V\beta_6$ Integrin

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Idiopathic Pulmonary Fibrosis (IPF) is a fibrotic lung disease in which the deposition of collagen within the pulmonary interstitium causes stiffness in the lungs and compromises the respiratory function. The decline is progressive and irreversible. Nintedanib, a tyrosine kinase inhibitor able to block the signaling of several growth factors receptors (GFRs), is one of two drugs nowadays approved as pharmacological treatment of IPF, that only slows down the progress of the fibrotic process. The $\alpha_V\beta_6$ integrin is overexpressed in fibrotic tissue and is the major activator of transforming growth factor-β (TGFβ), the principal pro-fibrotic mediator, that stimulates proliferation of fibroblasts, their transition into myofibroblasts and the deposition of collagen. For this reason, $\alpha_V\beta_6$ integrin has been recently recognized as a possible IPF marker and therapeutic target[1]. Our group recently synthesized six dual conjugates[2] in which the $\alpha_V\beta_6$ integrin-recognizing moiety *c*(AmpLRGDL) and a nintedanib portion were connected through different types of uncleavable linkers, with the aim of delivering nintedanib to the fibrotic tissue and inhibiting TGFβ activation. In particular, compound **1** (Figure 1) gave promising results in preliminary biological assays, thanks to the contribution of both active units (nintedanib and integrin ligand).

This communication will report on recent advances in the biological evaluation of dual covalent conjugate **1** both *in-vitro* on human fibroblasts from IPF patients and *in-vivo* on IPF-like mouse model.

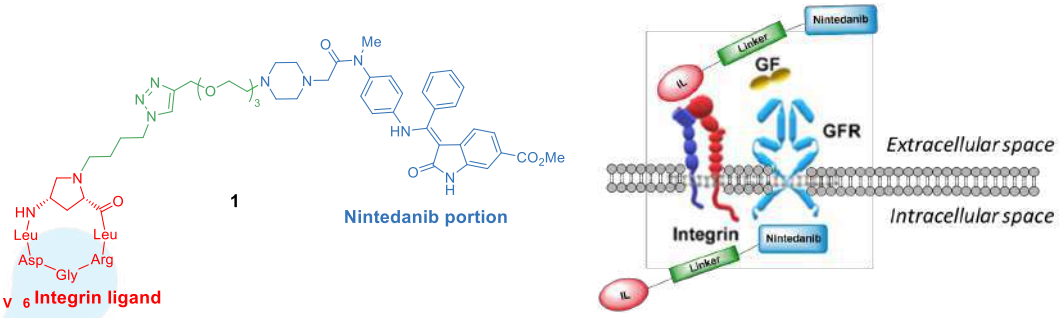

Figure 1: Dual conjugate **1** and its schematic interactions with $\alpha_V\beta_6$ integrin and GFRs.

References:

[1] C. Sofia, A. Comes, G. Sgalla, L. Richeldi, *Expert Opin. Emerg. Drugs* **2023**, *28*, 283.
[2] a) K. Bugatti *et al.*, *ACS Omega* **2022**, 7, 17658. b) E. Andreucci *et al.*, *Int. J. Mol. Sci*. **2023**, *24*, 1475.

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ORG-PO-242

Low-Impact Synthetic Strategies for Constructing Stereodefined Coumarin-Based Molecular Architectures

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Coumarins represent one of the most important tools in medicinal chemistry (MedChem) for designing and developing new bioactive molecules and drugs. Various coumarin-based compounds have been proposed for treating diverse human pathologies, as pesticides in integrated pest management, and as luminophores for developing fluorescent probes in bioimaging and theranostics. In recent years, our research group has conducted several studies aimed at developing different synthetic strategies for constructing novel coumarin scaffolds and achieving their chemo- and stereoselective transformations. This endeavor has enabled access to new chemical architectures with significant biological activity and notable photophysical properties. These results were attained through diverse synthetic approaches, spanning from photochemistry to organocatalysis, and the exploration of new reaction pathways. Herein we report our recent results in the development of novel stereo- and enantioselective synthetic processes aimed at obtaining a series of different coumarin-based compounds and their potential as antiviral drugs.

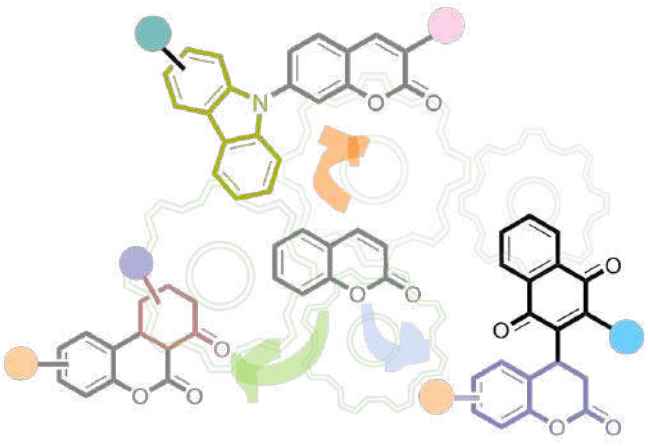

Figure 1: access to complex molecular structures through the functionalization of coumarin derivatives

References:

[1] A. Cocco, P. Caria, G. Sanna, L. Stagi, E. Cadoni, R. Corpino, P. C. Ricci, C. M. Carbonaro, F. Secci, *ACS Omega* **2021**, 6, 33708.
[2] Z. Liu, P. Verwilst, S. Koo, P. Jangjili, J. Seung Kim, W. Lin. *Chem. Rev*. **2019**, 119, 10403.

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A novel Fluorophore-ureido-Calix[5]arene receptor for the recognition of bioactive guests

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Supramolecular chemistry-based sensing offers distinct advantages, such as the possibility of selective and specific design based on the complementarity of size, shape, and function between the receptor and the analyte, and the ability of re-use the systems thanks to the non-covalent approach. Calix[5]arene macrocycles have been extensively tested against bioactive ammonium-containing substrates and the complexation processes have been observed by NMR spectroscopy.[1] However, it is known that the efficiency of the recognition process is strongly dependent on the ion pair interaction between the ammonium cation heads and their counterions. To this end we proposed a novel fluorophore-ureido-calix[5]arene luminescent receptor for the detection of bioactive species that contains linear alkylammonium motif. The design of this receptor implies that, in addition to the known complexing capabilities of calix[5]arenes for linear alkylammonium guests, the complexation will be improved by the synergistic action of the ureido group,[2,3] trapping the anionic counterion, and the presence of a fluorescent label will allow to follow the host-guest complexation by fluorescence spectroscopy.

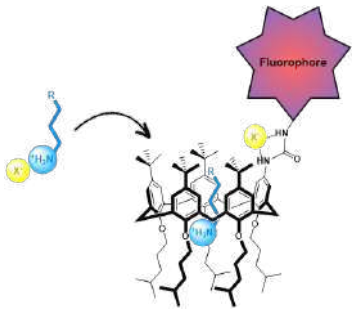

Figure 1: proposed recognition mechanism of fluorophore-ureido-calix[5]arene luminescent receptor.

References:

[1] F. Arnaud-Neu, S.Fuangswasdi, A. Notti, S. Pappalardo and M. F. Parisi, *Angew. Chem. Int. Ed.* **1998**, 37, 112–114.
[2] P. Ballistreri, A. Notti, S. Pappalardo, M. F. Parisi, I. Pisagatti, *Org. Lett.* **2003**, 5, 1071-1074.
[3] D. Garozzo, G. Gattuso, A. Notti, A. Pappalardo, S. Pappalardo, M.F. Parisi, M. Perez and I. Pisagatti, *Angew. Chem. Int. Ed.*, **2005**, 44, 4892–4896.

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New Easy Recoverable Cryogel-Based Palladium Catalyst for Suzuki Reaction in Water

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A new heterogeneous and recyclable bio-based cryogel containing palladium was synthesized as a heterogeneous catalyst for organic reactions.[1] The synthesis of the macroporous material started from the appropriately functionalized amino acid L-phenylalanine complexed with palladium and subjected to free radical polymerization in water at subzero temperature.[2,3] The pore size, surface morphology, composition, and thermal stability of the obtained cryogel were studied using SEM/EDX, FTIR, and TGA techniques. The hybrid cryogel was successfully used as a catalyst for Suzuki-Miyaura coupling reactions using water as solvent. The material demonstrated robust mechanical strength while reusable across multiple catalytic cycles without any discernible loss in activity. Moreover, palladium remains complexed within the cryogel and is not lost in solution once the catalytic cycle is complete. The catalyst can be easily recovered by removing the cryogel from the reaction and washing it with a mixture of ethanol/water, preserving its integrity with minimal weight loss or alteration in appearance. This innovative cryogel catalyst boasts several appealing features, including its utilization of eco-friendly and non-toxic solvents for catalysis and effortless recovery and reusability.

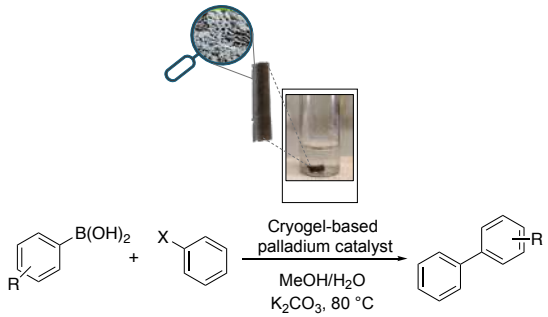

Figure 1: Schematic representation of the Suzuki reaction. The SEM image depicts the macroporous structure of the synthesized material.

References:

[1] M.-B. Li, J.-E. Bäckvall, Acc. Chem. Res. 2021, 54, 2275 – 2286.
[2] V.I. Lozinsky, O. Okay, Polymeric Cryogels 2014, Advances in Polymer Science, 263, 49 – 101.
[3] C. Zagni, A. Coco, S. Dattilo, V. Patamia, G. Floresta, R. Fiorenza, G. Curcuruto, T. Mecca, A. Rescifina, Mat. Today Chem. 2023, 33, 101715.

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Electrochemical Synthesis of 2-Oxazolines using electrodes from recycled aluminium cans

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Nowadays, the chemical industry is intensively working to achieve net-zero carbon dioxide emissions.[1] Electrochemical manufacturing, which uses electricity as the major source of energy, is becoming a promising alternative to reduce the environmental impact of chemical production.[2] Although the current research is focused on the optimization of key electrochemical parameters such as energy efficiency, product selectivity, productivity per time unit and so on, there is little attention on the use of electrodes made from waste.[3] For example, aluminium is a highly recyclable metal, and it can be recycled at a very low energy cost compared to its primary production.[4]

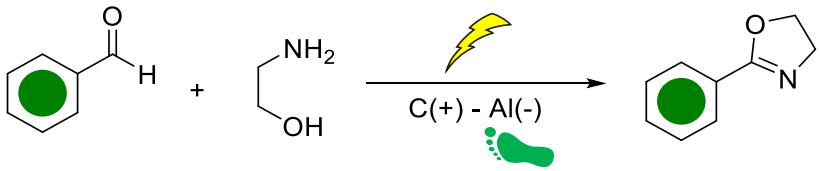

Figure 1: Recycling of aluminium cans in the electrochemical synthesis of 2-oxazolines.

We are currently developing electrosynthetic methods using electrodes deriving from inexpensive and recyclable materials, specifically spent aluminium cans. In this contribution, we report our study on the electrochemical synthesis of differently substituted 2-oxazolines. An extensive green metric assessment has been carried out to quantify the overall sustainability of our protocol compared to those reported in the literature.

References:

[1] M. H. Barecka, J. W. Ager, *Energy Adv.*, 2023, **2**, 268–279.
[2] R. Xia, S. Overa, F. Jiao, *JACS Au*, 2022, **2**, 1054-1070.
[3] N. Idusuyi, O. O. Ajide, R. Abu, O. A. Okewole, O. O. Ibiyemi, *Mater. Today Proc.*, 2022, **56**, 1712–1716.
[4] https://www.climateaction.org/news/carbon-footprint-of-recycled-aluminium.

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Synthesis of Dihydrofuroquinolinone Derivatives by Pd-Catalyzed Carbonylative Double Cyclization

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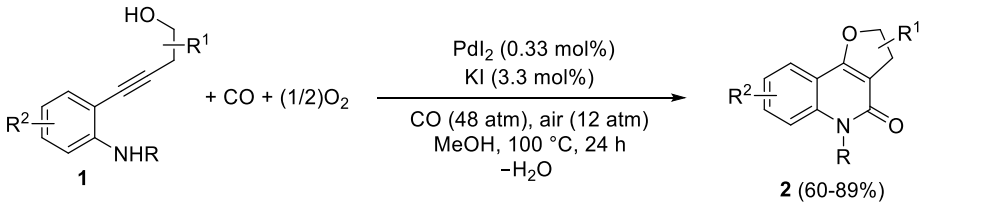
Quinolinone derivatives play a very important role in medicinal chemistry, as numerous molecules containing this scaffold have shown interesting antitumor[1] and antibacterial[2] activities. In this communication, a carbonylative double cyclization[3] approach to 2,3-dihydrofuro[3,2-*c*]quinolin-4(2*H*)-ones derivatives **2** from readily available 4-(2-aminophenyl)-3-yn-1-ols **1** is presented, based on the use of PdI_2/KI as the catalytic system[4] under oxidative conditions. Products have been obtained in fair to high yields (60-89%) in one step and in a multicomponent fashion, working under relatively mild conditions (100 °C in MeOH for 24 h, under 60 atm of a 4:1 mixture of CO-air).



(R = Me, Bn; R^1 = H, alkyl, aryl; R^2 = H, Me, Cl)

Scheme 1

The reaction represents a single-step method for synthesizing a particularly important class of fused heterocycles, using easily and accessible materials [4-(2-aminophenyl)-3-yn-1-ols, carbon monoxide and oxygen (from air)], with selective and sequential formation of three new bonds and two cycles. The working mechanism has also been investigated by DFT calculations following a protocol designed for Pd-containing systems,[4] and this approach helped to shed light on the molecular source of the catalytic activity, providing atomistic details on the intermediates and transition states of the chemical event.

References:

[1] J. M. Kraus, C. L. M. J. Verlinde, M. Karimi, G. I Lepesheva, M. H. Gelb, F. S. Buckner, *J. Med. Chem.* **2009**, *52*, 1639-1647.
[2] M. Naik, V. Humnabadkar, S. J. Tantry, M. Panda, A. Narayan, S. Guptha, V. Panduga, P. Manjrekar, L. Jena, K. Koushik, *J. Med. Chem.* **2014**, *57*, 5419-5434.
[3] B. Gabriele, R. Mancuso, Della Ca', N.; L. Veltri, I. Ziccarelli, *Catalysts* **2023**, *13*, 1025.
[4] M. Prejanò, R. Mancuso, T. Marino, B. Gabriele, *J. Catal.* **2023**, *427*, 115120.

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Smartphone-based sensing of cortisol by optical array: a supramolecular approach

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The monitoring of cortisol levels should be extremely important to control the human health, thus funding important medical application.[1] The standard analytical methods for cortisol identification and quantification cannot be self-performed, due to the bulky size of the instruments and the necessity of specialized persons.[2] Molecular probes solve these problems due to their fast and easy use.[3] In this contribution, the synthesis of new fluorescent rhodamine probes, able to interact with cortisol by non-covalent interactions, the recognition properties in solution as well as in solid state by optical array, using a smartphone as detector, is reported. DFT calculations and FT-IR measurements suggest the formation of hydrogen bonds between probes and cortisol. The ability to detect cortisol in artificial saliva, in a linear range from 1 mM to 1 pM has been demonstrated, thus leading to the realization of practical smart device for the detection of cortisol in real life.

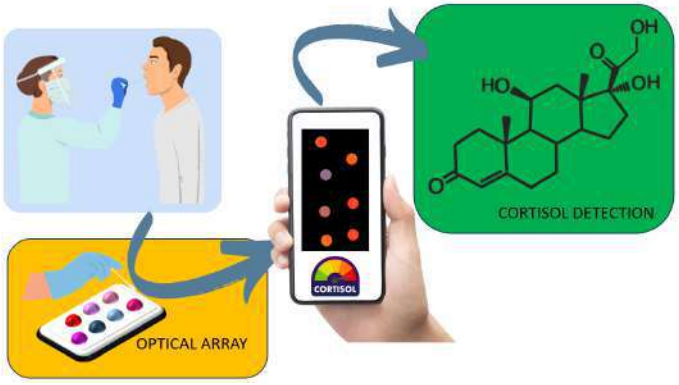

Figure 1: cortisol detection by optical array.

References:
[1] D. Gonzalez, D. Jacobsen, C. Ibar, C. Pavan, J. Monti, N. Fernandez Machulsky, A. Balbi, A. Fritzler, J. Jamardo, E. M. Repetto *Sci. Rep.* **2019**, *9*, 1–6.
[2] X. Liu, Z. Ser, J. W. Locasle *Anal. Chem*. **2014**, *86*, 4, 2175–2184.
[3] R. Santonocito, R. Puglisi, A. Cavallaro, A. Pappalardo, G. Trusso Sfrazzetto *Analyst*, **2024**, *149*, 989–1001

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TEC-PZ-01

Multifunctional hybrid materials from biowaste valorization

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According to a Circular Bioeconomy approach, humic acids (HA) are biowastes that can be viewed as a promising and cost-effective source for high-value products and novel materials, because of their chemical and biological richness. Indeed, HA are rich in phenolic and carboxylic groups, which enhance plant growth, flame retardancy and antiviral properties. The amphiphilic nature of HA allows them to self-assemble in water, act as metal chelating agents, and interact with organic contaminants. Quinone and phenol moieties in HA provide antioxidant and pro-oxidant properties by scavenging or generating reactive oxygen species (ROS). However, their technological use is limited by their instability in water, leading to their classification as waste nowadays, while their presence in water environment raises big issues to decontamination processes. The present PhD work defined different synthetic approaches to turn HA environmental issues into technological opportunities through the design and the development of multifunctional hybrid materials based on HA biomolecules. The PhD thesis has been focused on two main parts: I) Design of hybrid nanostructured HA-based materials; II) Design of HA-based polymeric materials. In the former, the molecular combination of these heterogeneous moieties with an inorganic matrix (e.g., SiO_2, TiO_2, ZnO) through a ceramic templated approach proved to be an effective method for limiting HA aqueous degradation phenomena, thus improving physicochemical stability, mechanical properties, and even enhancing intrinsic organic moieties features in the final hybrid nanostructured HA based materials [1]. This approach was also combined with the electrospinning technology to produce bioactive and sustainable nanocomposite films for active packaging applications made of electrospun biodegradable and bioderived polymers and hybrid nanoparticles [2]. In the latter, HA were explored as functional additives for polymer materials. Indeed, proper synthesis strategies were designed to use these biomolecules as functional biowaste flame retardant for epoxy-based systems or as an additive for gelatine hydrogels to obtain hybrid HA-3D network with tunable rheological features and significant biological activity, including antimicrobial and antioxidant efficacy, for a broader range of biotechnological applications [3]. From a scientific point of view, this thesis has contributed to clarify the chemistry of HA with a special focus on their interaction with either organic or inorganic components as well as on the physico-chemical features of HA-based hybrid nanomaterials. From a technological point of view, it has provided viable routes for HA valorization by developing different materials of interest in diverse areas, especially environmental ones.

References:

[1] V. Venezia, C. Prieto, Z. Evtoski, Marcoaldi C., B. Silvestri, G. Vitiello, G. Luciani, J. Lagaron, *J. Ind. Eng. Chem* 2023, 124, 510-522.
[2] V. Venezia, G. Pota, B. Silvestri, G. Vitiello, P. Di Donato, & G. Luciani, *Chemosphere*, 2022, 287, 131985.
[3] V. Venezia, P. Avallone, G. Vitiello, B. Silvestri, N. Grizzuti, R. Pasquino, G. Luciani, Biomacromolecules, 2021, *23*(1), 443-453.

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TEC-OR-001

Biomimetic Design of Novel Structural Biomaterials through Halogen Bonding

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A halogen bond occurs between an electrophilic region associated with a halogen atom in a molecule and a nucleophilic region in another molecule.[1] Although many modifications of peptide sequences have been utilized to tune their self-assembly behaviour, halogenation has rarely been pursued. The advantage of the introduction of halogen atoms on peptide motifs lies in the fact that halogenation is a minimal structural modification, which, on the other hand, induces a large difference in the peptide supramolecular behaviour as a consequence of the rich variety of noncovalent interactions given by halogen atoms.[2]

In this seminar, I will show how the halogen bond can be used to promote the molecular self-assembly of peptides. We have applied this new supramolecular concept to the augmented fibrillation of amyloidogenic peptides[3] and the control of their nanostructures (Figure 1).[4] The obtainment of a novel unnatural amino acid functioning as strong halogen-bond donor has allowed to engineer the hydrophobic cavity of an amyloid fibril. Our results prove that selective halogenation of an amino acid enhances the supramolecular organization of otherwise unstructured biologically-relevant sequences. This method may develop as a general strategy for stabilizing highly polymorphic peptide regions.

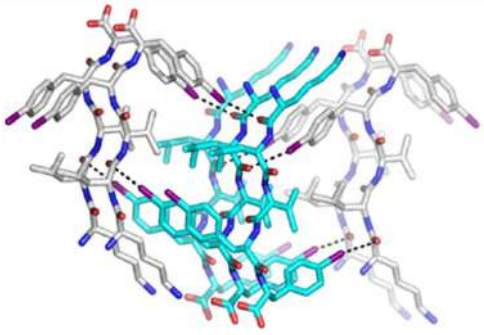

Figure 1: Steric zipper motif formed by KLVF(I)F(I) showing halogen bonds with the carbonyl oxygens.

References:

[1] G. Cavallo, P. Metrangolo, R. Milani, T. Pilati, A. Priimagi, G. Resnati, G. Terraneo, Chem. Rev. 2016, 116, 2478-2601.
[2] A. Pizzi, C. Pigliacelli, G. Bergamaschi, A. Gori, P. Metrangolo, Coord. Chem. Rev. 2020, 411, 213242.
[3] A. Bertolani, et al., Nature Commun. 2015, 6:7574.
[4] A. Pizzi, L. Sori, C. Pigliacelli, A. Gautieri, C. Andolina, G. Bergamaschi, A. Gori, P. Panine, A. M. Grande, M. B. Linder, F. Baldelli Bombelli, M. Soncini, P. Metrangolo, Small 2022, 18:2200807.

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TEC-OR-002

Adsorption of Cisplatin and Its Derivatives on Graphene.

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Cisplatin, is a key anticancer metallodrug, which is nowadays is a key-tool in the treatment of solid tumors. The mechanism of action consists in the diffusion into the cell, followed by activation via chloride group hydrolysis. This generates a highly reactive species which forms adducts, that trigger a cascade of events and cause cell death[1]. However, a significant % of administered cisplatin is excreted intact or as one of its reactive hydrolysis products. This uncontrolled release posed serious concerns for the potential threat to environment and human health, also due to its poor biodegradability[2]. To decontaminate aqueous solutions containing such persistent drug pollutants a simple and economic approach is to remove them by adsorption onto materials possessing high affinity towards these drugs. Carbon-based materials have been considered as promising adsorbents for the removal of pharmaceutical pollutants from water[3], especially when combined with advanced oxidation processes (AOP)[4]. In this his study we report the results of molecular dynamics (MD) simulations performed to investigate the adsorption of cisplatin and its mono- and di-aquo derivatives on a graphene model surface to provide insights into adsorption mechanisms and thermodynamics. MD simulations were conducted for cpt, wcpt, and w2cpt within a tetragonal box (x,y =5.1 nm, y= 11.0 nm). The graphene surface (5x5nm) was generated using the GOPY application, and its topology was established as previously described[5,6]. An in-house flexible force field was employed for the Pt-complexes[7]. The box was filled with SPC/E water molecules to replicate water density, and the particle-mesh Ewald method was used for long-range electrostatic interactions[8], with a 1.2 nm cut-off for short-range interactions. Following energy minimization, the system was equilibrated for 5 ns in both the NVT and NPT ensembles at 1 bar and 300 K. Production simulations were run for 50 ns. Potential of mean force profiles were obtained via umbrella sampling. Furthermore, ΔH and ΔS were computed from the van't Hoff relation using free energies calculated at multiple temperatures. All simulations were performed using GROMACS 2021.3. Platinum complexes spontaneously adhered to graphene surfaces in a parallel orientation, with derivatives showing stronger affinity than cisplatin. This was confirmed by lower adsorption free energies (ΔG_{ads}) for cisplatin compared to its derivatives, possibly due to increased mechanical strain upon adsorption. Van't Hoff plots suggested an enthalpy-driven process for all complexes, facilitated by water molecule liberation from graphene to the bulk phase, enhancing adsorption.

References

[1] L. Kelland, Nature Reviews Cancer 2007, 7, 573–584.
[2] Y. Roque-Diaz, et al., Processes 2021, 9, 1873.
[3] M. Del R. Cuevas-Flores, M. A. et al., J Comput Chem 2018, 39, 2, 71–80.
[4] D. Veclani, et al., Processes 2020, 8, 642.
[5] S. Muraru, et al., Coatings 2020, 10, 289.
[6] S. Muraru, et al., Compos B Eng 2020, 196, 108140.
[7] A. Melchior, et al., J. Chem. Theory Comput. 2015, 11, 1735–1744.
[8] T. Darden, et al., J Chem Phys 1993, 98, 10089–10092.

TEC-OR-003

Synthesis and cytotoxic activity of a series of chloro-oxo-dihydroquinoline-hydrazones Copper(II) complexes

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Starting from a series of chloro-2-oxo-1,2-dihydroquinoline-3-hydrazone derivatives bearing different aroyl moieties, we synthesized the corresponding copper (II) complexes to study their biological activity against selected cancer cells lines.

Hydrazones have shown a great potential as modulable ligands in medicinal chemistry for the preparation of cytotoxic agents.[1,2] Thanks to the huge variety of available building blocks to make the hydrazone X-CH=N-NH-C(=O)-Y structure, it is possible to create species with tuned chemical and coordination properties.

The new complexes have been characterized in terms of X-ray structure and solution behaviour with the support of DFT calculations.[3] They showed very promising cytotoxic activity against human colon (HCT-15), lung (H1573), pancreatic (BxPC3 and PSN-1), ovarian (A2780), and colorectal (LoVo) cancer cell lines and their resistant sublines.

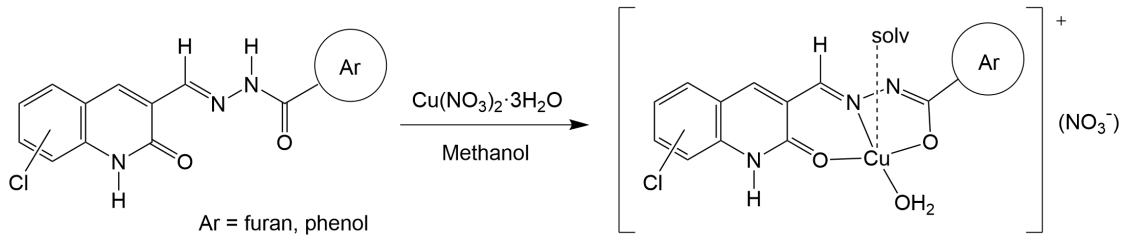

Figure 1: Synthesis of chloro-oxo-dihydroquinoline-hydrazones Cu(II) complexes.

References:

[1] J.P. Rada, J. Forté, G. Gontard, C.M. Bachelet, N.A. Rey, M. Salmain, V. Corcé, J. Biol. Inorg. Chem. 2021, 26, 675-688.

[2] M. Sutradhar, E.C.B.A. Alegria, T.R. Barman, M.F.C. Guedes da Silva, C-M. Liu, A.J.L. Pombeiro, Frontiers in Chem. 2020, 8, article n.157.

[3] T. Thirunavukkarasu, H.A. Sparkes, V. Gandin, C. Marzano, R. Bertani, M. Mozzon, A. Scettri, A. Albinati, F. Demartin, G. Casella, F. Ferrante, A. Zoleo, Inorganica Chimica Acta, 2024, 566, article n.122022.

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TEC-OR-004

Radiation crosslinked hydrogel wound dressings containing egg white proteins

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The wound healing process results in chronic wounds if the complex interplay between cytokines, growth factors, blood components and the extracellular matrix is disrupted by aging or underlying health conditions like diabetes.[1] In chronic wounds, an excessive inflammatory response prevents the proliferation of the healthy tissue, causing a serious infection which can even be life-threatening, if not treated properly.[2]
Egg white proteins, such as ovoalbumin, ovotransferrin and lysozyme, are attracting interest because of their demonstrated antioxidant and antibacterial activities.[3] By incorporating these bioactive proteins, advanced wound dressing films gain the ability to manage oxidative stress in the wound. This promotes faster healing and potentially reduces the risk of bacterial infection.
Wound dressing films can be easily produced crosslinking polymers, such as polyvinyl alcohol (PVA) or polyvinyl pyrrolidone (PVP), by high-energy radiation.[4] This technique does not require expensive initiators and catalysts and it can guarantee simultaneous product sterilization, depending on the irradiation doses. When PVA is mixed with selected polysaccharides, the hydrogel wound dressings have shown faster healing rates and scarless healing, probably due to antioxidant properties of polysaccharide fragments produced upon irradiation.[4] The aim of this work is to develop novel hydrogel formulations incorporating egg white proteins and/or their peptides. The hydrogel systems demonstrated rheological and adhesion properties that make it suitable for a wound dressing. Fluid retention ability, morphology, protein release and the antibacterial and antioxidant properties were also assessed to investigate the applicability of the hydrogel formulation as an advanced wound dressing.

References:

[1] S. Dhivya, V. V. Padma, E. Santhini, 2015; 5, 24-28.
[2] Z. Xu, S. Han, Z. Gu, J. Wu, 2020, 9, 1-11.
[3] J. Kovacs-Nolan, M. Phillips, Y. Mine, 2005, 53, 8421–8431.
[4] E. A. Kamoun, E. R. S. Kenawy, X. Chen, 2017, 8, 217-233.

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TEC-OR-005

Branched fluorinated Janus-type dendrimers: From physico-chemical properties to gene delivery applications

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Janus-type dendrimers (JDs) are dendritic macromolecules bearing two domains of different polarity. A tailored balance between the two portions allows to control their physico-chemical properties, and therefore their function.[1] The use of fluorinated chains is a powerful tool to increase JDs colloidal stability and influence their self-assembling properties.[2] Moreover, the use of branched fluorinated moieties can be exploited for non-invasive *in vivo* monitoring by ^{19}F-MRI to develop new theragnostic systems.[3]
Here, we show how the balance between a perfluoro-*tert*-butyl moiety and polyester dendrons of generations 1-3 can strongly affect self-assembling behavior of a family of Fluorinated JDs (FJDs),[4] see Figure 1, and how the final physico-chemical properties can be exploited to synthesize an ionizable fluorinated JD for gene delivery applications.[5]

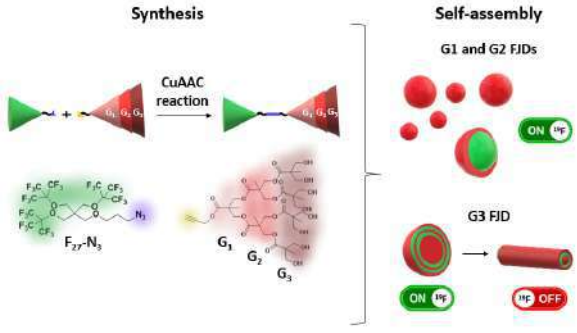

Figure 1: The three fluorinated JDs (Gen. 1 to 3) showed different magnetic properties at ^{19}F-NMR depending on their self-assembly in aqueous media.

References:

[1] D. Astruc, E. Boisselier, C. Ornelas, Chem. Rev. 2010, 110, 1857-1959.
[2] M. Wang, H. Liu, L. Li, Y. Cheng, Nat. Commun. 2014, 5, 1–8.
[3] C. Chirizzi, C. Morasso, A. A. Caldarone, M. Tommasini, F. Corsi, L. Chaabane, R. Vanna, F. Baldelli Bombelli, P. Metrangolo, J. Am. Chem. Soc. 2021, 143, 12253–12260.
[4] M. Rosati, A. Acocella, A. Pizzi, G. Turtù, G. Neri, N. Demitri, Nonappa, G. Raffaini, B. Donnio, F. Zerbetto, F. B. Bombelli, G. Cavallo, P. Metrangolo, Macromolecules 2022, 55, 2486–2496
[5] Baldelli, F.; Metrangolo, P.; Cavallo, G.; Bono, N.; Candiani, G.; Rosati, M.; Pinter Lauria, G.; Marcuzzo, S. Non-Viral Vectors for Gene Therapy. WO2023170543A1, September 14, 2023.

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TEC-OR-006

Surface coating of magnesium alloy resorbable implants manufactured *via* superplastic forming

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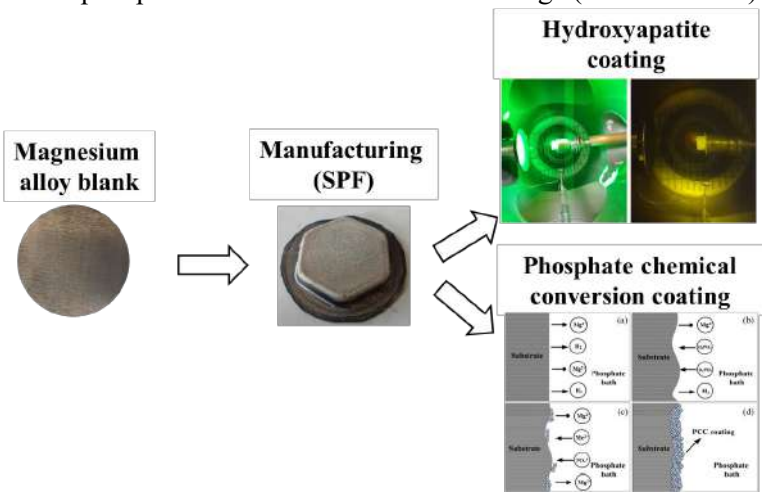
Magnesium alloys are considered as promising candidates for biodegradable orthopaedic implants, due to their mechanical properties and biocompatibility. Challenges related to the production of Mg-based prostheses are (a) the choice and the design of flexible manufacturing processes to produce complex-shaped parts (e.g. reproducing geometries of the human bones) and (b) the control of magnesium degradation rate in body fluids *via* specific surface coating techniques. Among flexible sheet metal forming processes, superplastic forming (SPF) allows to produce customized and complex-shaped implants characterized by a satisfying shape accuracy and surface quality. SPF can affect the microstructure and, thus, the corrosion resistance of the alloy, whose value is crucial in influencing the biodegradation rate. In the present contribution, a pulsed laser deposition of hydroxyapatite (HA)[1] coating and a phosphate chemical conversion coating[2] (see Scheme 1) were applied to AZ31 Mg alloy components, formed by SPF process, to decrease their degradation rate. Chemical-physical characterizations, electrochemical corrosion tests and electrochemical impedance spectroscopy were performed to assess the most promising deposition route and the possible beneficial effect of the applied coating on the corrosion behaviour of the superplastic formed AZ31 Mg components.



Scheme 1: Surface coating approaches applied to AZ31 Mg alloy.

References:
[1] A. De Bonis, V. Uskoković, K. Barbaro, I. Fadeeva, M. Curcio, L. Imperatori, R. Teghil, J. V. Rau, Cell Biology and Toxicology 2020, 36, 537 – 551.
[2] B. Liu, X. Zhang, G. Xiao and Y. Luet, Materials Science and Engineering C 47 (2015) 97–104.

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TEC-OR-007

Devices for the isolation of rare cells in biological specimens for diagnostic applications

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Early detection and effective treatment significantly impact survival rates in disease management. In prenatal diagnostics, micromanipulation is a dependable method for manually isolating rare fetal cells from maternal fluids for molecular or cytogenetic analysis. While effective, this approach is costly and time-consuming due to the need for skilled personnel and specialized equipment[1].

This study aims to enhance the efficiency and affordability of prenatal diagnosis in hospital settings by developing a device for semi-automated selection of rare cells from biological samples. The device utilizes polymeric mats functionalized with antibodies to selectively capture target cells based on surface antigens.

The polymeric mats were electrospun with materials that provide the fuctional groups for further coupling. Bioconjugation methods employing EDC/NHS chemistry were developed to impart cell-capture capabilities to the mats, exploiting the streptavidin or avidin with biotin lock and key bound. Fluorescently labelled antibodies enabled assessment of conjugation success via fluorimetry and spectrofluorimetry.

Cell capture tests were conducted using fetal cells (CF) and mesenchymal stem cells (MSC) on antibody-decorated mats, with observations made using optical and confocal microscopy to evaluate capture efficacy. Release after capture mechanism of the streptavidin or avidin with biotin lock and key bound was also tested using fluorescent biotinylated probes.

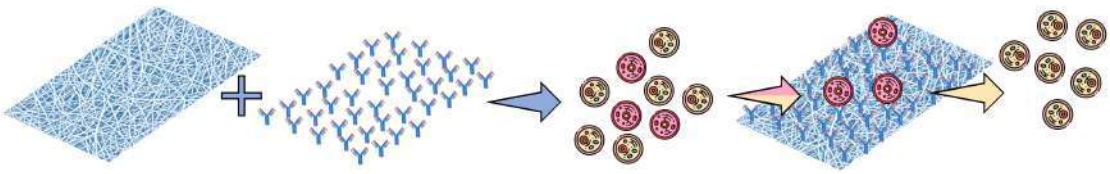

Figure 1: Schematic representation of mat antibody decoration and specific cells selection.

References:

[1] G. Makrydimas, G. Damiani., C. Jakil, V. Cigna., M. Orlandi, F. Picciotto, K. H. Nicolaides, 2020, Ultrasound in Obstetrics & Gynecology, 56(5), 672-677.

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TEC-OR-008

Selective modulation of A1 astrocytes by drug-loaded nano-structured gels in spinal cord injury

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Spinal cord injury (SCI) is a frequent disabling injury of the spine that leads to cell degeneration, involving neurons, astrocytes and oligodendrocytes[1]. Secondary processes (e.g. inflammation, apoptosis and oxidative stress) cause additional loss of neurons and glial cells (secondary injury). After an acute damage, the reactive pro-inflammatory response of the astrocytes, with the subsequent formation of scar tissue and the inhibition of axonal regrowth, is pivotal. Astrocytes with A1 phenotype exert indeed neurotoxic effects, upregulating genes associated with the synapse and neuronal degeneration, suggesting that A1 has harmful pro-inflammatory action[2]. Various approaches have been employed to counteract this detrimental progression of the secondary injury[3]. For this purpose, a large number of nanoparticles-based systems have been tested, but none are selective for pro-inflammatory astrocytes[4]. Therefore, the challenge is to formulate a targeted, effective therapy with neuronal protective effects, reducing the side effects. In this study we have developed a novel delivery tool, a nanogel-based nanovector able to be selectively internalized in activated astrocytes. When loaded with Rolipram, an anti-inflammatory drug, this nanovector allows a selective and controlled release in the spinal cord, reversing the toxic effect of A1 astrocytes on motor neurons in vitro. When tested acutely in a SCI mouse model it improves motor performances, reducing the astrocytosis and preserving neuronal cells[5]. Interesting results are being obtained for the regulation of other neuronal cells, e.g. the glial component, involved in the inflammation process.

References:

[1] A.D. Gaudet, et al. *Neurotherapeutics* **2018**, *15*, 554-577.
[2] S.A. Liddelow, et al. *Nature* **2017**, *541*, 481-487.
[3] K. Gorshkov, et al. *Drug discovery today* **2018**, *23*, 673-680.
[4] X. Li, et al. *Biomaterials science* **2016**, *4*, 1100-1112.
[5] I. Vismara, et al. *ACS Nano* **2020**, *14*, 360-371.

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TEC-OR-009

Insights into factors influencing the performance of immobilized enzymes and biocatalytic membrane reactors

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It is known that heterogenization of enzymes by attaching/loading to a carrier such as nanoparticles, nanoemulsions and nanostructured membranes increases their stability, although this may lead to a decrease in their catalytic activity and selectivity. However, this inverse relationship is not a general rule. The lecture will illustrate that high catalytic activity and selectivity (including enantioselectivity) and high stability can be achieved simultaneously. This was confirmed by case studies with different enzymes (including lipase, beta-glucosidase and phosphotriesterase) immobilized on supports of different materials (organic, inorganic, mixed matrix) and shapes (nanoparticles, droplets, porous membranes) using different methods (entrapment, covalent binding).

Studies on the performance of enzyme-loaded membranes in continuous biocatalytic membrane reactors show that, in addition to the immobilization conditions and the physicochemical properties of the microenvironment in which the catalytic biomacromolecule is located, the topography of the support and the transport phenomena through the biocatalytic matrix also play a role in the resulting biocatalytic performance of heterogenized enzymes. A better understanding of the factors that influence a biomacromolecule such as an enzyme when it is compartmentalized in an artificial, durable membrane opens up strategies to enable green, intensified, sustainable biocatalytic membrane reactors for numerous applications[1-4].

Acknowledgments:

Authors acknowledge the project Tech4You - Technologies for climate change adaptation and quality of life improvement financed by the European Union – Next Generation EU

References:

[1] G. Vitola, R. Mazzei, L. Giorno, Environmental Technology & Innovation 30 (2023) 103053

[2] R. Mazzei, A. Yihdego Gebreyohannes, E. Papaioannou, S. P. Nunes, I. F.J. Vankelecom, L. Giorno, Bioresource Technology 335 (2021) 125248

[3] E. Piacentini, R. Mazzei, L. Giorno, Membranes, 11 (2021) 137

[4] G. Vitola, R. Mazzei, T. Poerio, G. Barbieri, E. Fontananova, D. Büning, M. Ulbricht, L. Giorno, Bioconjugate chemistry 30 (8) (2019) 2238-2246

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TEC-OR-010

Adducts of sp^2 Carbon Allotropes Functionalized with Pyrrole Compounds and with Transition Metal atoms: Towards Single Atom Catalysis

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The confinement of organic synthesis within nanospaces is being considered with increasing attention to improve its yield and reduce environmental impact. Along with this, active site heterogeneity, achievable through anchoring metals onto solid supports, offers a promising means to combine the advantages of homogeneous and heterogeneous systems.

With a view to further optimizing the two processes, a synergy between the two systems would be desirable.

In this work, facile metal decoration of sp2-hybridized carbon allotropes is achieved, and their compatibilization into compostable matrices through 3D printing was used to obtain the zeolike's concept.

First, functionalization of the graphene layers was performed with 2-(2,5-dimethyl-1*H*-pyrrol-1-yl)-1,3-propanediol (serinol pyrrole, SP).[1]

SP is a serinol derivative obtained from the pure reaction of 2-amino-1,3-propanediol with 2,5-hexanedione, with an atom economy of approximately 85%, almost quantitative yield, and therefore high atom efficiency. The only co-product is water, in the absence of solvent and catalyst.

The decoration of the allotrope was carried out with metals such as ruthenium, copper, and silver, and the catalytic activity was tested in C-H activation reactions (hydrogen isotope exchange), reductions, and cross-coupling reactions.[2,3]

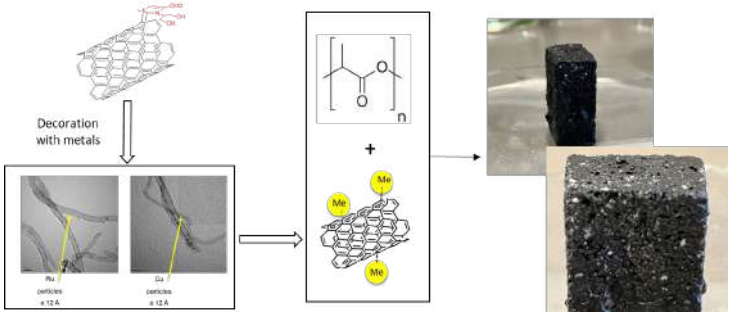

Figure 1: process for the preparation of zeolike's.

References:

[1] V. Barbera, A. Bernardi, A. Palazzolo, A. Rosengart, L. Brambilla, M. Galimberti, 2018, Pure and Applied Chemistry, 90(2), 253-270.

[2] Barbera, V. Galimberti, M. S., & Candiani, G. EP4196484A1.

[3] Barbera, V., Galimberti, M. S., Pieters, G. & Palazzolo, A. EP4196485A1.

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TEC-OR-011

Tuning the morphology and optical properties of Eu-doped YPO_4 nanopowders by a rapid microwave-assisted hydrothermal method

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Europium-doped yttrium orthophosphate (Eu^{3+}:YPO_4) is attracting increasing interest as luminescent material due to its applications in bioimaging and as advanced light sources and optical markers. [1, 2] In this work, a rapid microwave-assisted hydrothermal method under mild aqueous conditions was investigated for the preparation of such phosphors with tunable morphology and narrow size distribution in the nanometre range. Well-crystallised Eu^{3+}:YPO_4 (5% mol Eu) nanopowders with tetragonal single phase structure and low degree of hydration were obtained in very short times (5 min) of MW heating at 200°C compared to conventional methods and without the need for additional calcination treatment. In addition, varying the reaction time (up to 30 min) and temperature (up to 240°C) resulted in different nanocrystal morphologies and sizes, which can be tuned by controlling the reaction parameters, thus potentially tuning the optical properties of the nanoparticles. The resulting nanopowders exhibit intense red emission using 396 nm as the excitation wavelength, showing the characteristic emission bands of the Eu^{3+}in the crystal matrix. Moreover, their optical properties, studied by measuring both excitation and emission spectra, luminescence lifetimes and quantum yields, are comparable to those of analogous materials prepared by conventional hydrothermal method. [3, 4] These results suggest that the MW-assisted hydrothermal process optimized in this work is a faster and energy-saving strategy to efficiently produce single-phase Eu^{3+}:YPO_4 (5 mol% Eu) luminescent nanopowders with monodisperse tuned morphology and narrow particle size distribution together with suitable optical properties which could have potential applications in both biological and security fields.

References:

[1] R. Priya, R. Mariappan, A. Karthikeyan, E. Palani, E. Krishnamoorth, G. Gowrisankar, *Solid State Commun.* 339 (**2021**) 114457. DOI: https://doi.org/10.1016/j.ssc.2021.114457
[2] F. Armetta, V. Boiko, D. Hreniak, R. C. Ponterio, M.L. Saladino, *Mater. Lett.* 333 (**2023**) 133653. DOI: https://doi.org/10.1016/j.matlet.2022.133653
[3] F. Armetta, V. Boiko, D. Hreniak, C. Mortalò, C. Leonelli, L. Barbata, M.L. Saladino, *Ceram. Int.* 49 (**2023**) 23287. DOI: https://doi.org/10.1016/j.ceramint.2023.04.159
[4] E. Paradisi, C. Mortalò, V. Zin, F. Armetta, V. Boiko, D. Hreniak, M. Zapparoli, S.M. Deambrosis, E. Miorin, C. Leonelli, M.L. Saladino, *ACS Applied Nano Materials*, under review.

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TEC-OR-012

SYSTEMATIC INVESTIGATION ON THE SURFACTANT-ASSISTED LIQUID PHASE EXFOLIATION OF MoS2 AND WS2 IN WATER FOR SUSTAINABLE 2D MATERIAL INK

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2D materials have gathered significant attention due to their interesting and tunable properties and their wide range of applications. They can be produced in several ways, but one important and easy methodology is the "liquid phase exfoliation" (LPE)[1]. It consists in using specific solvents to exfoliate the material, however N-methyl-2-pyrrolidone (NMP), dimethyl sulfoxide (DMSO) and N,N-dimethyl formamide (DMF) are expensive, high boiling point solvents and toxic[2], therefore limiting their use and applications. Ideal solvents are instead low boiling point solvents and above all: water, but it has a low exfoliation yield and quality.

Therefore, it is possible to add stabilizers, for example surfactants, to improve the process[3]. However, the surfactant concentration can influence the final concentration and quality of the material and high concentrations can also be detrimental for different applications. In this work, we investigate the role of the surfactant concentration on the exfoliation process of two bi-dimensional materials, MoS_2 and WS_2 using sodium dodecyl sulfate (SDS), sodium dodecylbenzene sulfonate (SDBS) and sodium hexadecyl sulfonate (SHS) as surfactants.

Moreover, it is necessary to confirm the outcome of exfoliation using different characterization techniques such as TEM, UV/Visible and Raman spectroscopies, which provides informations on the structural integrity and size of the nanosheets. We find that all the surfactants work efficiently to exfoliate the materials, particularly SHS.

References:

[1] S. Ott et al., Chem. Mater. 2019, 31, 8424-8431.
[2] C.X. Hu et al., Nanoscale 2021, 13, 460-484.
[3] A. Griffin et al., Chem. Mater. 2020, 32, 2852-2862.

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TEC-OR-013

Development of Doped Li_4SiO_4-based Pellets for CO_2 Capture at High Temperature

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This study focuses on the development of K_2CO_3-doped lithium orthosilicate (Li_4SiO_4) sorbents for CO_2 capture from high-temperature flue gas generated by gas turbines [1] using a versatile process aimed at the easy production of sorbent pellets. The methodology involves the synthesis of Li_4SiO_4 powders from quartz silica (SiO_2) and Li_2CO_3 followed by the addition of different amounts of K_2CO_3 as an activity promoter and viscous linear polyalphaolefins. The latter acts as both a compatibiliser and a pore-forming agent. The resultant mixture was extruded in form of cylindrical pellets and sintered at moderate temperatures (550 °C) to obtain porous and mechanically resistant sorbents [2]. The performance of the resultant pellets was assessed by thermogravimetric analysis at 580 °C, during sorption under low CO_2 partial pressure conditions, and 620 °C, during desorption with N_2. The results indicate that an optimal K_2CO_3 content of 20 wt.% facilitates the formation of a homogeneous molten K_2CO_3-Li_2CO_3 mixture during CO_2 chemisorption, thereby preventing phase segregation across multiple cycles. The inclusion of 30 wt.% olefin yields durable, porous pellets (Fig. B-D) capable of maintaining a consistent and regenerable CO_2 sorption capacity of 130 mg CO_2/g (with a Li_4SiO_4 conversion of 45 %) over 25 cycles, each spanning 30 minutes (Fig. A). The sorption kinetics of these sorbents were characterised and analysed using the double exponential model to elucidate the influence of cycling and K_2CO_3 concentration on the overall sorption performance.

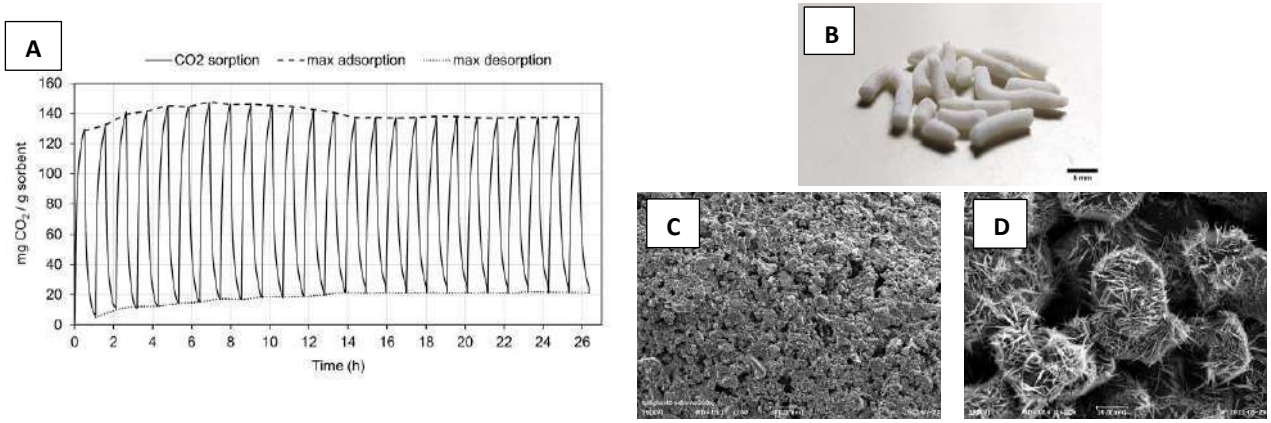

Figure: (**A**) Pellet sorbent capacity during 25 CO_2 sorption/desorption cycles. (**B-D**) Porous pellets.

This research introduces a simplified pelletizing technique for developing innovative, solid, and robust pellets with enhanced CO_2 capture and cycling capabilities making their use feasible in industrial fixed-bed adsorption systems.

References:

[1] Essaki, K.; Kato, M.; Nakagawa, K. CO_2; *J. Ceram. Soc. Japan* **2006**, *114*, 739–742

[2] Seggiani, M.; Stefanelli, E.; Puccini, M.; Vitolo, S. *Chem. Eng. J.* **2018**, *339*, 51–60

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TEC-OR-014

EXPLORING THE POTENTIAL OF AMINO-ACID IONIC LIQUIDS AS HIGHLY PROMISING ABSORBENTS FOR EFFECTIVE CO_2 CAPTURE

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Carbon capture technology is an essential option for mitigate climate change by reducing greenhouse gas emissions (GHG).[1,2] Governments worldwide are urged to adopt net-zero transition strategies.[3] This study proposes a promising class of sustainable CO_2-effective absorbents: Ionic liquids based on amino acid (AAILs). Ionic liquids (ILs) are organic molten salts with melting temperature below 100 °C and high thermal stability.[4] These innovative materials hold promise for application in energy and industrial sectors to foster in climate change mitigation. With their tuneable properties driven by cation and anion selections,[5] AAILs exhibit potent reactivity with CO_2. Despite their efficacy, their viscosity at room temperature has hindered widespread use. However, by employing various CO_2 separation methods, including solvent mixing to reduce viscosity, AAILs can be effectively utilized. Through a comprehensive analysis involving CO_2 absorption tests, ATR Spectroscopy, TGA, and DSC, this study explores the synthesis and characterization of AAILs and their solutions. Newly developed solutions such as [Cho][AA] (Choline-based AAILs) and [MMPyrr][AA] (Dimethylpyrrolidinium-based AAILs) exhibit remarkable CO_2 absorption capability, low energy consumption, and low release temperature, offering a sustainable strategy for post-combustion capture technologies.

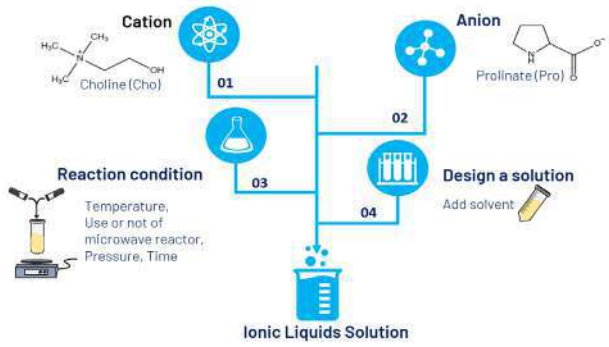

Figure 1: Overview of Ionic Liquid solution's procedure

References:

[1] S. Paltsev, Hard-to-Abate Sectors: The role of industrial carbon capture and storage (CCS) in emission mitigation. Applied Energy, Volume 300, 2021, 117322,ISSN 0306-2619, DOI: 10.1016/j.apenergy.2021.117322.
[2] Nature Communications volume 14, Article number: 534 (2023) DOI: 10.1038/ s41467-023-36199-4
[3] Addendum to the Emissions Gap Report 2021. UNEP. wedocs.unep.org/bitstream/handle/20.500.11822/37350/AddEGR21.pdf (last view 30/03/2024)
[4] Hayes R, Structure and nanostructure in ionic liquids. Chem Rev 115:6357–6426 (2015). https://doi.org/10.1021/cr500411q
[5] A. Le Donne, Cholinium amino acid-based ionic liquids. Biophys Rev 13, 147–160 (2021). https://doi.org/10.1007/s12551-021-00782-0

TEC-OR-015

Nanocellulose-based eco-safe materials for water treatment

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The growing and urgent demand for water and wastewater decontamination from a wide range of pollutants asks for the development of more effective and safe technologies. In this context, the design of manufactured nanomaterials (MNM) for an efficient water treatment is attracting more and more interest due to their promising adsorption performances. At the same time, MNM also raise concerns due to their potential (eco)toxicity and the uncertainty related to their final fate. For this reason, a safer-by design strategy is recommended in developing new MNM, which should combine a high decontamination efficiency with verified eco-safety.[1] The goal of this work is to show an overview of our recent findings on how nanocellulose, simply derived from biomass as renewable source, can represent a sustainable and eco-safe solution for developing new MNM with high sorption performances for water treatment. 2,2,6,6-Tetramethypiperidinyloxyl (TEMPO)-oxidized cellulose nanofibers (TOCNF), bearing carboxylic groups on the C6 position of some glucopyranose units, have been produced from different sources and their eco-safety has been verified by an *in vivo* acute study with marine mussels *Mytilus galloprovincialis*.[2] Cellulose nanofibers have been successfully used as suitable supports for silver nanoparticles, providing nano-composites with enhanced sorption performances towards heavy metals[3] and as building blocks for the design of nanostructured cellulose-based materials, obtained by thermal cross-linking with branched polyethylenimine. These cellulose-based nanosponges (CNS) were proven to be suitable for removing heavy metal ions from fresh- and seawater, also confirming their efficiency after several cycles of reuse. To support a non-impacting *in-situ* application, their eco-safety was demonstrated performing *in vivo* tests on marine species, toward which no genotoxic effects were observed.[4] Further studies were conducted on freshwater species, proving that CNS can be considered suitable safe candidates for metal sequestering, without altering cellular physiological activity in the considered organisms.[5] A more recent study of eco-safety assessment of CNS on sea urchins demonstrated that appropriate conditioning of these materials can lead to their safe use in water remediation applications.[6] All the topics described are investigated within Spoke VS4 of the PNRR RETURN project.

References:

[1] I. Corsi, A. Fiorati, G. Grassi et al., Materials 2018, 11, 1228.
[2] T. Rusconi, L. Riva, C. Punta et al., Env. Sc. Nano 2024, 11, 61-77.
[3] L. Riva, A. Dotti, G. Iucci, et al., ACS Appl. Nanom. 2024, 7, 2401-2413.
[4] A. Fiorati, G. Grassi, A. Graziano et al., J. Clean. Prod. 2020, 246, 119009.
[5] P. Guidi, M. Bernardeschi, M. Palumbo et al., Nanomaterials 2021, 11, 2219.
[6] C. Esposito, G. L. Russo, L. Riva et al., Env. Poll. 2023, 334, 122169.

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TEC-OR-016

Membrane processes as an effective and environmentally friendly technology for treating municipal water polluted by micro- and nanoplastics

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In the last decades, the production and consumption of plastic items have seen exponential growth, causing both aquatic and terrestrial pollution. In particular, micro- and nanoplastics (MNPs), due to their small size and a non-biodegradable nature, enter the food chain posing a potential health risk to all living organisms.[1,2] Currently, municipal water treatment plants are not suitable for the removal of MNPs, thus reducing the quality of water released into the environment. In this context, membrane technology[2] represents a concrete and promising solution for the removal of small plastic particles from municipal water. For this purpose, water leaving a municipal plant was treated using an integrated membrane system (Figure 1), combining ultrafiltration (UF) and nanofiltration (NF) processes, to evaluate its performance in terms of permeate flux, fouling index (FI%), cleaning efficiency (CE%) and MNPs rejection. The integrated system houses tubular ceramic membranes, selected to improve transmembrane flow and reduce membrane fouling. Results showed that proposed integrated system allowed the complete recovery of MNPs from municipal water and the complete recovery of the initial performance of the membranes used with a CE of 98% and a FI of 30%. In addition, a degradation step for retentate streams was studied by means of a photocatalytic process using TiO_2 and UV light, to completely degrade the MNPs coming from municipal plants.

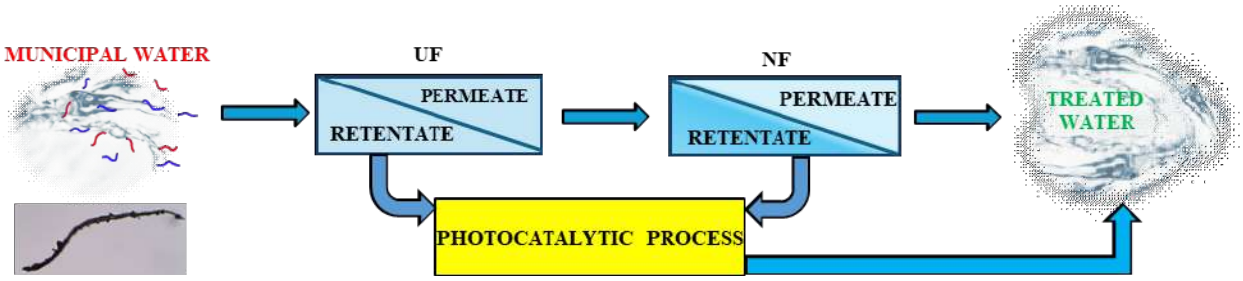

Figure 1: Scheme of UF/NF lab-scale plant.

References:

[1] T. Poerio, E. Piacentini, R. Mazzei, Molecules 2019, 24, 4148-4162.
[2] T. Poerio, C. Lavorato, A. Severino, B. Russo, R. Molinari, P. Argurio, A. Figoli, Available at SSRN: https://ssrn.com/abstract=4763919 or http://dx.doi.org/10.2139/ssrn.4763919.

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Waste to Wastewater Treatment: Sustainable Remediation from Dyes and Metals using Mono-Combusted Sewage Ash

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In wastewater treatment plants (WWTP), sewage undergoes comprehensive purification processes to remove contaminants. The residual solids from this treatment, known as sludge, can be incinerated, transforming into ash, a practice that necessitates careful management due to potential environmental and health considerations[1]. Harnessing the latent potential of fluidized bed mono-combusted ash from sewage water treatment, this study unveils a versatile approach to water remediation within the framework of a circular economy. Through activation, the ash demonstrates heightened sorption efficiency, actively participating in the adsorption of dyes and metals from contaminated water, showcasing competitive Qmax values across various isotherm fits and dynamic kinetic studies, tailored to address different types of contaminants present. Additionally, characterization studies such as SEM, BET, and XRD analyses provide valuable insights into the structural and surface properties, enhancing our understanding of its adsorption mechanisms and performance. The incorporation of both direct ash and activated ash into immobilized polymeric-ash beads, collectively forming effective adsorption matrices, demonstrates their effectiveness in adsorption and their improved ability to be regenerated for different types of contaminants. Polymer immobilization involves confining polymers in a fixed matrix, which enhances their performance and usefulness. The successful regeneration of ashes, with an 80% reuse rate and sorption efficiency, is contingent upon the types and levels of contaminants present. Ash in landfilling entails health hazards and environmental concerns, yet its advantageous role in adsorption processes makes it a valuable tool for efficiently removing contaminants[2]. This study not only facilitates the simultaneous removal of diverse contaminants but also contributes to a waste-to-waste treatment paradigm, advancing eco-friendly methodologies in wastewater treatment.

References:

[1] Shi, Y., Li, Y., Yuan, X., Fu, J., Ma, Q., & Wang, Q. (2020). Environmental and human health risk evaluation of heavy metals in ceramsites from municipal solid waste incineration fly ash. Environmental Geochemistry and Health, 42, 3779-3794.

[2] Reijnders, L. (2005). Disposal, uses and treatments of combustion ashes: a review. Resources, Conservation and Recycling, 43(3), 313-336.

TEC-OR-018

Effect of agri-food by-product additives on properties of biodegradable composites: Evaluation of Chestnut Wood Fiber as functional filler

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Phenolic compounds, such as tannins, are widely recognized for their antioxidant and antimicrobial properties that can help inhibit the growth of bacteria and prevent oxidation in packaged foods. These compounds can be extracted from various natural sources as well as from agri-food industry by-products, leaving exhausted ligneous residues rich in lignin. The latter is widely used as a green additive, capable of imparting functional properties to polymeric composites used for food packaging, drug delivery, and environmental applications. Undoubtedly, the effectiveness of the extraction process and consequently the chemical composition of extracts and residues of the extraction process are principally determined by the extraction parameters, such as temperature, time, solvent, etc.

In a previous study by Moccia et al. [1] it was demonstrated that the choice of solvents and extraction protocols for chestnut wood fiber (CWF), derived from exhausted chestnut wood, significantly influences the composition of the extracted compounds. In the literature, there are also studies where entirely biobased composites are produced by dispersing lignin of different origins into a bioderived polymer [2]. It was evident that the nature of the lignin additive affected the thermal and mechanical properties of these biocomposites.

Here we present a work where the extracts and extraction residues of CWF, as well as the CWF themselves, are used as functional fillers in biopolymer-based composites. The effects of the addition of these fillers on the composite's structural and functional properties are evaluated. The final purpose is to assess whether the extraction process effectively leads to an enhancement of filler antioxidant efficiency compared to untreated CWF, together with their effect on composite mechanical properties.

Aknowledgments: This study was conducted within the Agritech National Research Center (Task 8.1.1. Valorisation of the waste by green chemistry to obtain high value molecules or new products, and Task 8.1.3. Valorization of the waste to obtain biomaterials) and received funding from the European Union via Next-Generation EU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR)—MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4—D.D. 1032 17/06/2022022, CN00000022).

References:

[1] F. Moccia, N. Gallucci, S. Giovando, A. Zuorro, R. Lavecchia, G. D'Errico, L. Panzella, A. Napolitano, Journal of Environmental Chemical Engineering 2022, 10, 107773.
[2] S. Pawale, K. Kalia, S. Alshammari, D. Cronin, X. Zhang, A. Ameli, ACS Applied Polymer Materials 2022, 4, 5861–5871.

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TEC-OR-019

Unlocking the potential: green strategies for rapeseed meal

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Figure 1. A green way from waste to useful product.

Rapeseed meal (RSM) is a byproduct of rapeseed extraction for oil manufacturing. It is reported to be high in proteins [1], phenolics, and flavonoids [2], substances with antioxidant and anti-inflammatory qualities that make it suitable for use in functional foods, nutraceuticals, and cosmetics. Various valorization procedures have been developed for fully exploiting RSM, including numerous extraction strategies [3] aimed at bioactive extraction.

In this study, we compared a traditional ethanol Soxhlet extraction to a supercritical CO_2-based technique with ethanol as a modifier. This approach, which uses supercritical carbon dioxide as a solvent to extract target molecules from a feedstock, is widely regarded as environmentally friendly and efficient. It has various advantages over standard extraction procedures, including minimal toxicity, good selectivity, and high purity of extracted chemicals. [4]

The current study seeks to valorize the RSM by developing "green" extraction techniques for bioactive substances using alcoholic solvents and/or supercritical CO_2.

Enhancing the recovery of polyphenolic components was prioritized, and the results were assessed using NMR and HPLC-DAD studies. Additionally, using specific methods, the antioxidant qualities of the extraction residues were investigated. Based on our findings, a quantitative recovery hypothesis has been put forth for bioactive-rich extracts that are repurposed in nutraceuticals and cosmetics. [5]

References:

[1] Z. Zhang, S. He, H. Liu, X. Sun, Y. Ye, X. Cao, Z. Wu, H. Sun, Food Chem. 2020, 327, 126998.
[2] M. Zhang, C. Zheng, M. Yang, Q. Zhou, W. Li, C. Liu, F. Huang, J. Am. Oil Chem. Soc. 2019, 96, 303-317.
[3] S. Vuorela, A. S. Meyer, M. Heinonen, J. Agric. Food Chem. 2004, 52, 8202–8207.
[4] M. Zoccali, P. Donato, L. Mondello, Trends Analyt. Chem. 2019, 116, 158-165.
[5] D. Rivera, K. Rommi, M. M. Fernandes, R. Lantto, T. Tzanov, Int. J. Cosmet. Sci. 2005, 37, 496–505.

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TEC-OR-020

Molecular recognition of aromatics in spherical nanocages

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Metal-organic cages (MOCs) represent a great option for molecular recognition, sensing and guest inclusion.[1] This is possible via host-guest chemistry because of the presence of internal binding sites that can interact with specific moieties of the guest, anchoring it to the host structures. One special kind of these assemblies, still little investigated, is the $M_{12}L_8$ poly-[*n*]-catenane[2] (**1**) formed from the mechanochemical bonding of interlocked icosahedral $M_{12}L_8$ MOCs using a tridentate pyridine-based ligand and ZnI_2. This material showed dynamic behaviour and presents interesting binding sites for the trapping of aromatic compounds.[3,4] In this work[5] we present the uptake of different aromatic guests by molecular recognition via several single-crystal-to-single-crystal (SCSC) experiments and the mechanics behind the dynamic behaviour enabling their capture. By means of single crystal X-ray diffraction (SC-XRD) we could determine the complete structure of a single crystal under multiple gas-solid SCSC guests exchange and identify preferential guest uptake. DFT calculations were fundamental to confirm the experimental results. The combination of SC-XRD, DFT and solid-state ^{13}C NMR allowed the full characterization of **1**, proposing a mechanism in which the pyridines of the ligand act as nanorotors, making possible the guest diffusion inside and outside the cages.

This study shows the responsiveness of **1** to external stimuli, making $M_{12}L_8$ MOCs candidates in the application fields of sensing, potentially able to trap pollutants and toxic compounds from the air.

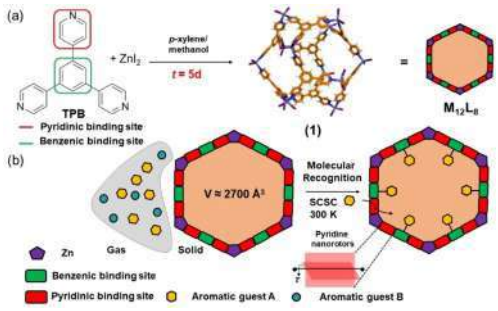

Figure 1: Molecular recognition of aromatic guests by $M_{12}L_8$ in **1** in a gas-solid reaction.

References:

[1] Y. Inokuma, T. Arai, M. Fujita, *Nature Chemistry*, **2010**, *2*, 780-783.
[2] S. Torresi, A. Famulari, J. Martí-Rujas, *J. Am. Chem. Soc.*, **2020**, *142*, 9537–9543.
[3] A. Famulari, J. Martí-Rujas, *Cryst. Growth Des.*, **2022**, *22*, 4494–4502.
[4] J. Martí-Rujas, S. Elli, A. Famulari, *Sci. Rep.*, **2023**, *13*, 5605.
[5] J. Martí-Rujas, S. Elli, A. Zanotti, A. Famulari, F. Castiglione, *Chem. Eur. J.*, **2023**, *29*, e2023020. (Hot Paper)

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TEC-OR-021

Engineered Amino Acid-based Supramolecular Architectures

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Non-natural amino acids, in particular fluorinated ones (F-AA), are attracting considerable interest in materials and biomedical sciences, thanks to their ability to self-assemble into peculiar supramolecular structures. The conformational changes induced by the presence of fluorine atoms obviously affect their functions, as well as their aggregation behaviour, resulting for instance in an improved tendency to form fibrils, and gels therefrom.

We recently investigated a crystal engineering-based approach for obtaining multicomponent F-AA hydrogels with tuneable strength and properties, by mixing them with suitable partner molecules. Our studies proved the matching between the driving noncovalent interactions in crystals and hydrogels, as shown by the exemplary case of *N*-Fmoc-pentafluoro-phenylalanine (**1**, Fig. 1).[1]

The ability of fluorination to influence physical, chemical, and structural properties of these substrates offers the possibility to engineer bioinspired materials with specific and tuneable functions.

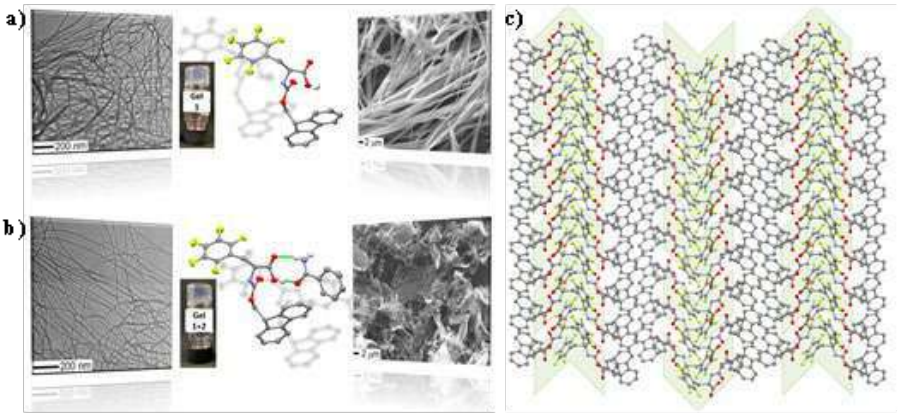

Figure 1: Supramolecular hydrogels of fluorinated amino acids: a) TEM and SEM images of **1** hydrogel; b) TEM and SEM images of bicomponent hydrogel of **1** with benzamide (**2**); c) crystal packing of **1**·**2** supramolecular complex.

References:

[1] E. Veronese, C. Pigliacelli, G. Bergamaschi, G. Terraneo, V. Dichiarante, P. Metrangolo, Chem. Eur. J. 2023, 29, e202301743.

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TEC-OR-022

Eco-design of recycling/reuse channels for biobased and biodegradable plastics

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Plastic has become ubiquitous in modern life due to its practicality, convenience, and safety benefits. However, its widespread use has led to significant environmental issues, particularly in the field of food packaging, significant contributor to world's plastic waste[1]. Once used, most of this packaging is either incinerated or landfilled, contributing to ecosystems contamination. Plastic pollution could be reduced by replacing conventional plastics with biodegradable ones. However, to ensure the sustainability of these alternatives, it is crucial to keep them in the economy and out of the environment for as long as possible. Hence the need to study their recycling, particularly in closed-loop system for food packaging applications. Today, only PET bottles are decontaminated and thermally reshaped in the recycling process[2], and there is a huge lack of knowledge on the end of life (EoL) loops of biodegradable plastics. This is partly due to misconceptions about the technical and economic challenges of their recycling, such as insufficient volumes, contamination risks, and greater degradation under thermal recycling conditions. ECO2R project in which this work is included seeks to challenge the misconception that biodegradable plastics are only suitable for composting. It aims to design the end-of-life route for biodegradable plastic packaging by identifying the properties that influence recyclability in a closed-loop system, such as decontamination efficiency and structural stability (figure 1). In particular, the work presented here is focusing on the ability of certain biodegradable polyesters such as PLA, PBS and PBAT to be contaminated by the surrogate's panel identified for PET and referenced in FDA and EFSA regulations. The relationship between the polymer structures and their capacity for contamination was studied. In the future, a wider range of contaminants will be investigated.

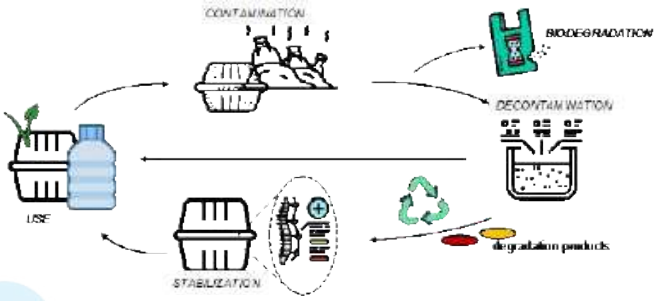

Figure 1: Recycling strategy scheme for a closed-loop system

References:

[1] Defruyt, S., 2019, (Special Issue 19), 78-81
[2] Aldas, M. *et al.*, 2021, Journal of Polymers and the Environment, 29:2686–2700

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TEC-OR-023

From biowaste to functional nanodevices: green design of colloidal carbon quantum dots with tunable physicochemical features for bio/chemo-sensing

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The expansion of industries like textile, food, cosmetics, and pharmaceuticals has led to the release of hazardous and persistent pollutants, including heavy metals[1], microorganisms (such as bacteria, fungi, and viruses)[2], and nano/microplastics[3], which are associated to serious risks for nature and humans. Similarly, monitoring the intricacies of cellular signalling pathways and networks is decisive to understand cellular regulation, homeostasis and progression of complex disease states related to many serious pathologies[4]. In this context, a growing request of rapid, highly sensitive, and precise sensing technologies able to detect and monitor chemical and/or biological analytes is attracting a great scientific interest to safeguard human health and environmental integrity. Colloidal quantum dots (QDs) present a promising alternative to conventional, expensive, and time-consuming methods[5]. Among them, carbon quantum dots (CQDs) offer distinct advantages due to their non-toxic nature, sustainability, biocompatibility, and versatile properties in terms of redox activity and photoluminescence[6].

Here, a waste-to-wealth approach was adopted to synthesize colloidal CQDs with enhanced photoactivity, photoluminescent and pro/anti-oxidant functionalities through a green hydrothermal route by using molecular precursors derived from different biowaste sources, such as humic substance (HS), lignin (LG), and coffee grounds (CG), and bi-distilled water serving as the solvent. The functional abilities of such CQDs were finely tailored based to the surface, structural, and optical characteristics directly influenced by the chemical composition of the biowaste feedstocks. Through a comprehensive physicochemical analysis based on cryo-TEM, dynamic light scattering (DLS), X-ray photoelectron (XPS), Fourier-transform infrared (FT-IR), UV-visible and photoluminescence (PL) spectroscopies, the formation of ultra-small QDs with an average diameter ranging from 2 to 4 nm was assessed, showing distinct atomic doping and surface defects that significantly influenced their redox behaviour and emission yield. Notably, CQDs derived from coffee grounds exhibited remarkable radical-scavenging properties and excellent colloidal stability. Also, fluorescence analysis was useful to monitor the optical ability of CQDs to detect metals in aqueous media. Finally, bioassays lead to evaluate the biocompatibility, cytoprotecting behaviour as well as cells internalization as function of chemical and physicochemical assets of CQDs, thus proposing them as multifunctional fluorescent nanodevices for probing different biological or chemical processes.

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Innovative clay based hybrid materials for thermochemical energy storage applications

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The capacity to decrease and reuse energy is pivotal for preserving the environment. Thermal energy storage (TES) systems are commonly employed for these purposes. Although sensible and latent heat storage technologies represent convenient alternatives, thermochemical materials (TCM) are the most interesting candidates for their high energy storage density. TCM usually exploit a reversible solid-vapour reaction in which the direct endothermic process represents the charge step, while with the subsequent reverse stage the heat stored is released.[1] Recently, hydrated organic salts such as Calcium Lactate pentahydrate (CL) have been suggested to overcome deliquescence issues in low temperature applications.[2] CL presents a large storage capacity (1127 J/g) and it is an environmentally safe material, however it exhibits a slow hydration kinetic.[3] The possibility of distributing CL onto the surface of a natural clay could promote not only hydration kinetics but also avoiding salt agglomeration during multiple dehydration/hydration cycles. In this work CL was impregnated with sepiolite at different load of salt respect clay (30-90 %wt.). The obtainment of a hybrid TCM/sepiolite material represents a novelty in the present literature. Complementary characterization techniques were used for studying the composite materials. The salt presence and its transition phase from dehydrated to hydrate in composite was investigated by X-Ray Diffraction. Infrared spectroscopy analyses show only the spectra of the constituent material. On a morphological point of view, micrographs obtained by scanning electron microscope show the formation of agglomerates where CL is uniformly distributed among sepiolite particles. Thermal analyses were carried out to investigate the water losses suffered by hybrid materials and the corresponding storage capacities. On the other hand, the water uptake was tested in both static and dynamic vapour conditions resulting in a clear enhancement of hydration kinetics and vapour sorption at higher mineral content. Considering the low cost of CL and the large natural reserve of sepiolite, in view of the preliminary studies carried out, the mineral results a valid support for hydrated salt loadings, promoting, therefore, the combination of both as a promising technology for TES applications.

References:

[1] R.-J. Clarke, A. Mehrabadi, M. Farid, Journal of Energy Storage 2020, 27, 101145 – 101162.
[2] E. Mastronardo, E. La Mazza, D. Palamara, E. Piperopoulos, D. Iannazzo, E. Proverbio, C. Milone, Energies 2022, 15, 4339 – 4351.
[3] Y. Sakata, S. Shiraishi, M. Otsuka, Colloids and Surfaces B: Biointerfaces 2005, 46, 135 – 141.

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Multifunctional Shape Memory Epoxy Nanocomposites Containing Carbon Dots

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Recent statistics have demonstrated that the direct reuse of polymeric wastes can be considered one of the most sustainable and advantageous approaches. However, many applications require the use of products with specific shape and geometry: in this context, thermosetting wastes may be very difficult to readapt for new uses. To overcome this challenging issue, the scientific literature has witnessed the potential of shape memory epoxy thermosets. The shape recovery can be triggered by various stimuli, including pH, heat, and electricity, though the most studied is the thermally-induced shape recovery. Shape memory epoxies are employed as components in the transportation industry, where the demand for transparent and fire-resistant coatings is enormously increasing. Mostly, the flame retardancy of such coatings is improved by the chemical modification of the polymer matrix, together with the use of specific flame retardants. Unfortunately, these approaches often lead to the loss of transparency and a detrimental effect on the overall mechanical performance of the final product.

In our work, we report the design and development of new multifunctional epoxy nanocomposites that exhibit photoluminescence, high hydrophobicity, fire resistance, and heat/flame-triggered shape recovery features [1]. It is worth noting that these all-in-one peculiarities can be achieved using very simple formulations, without using halogen- or phosphorus-based flame retardants, avoiding any specific modification of the polymer network, and employing carbon dots at very low loadings (namely, 0.1 and 0.3 wt.%). These latter are synthesized starting from vegetable wastes by a sustainable hydrothermal route, hence also fulfilling the circular economy concept [1].

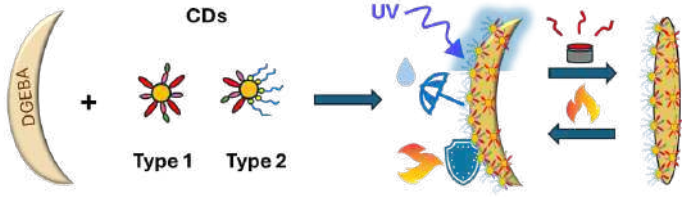

Figure 1: Synthesis strategy and functionalities of the multifunctional epoxy nanocomposites.

References:

[1] A. Bifulco, C. Imparato, I. Climaco, D. Battegazzore, M. Perrella, G. Vitiello, A. Aronne, G. Malucelli, Chemical Engineering Journal 2024, 484, 149327.

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TEC-OR-026

Sustainable valorisation of industrial black mass through circular solvometallurgy

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The extraction of Critical Raw Materials (CRMs) from exhausted Li-ion batteries (LIBs) represents a pivotal target for industry and academics. Once the electrodes are discarded and mechanically treated, a black powder called Black Mass (BM) is obtained. It is rich of valuable elements which can be extracted through different procedures, as hydro-, solvo-, and pyro-metallurgy which, however, suffer from low degree of sustainability and circularity.
In this context, a high sustainable solvometallurgy approach to treat different types of BM arising from lithium-cobalt oxides cathode (LCO) and nickel-cobalt-manganese oxides anode (NCM) was designed and tested. With the target of maximizing the extraction of CRMs while simultaneously minimizing environmental impact, three types of extractants were explored: water-, glycerol-, and eutectic-based systems.
Lithium recovery rate was assessed by a customized quantitative ^{7}Li NMR methodology, while the extraction of Co, Ni, Mn, and Al were determined by ICP analysis. Characterization of starting and treated BMs was conducted by powder x-ray spectroscopy and through SEM/EDS microscopy.
Excellent extraction rates were reached in different conditions and graphite recovery was also achieved by employing water or glycerol/water mixtures. Hydrophobic eutectic combinations of Free Fatty Acids (FFAs, hydrogen bond donors) and menthol (hydrogen bond acceptor) showed good selectivity toward some elements such as Al. The glycerol and the FFAs employed were derived rom the recycling of Used Vegetable Oils (UVOs) and subsequent hydrolysis, crosslinking two main value chains: exhausted LIBs and UVOs and thus increasing the overall sustainability of the processes.
Finally, green metrics (mass yield, mass productivity, E-factor, process mass intensity) and EcoScale were calculated for the best performing procedures.

Acknowledgements: Part of this study was carried out within the WORLD Project-RISE EU Horizon 2020 Grant Agreement No. 873005, and within the MICS (Made in Italy – Circular and Sustainable) Extended Partnership and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3 – D.D. 1551.11-10-2022, PE00000004).

References:

[1] J. Neumann et al., Adv. Energy Mater. 2022, 12, 2102917.
[2] A. Mannu et al., Processes 2020, 8, 3, 366.

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TEC-OR-027

$CaMnO_3$: a promising material for low temperature hydrogen storage

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To our days, the hydrogen storage, especially in the solid state, is a very interesting and challenging research topic. Hydrogen, in fact, is one of the most favourite candidates to replace fossil fuels, that are not sustainable and renewable energy sources.[1] This gas has a high energy density (of 120 MJ/kg = 33.33 kWh), and its only reaction product is H_2O. However, due to the extremely low density of hydrogen (0.089 kg/m^3) solid-state storage systems are one of the most viable solutions. Particularly, we are studying ABO_3 perovskite oxides, that have a high thermal stability, they are relatively active and they allow the exploitation of a great variety of elements in the composition while maintaining the basic structure unchanged.[2] We are focused on $CaMnO_3$ that is a promising material for hydrogen storage at low temperature. This perovskite oxide, whose constituent elements are earth-abundant and non-toxic, was synthesized by a modified Pechini method and characterized by X- ray diffraction (XRD), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX) microscopy analyses. Then the hydrogen storage capacity was tested as a function of pressure with a High Pressure Gas Sorption Analyzer volumetric system (i-Sorb, Anton Paar). Specifically, we are considering the storage capacity of this material up to 40 bar of H_2 at 100 °C. In these conditions $CaMnO_3$ shows a storage capacity of 0.02 wt% (0.89 kg/m^3). In order to improve the hydrogen sorption for this material, Pd^0 was added (1 wt%.), since it can help the hydrogen molecule dissociation into atoms and therefore promote its absorption. $CaMnO_3$/Pd 1%, in fact, in the same condition of pressure and temperature, has a hydrogen storage capacity equal to 0.86 wt% (38.70 kg/m^3). The sorption kinetics of this material was investigated considering different equilibration times (5, 60, 120 minutes, and until equilibrium condition is reached) for each adsorption step (from 0 up to 40 bar). The maximum adsorption recorded at 120 min of time limit is comparable with the longest equilibration time, indicating that 2h is an optimum compromise for the equilibration time for this hydrogen storage material. With respect to other materials, such as metal hydrides, despite a relatively lower gravimetric storage capacity but a comparable volumetric capacity, perovskite oxides enable the hydrogen storage at significantly lower temperature, namely 100 °C vs 300 °C required for hydrides. [3] Moreover $CaMnO_3$/Pd 1% can retain hydrogen even by decreasing pressure and release it when required at low temperatures. The evaluation of the storage kinetics model is ongoing.

References:

[1] J. O. Abe, A. P. I. Popoola, E. Ajenifuja, O. M. Popoola, International Journal of Hydrogen Energy 2019, 44, 15072-15086.

[2] S. M. A. A. Ibrahim, Korean J. Chem. Eng. 2014, 31, 1792-1797.

[3] N.Z.A.K. Khafidz, Z. Yaakob, K. L. Lim, S. N. Timmiati, International Journal of Hydrogen Energy 2016, 41b (30), 13131-13151.

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TEC-OR-028

Molecular Tweezer based on Zn(salen)-type complexes: role of spacer flexibility on aggregation and sensing properties towards biogenic amines

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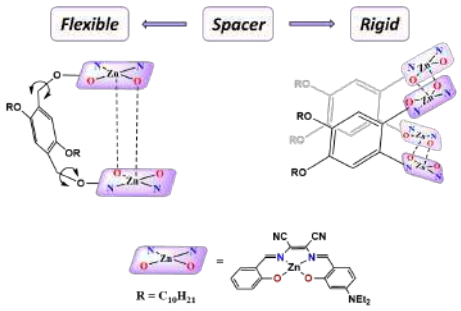
Biogenic amines (BA) are nitrogen Lewis bases formed by the decarboxylation of amino acids that represent a health hazard when they are formed in foods in inadequate hygienic and storage conditions.[1] For the latter reason, the development of chemosensors for the rapid and sensitive detection of BA plays a crucial role in the field of food safety.

Recently it was demonstrated that the dinuclear Zn(salen)-type complex **1**, having a flexible spacer, is a chromogenic and fluorogenic chemosensor for biogenic amines.[2] Considering that spacer flexibility could limit selectivity of the chemosensor,[3] here we present the synthesis and characterization of a new dinuclear Zn(salen)-type complex **2**, having a rigid spacer, in order to study the role of spacer flexibility on aggregation and sensing properties towards biogenic amines.



Through a combinate approach of ^{1}H NMR, ^{1}H DOSY NMR, UV-vis and fluorescence spectroscopy, we have demonstrated that complex **2**, forms dimeric aggregates via intermolecular Zn···O interactions in non-coordinating solvents unlike to complex **1** which, under the same conditions, is stable as intramolecular aggregate.[4] This different aggregation mode, which could be attributed to rigidity of the spacer, has a significant impact on sensing properties of complex **2**.

This work was supported by the University of Catania, PIACERI 2020/2022, Linee di Intervento 2 e 3, and partially funded by European Union (NextGeneration EU), through the MUR-PNRR project SAMOTHRACE (ECS00000022).

References:

[1] W. Wojciech, M. Łukasiewicz, K. Puppel, J. Sci. Food Agric, 2021, 101, 2634-2640.
[2] G. Munzi, S. Failla, S. Di Bella, Analyst, 2021, 146, 2144-2151.
[3] J. Leblond, A. Petitjean, ChemPhysChem 2011, 12, 1043 – 1051.
[4] G. Consiglio, I.P. Oliveri, S. Cacciola, G. Maccarone, S. Failla, S. Di Bella, Dalton Trans., 2020, 49, 5121-5133.

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TEC-OR-029

Monitoring of contaminants in irrigation water by electrochemical sensors

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In recent years, water quality conservation has emerged as a critical global concern due to the growing threat posed by heavy metal contamination, which impacts both agricultural ecosystems and public health. Among these pollutants, arsenic is a potent and dangerous toxic element that is widely present in natural watersheds, especially in regions that rely on groundwater sources for consumption.[1] Traditional monitoring methods are often insufficient in terms of sensitivity, selectivity and environmental sustainability. This study employs an innovative approach using electrochemical sensors with bacterial polysaccharides.[2,3] These modifications are designed to optimise the sensors' ability to selectively bind to heavy metal ions, thereby amplifying their sensitivity. The ecological nature of polysaccharides aligns with the overall goal of sustainable and environmentally friendly sensing technologies. Preliminary electrochemical results, performed at pH 7.4 using As^{3+} concentrations in the nanomolar range, are promising and indicate improved detection limits and selectivity compared to conventional sensor configurations. The incorporation of natural polysaccharides not only improves the analytical capabilities of sensors, but also contributes to reducing the environmental footprint associated with sensing technologies.

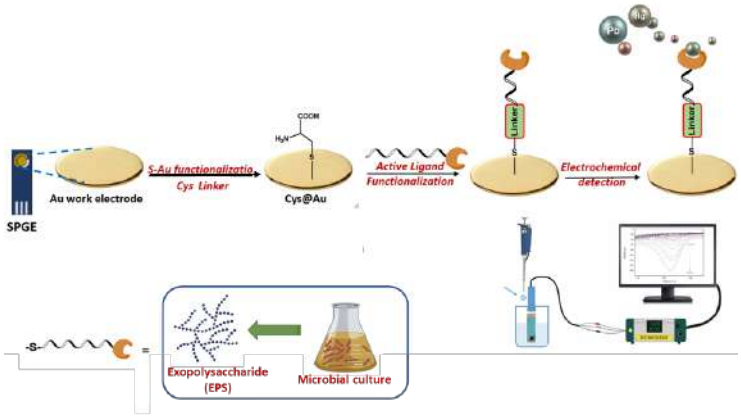

Figure 1: Monitoring of heavy metals in irrigation water by electrochemical sensors.

References:

[1] A. Spanò et al., *J. Mar. Sci. Eng.*, **2023**, 11, 325.
[2] V. Zammuto et al., *Microorganisms* **2023**, 11, 1842
[3] M.T. Caccamo et al., *Materials* **2022**, 15, 5988

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TEC-OR-030

Recovery of strategic metals from NCM-lithium battery black mass through a microwave hybrid heating process

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The energetic transition to electric power, needed to reduce CO_2 emissions, has driven a rapid expansion of the new global electric vehicle (EV) industry in recent years. It is estimated that by the year 2030, the worldwide EV population will reach 140 million, leading, in the next future, to the disposal of approximately 11 million tons of depleted batteries[1]. NCM-lithium batteries are the most used in the automotive industry. They are mainly composed by nickel, cobalt, manganese and lithium, inserted in the list of critical raw materials (CRMs). The recovery of these strategic materials becomes imperative pursuing solutions with low environmental impact. This work proposes a hybrid heating process based on microwaves[2] that, in few minutes, allows to reach temperature higher than 650 °C in a patented equipment. The thermal treatment promotes the formation of Li_2O, soluble in water, and increases the solubility of Co, Mn, Ni that can be recovered by a weak acid leaching.

References:

[1] D.L. Thompson, J.M. Hartley, S.M. Lambert, M. Shiref, G.D.J. Harper, E. Kendrick, P. Anderson, K.S. Ryder, L. Gaines, A.P. Abbott, Green Chemistry 2020, 22, 7585–7603.

[2] M. Scaglia, A. Cornelio, A. Zanoletti, D. La Corte, G. Biava, I. Alessandri, A. Forestan, C. Alba, L.E. Depero, E. Bontempi, Batteries 2023, 9, 536.

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TEC-OR-031

Rosin-modified titanium oxide active in radical-mediated degradation of microplastics under ambient conditions

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Advanced oxidation processes are potentially effective solutions for water remediation and wastewater treatment by means of reactive oxygen species (ROS). ROS can be produced at metal oxide surfaces either through photocatalysis (light irradiation), upon energy-intensive pre-treatments, or in the presence of a radical source. Recently, this research group discovered that hybrid materials based on TiO_2 or ZrO_2 with specific organic ligands can spontaneously generate and preserve superoxide radicals ($O_2^{\bullet-}$) on their surface owing to the ligand-to-metal charge transfer complexes.[1] The consequent oxidative ability of these materials enables the degradation of various organic pollutants in water without any illumination.[1,2] Moreover, the visible light absorption of TiO_2-β-diketone hybrids allows increasing the reaction rate under sunlight.[2]

In the search for a suitable biowaste organic ligand, we found that rosin, a derivative of pine resin mainly composed of abietic acid, can be directly used in the sol-gel synthesis of redox-active hybrid TiO_2 (T-Abi, see Figure 1). This was assessed by XPS, FTIR and EPR spectroscopy.[3] Due to the growing concern for the spread of microplastics in the environment, this material was tested to treat LLDPE samples in aqueous suspension under indirect daylight at room temperature. Chemical alterations of the polymer were observed, as confirmed by the detection of degradation products by GC-MS.[3] These results open to the potential application of T-Abi in the chemical recycling of plastic waste, in addition to other ROS-related processes.

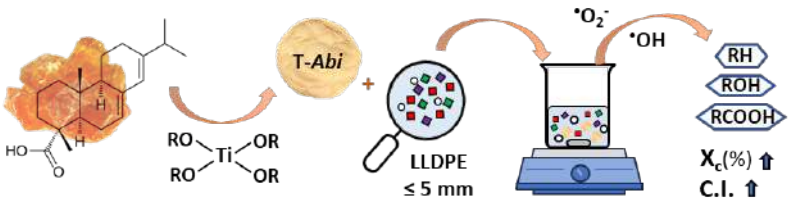

Figure 1: Scheme of the synthesis of TiO_2-rosin (T-Abi) and its use in LLDPE degradation tests.

References:

[1] D. Pirozzi, C. Imparato, G. D'Errico, G. Vitiello, A. Aronne, F. Sannino, *J. Hazard. Mater.* 2020, 387, 121716.
[2] C. Imparato, M.M. Bonifazzi, G. D'Errico, et al., *Colloids Surf. A Physicochem. Eng. Asp*. 2024, 684, 133148.
[3] P. Amato, M. Fantauzzi, F. Sannino, et al., *J. Hazard. Mater.* 2024, 463, 132907.

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TEC-OR-032

Catechol as Sensitizer for Visible Light Absorbance Enhancement of TiO_2 Nanorods

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Titanium dioxide stands out as a highly interesting photocatalysts due to its low cost and toxicity; however, a notable obstacle must be overcome for its practical applications. Commercial TiO_2 nanoparticles (e.g. P25) have a band gap energy of 3.2 eV resulting predominantly UV-photoactive. This limitation hinders the full harnessing of solar power. To circumvent this problem, it is possible to functionalize this inorganic material with an organic charge transfer sensitizer. In this framework, catechol is a small and simple molecule that can easily and stably bind the surface of TiO_2, reducing the band gap.[1,2] In this study, we adopted this strategy to functionalize the surface of TiO_2 nanorods (NR), a peculiar nanostructured titania that, due to its pronounced dimensional anisotropy, exhibits a better delocalization of the photoinduced charge carriers with respect to their sphere-like counterpart.[3,4] Therefore, oleic acid capped TiO_2 anatase nanorods (NR) were synthesized[4] and a partial ligand substitution was conducted to bind catechol on their surface to act as sensitizer (NR-Cat). The success of the functionalization procedure was testified by diffuse reflectance spectroscopy (DRS, fig.1) as well as thermogravimetric analysis, X-ray photoelectron spectroscopy and ^{1}H-NMR spectroscopy. While the as-synthesised NRs show an optical band gap of 2.75 eV, the binding of catechol on the surface of the rods caused a further remarkable red-shift of the absorbance and a band gap of 1.72 eV. This study reports novel findings on the catechol functionalization of TiO_2 nanorods specifically designed for photocatalytic processes that would greatly benefit from activity in the visible range, from contaminants degradation to hydrogen evolution processes. This work is part of the NEST-Network 4 Energy Sustainable Transition project (PE0000021–Next Generation EU).

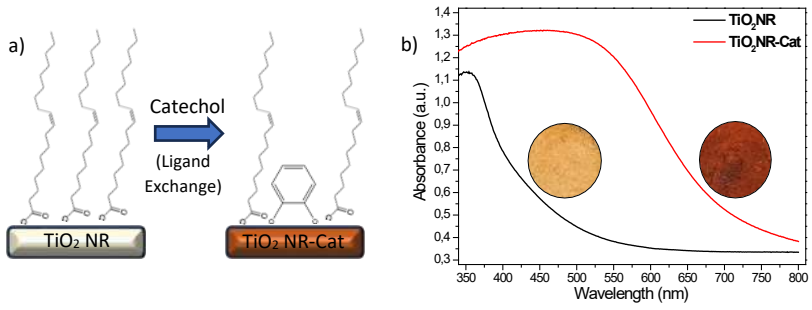

Figure 1: a) Scheme of the TiO_2 nanorods functionalization step, b) corresponding UV-Vis DRS spectra.

References:

[1] K.L. Orchard, D. Hojo, T. Adschiri, E. Reisner, et al., Chem. Commun. 2017, 53, 12638-12640.
[2] E. Schechtel, R. Dören, H. Frerichs, M. Panthöfer, M. Mondeshki, W. Tremel, Langmuir 2019, 35, 12518−12531.
[3] H.J. Yun, H. Lee, J.B. Joo, W. Kim, J. Yi, J. Phys. Chem. C 2009, 113, 3050–3055.
[4] P.D. Cozzoli, A. Kornowski, H. Weller, J. Am. Chem. Soc. 2003, 125, 14539-14548.

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TEC-OR-033

Deep Eutectic Solvents for HMF valorization

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The development of sustainable and efficient processes for biomass exploitation represents a primary target both in industrial and academic research. In particular, hydroxy methylfurfural (HMF) has gained increasing attention as it is a valuable synthon for many chemicals.[1-3] New and sustainable chemical routes can be achieved by using alternative reaction systems as selected mixtures of Hydrogen Bond Donors and Acceptors (HBDs, HBAs). In this context, HMF interaction with selected type V Deep Eutectic Solvents (DESs) has been assessed by multinuclear NMR, FTIR and Raman spectroscopy. Based on previous HMF-DES systems scouting, HMF reactivity in the most promising DESs has been studied (**Figure 1**).

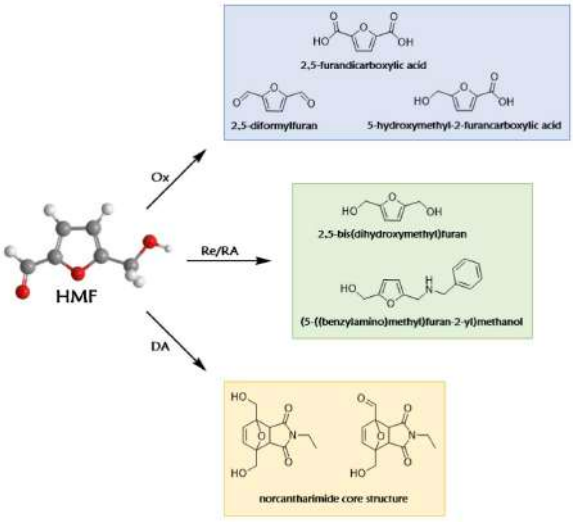

Figure 1: Proposed HMF transformation in DES.

Finally, green metrics such as atom economy, solvent recycling, environmental factor and EcoScale have been calculated for the most relevant scenarios.

Acknowledgement: The SEED4GREEN project has been funded by European Union – Next Generation EU in the framework of the PRIN 2022 (project SEED4GREEN - Code 20223W4RT9).

References:

[1] Nolan M. D., Mezzetta A., Guazzelli L., Scanlan E. M., Green Chemistry, 2022, 24, 1456-1462.
[2] Arnaboldi S., Mezzetta A., Grecchi S., Longhi M., Emanuele E., Rizzo S., Arduini F., Micheli L., Guazzelli L., Mussini P. Electrochimica Acta, 2021, 380, 138-189
[3] Iris K.M. Yu, Daniel C.W. Tsang, Biosourced Technology, 2017, 238, 716-732

TEC-OR-034

Spectroscopic fingerprinting for early detection of *Xylella fastidiosa* infection and insights into the resistance mechanisms

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Xylella fastidiosa (*Xf*) has been extensively documented as a quarantine pathogen threatening important crops and natural species in the Americas. The outbreak discovered in 2013 in Salento has raised major concerns, being the bacterium associated with a deadly and rapidly spreading disease: the quick decline olive syndrome (OQDS). Considering the complexity of this phytosystem and the heavy economic impact, it is a matter of urgency to understand the host-pathogen interaction in a way to *i*. identify a containment solution; *ii*. understand the base of the immunity-resistance-susceptibility behavior of different species to *Xf* infection.

Plant metabolomics represents a useful approach to acquiring information on the composition of a metabolite pool in plants. Metabolomic regulation in plants is often affected by biotic and abiotic stresses. Thus, unveiling variations in the metabolite composition can help to understand plant adaptation, acclimation, and defense responses to environmental stresses. Thus, metabolomics can help both in detecting plant desease at an early stage and in understanding the determinants of host-specificity, namely the reason at the base of the incompatibility between a plant species with a given bacterial strain (i.e. immunity), or, conversely, which are the interactions that, for the same plant species, result in a successful host colonization (susceptibility) by a different Xf strain. Resistance consists of the intermediate scenario between immunity and susceptibility. The crop species characterized by this phenotype are of particular interest, since their study can help in discovering new strategy of management of Xf diseases.

In the present communication, an overview of the projects currently in progress in our lab will be described focusing on the hetero-spectral non-targeted approach for the early detection of the Xf infection and on the combination of NMR-based metabolomics and in vitro study to unravel biological features of Xf subspecies pauca ST53 in immune, resistant and susceptible crop species. Both the research pipelines are aimed at intercepting the infections before the bacterium gets established and colonizes a new environment.

References:

[1] A. Jlilat, R. Ragone, S. Gualano, F. Santoro, V. Gallo, L. Varvaro, P. Mastrorilli, M. Saponari, F. Nigro, A.M. D'Onghia, Sci. Rep. 2021, 11, 1070.
[2] E. Ahmed, B. Musio, S. Todisco, P. Mastrorilli, V Gallo, M. Saponari, F. Nigro, S. Gualano, F. Santoro, Molecules 2023, 28, 7512.
[3] A. Surano, C. del Grosso, B. Musio, S. Todisco, A. Giampetruzzi, G. Altamura, M. Saponari, V. Gallo, P. Mastrorilli, D. Boscia, P. Saldarelli, Front. Plant Sci. 2024, 14, 1343876.

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A virtuous cycle of wastes: iron oxides supported on steel slags as catalyst for the hydrogenation of nitroarenes

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Nitroarenes are a class of environmental pollutants generated by various industrial processes such as dye and pharmaceutical production. This harmful waste can be possibly valorised by reducing the nitro group to amine to obtain substituted anilines, which are highly valuable chemical intermediates[1,2].
This presentation deals with the reduction reaction of nitroarenes employing hydrazine monohydrate as reducing agent and modified steel slags as a novel heterogenous catalyst prepared by treating steel slags with iron (II and/or III) salts.
Steel slag is a waste product from steelmaking industry, which represents an interesting support for the catalytically active iron species. Indeed, because of their basicity, ensured by the presence of calcium hydroxide and calcium carbonate, it was possible to deposit iron oxides/hydroxides on the surface of the support by easy precipitation.
A systematic study was carried out comparing the catalytic activity of steel slags modified with the following salts (or mixtures): $FeCl_3$, $FeSO_4$, $FeCl_3$ + $FeSO_4$ in various proportions, $FeCl_2$.
The modified steel slags were characterized by X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDX) and X-ray Photoelectron Spectroscopy (XPS).
All iron-charged steel slags revealed active in the hydrogenation of nitrobenzene at 80 °C with the best results, in terms of activity, selectivity and recyclability achieved with the precatalyst loaded with Fe(III), for which the scope of the reaction was also explored.

Acknowledgements: This work has been supported under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 – Call for tender No. 3138 of December 16, 2021 of the Italian Ministry of University and Research, funded by the European Union – NextGenerationEU [Award Number: CNMS named MOST, Concession Decree No. 1033 of June 17, 2022, adopted by the Italian Ministery of University and Research, CUP: D93C22000410001, Spoke 14 "Hydrogen and New Fuels"].

References:

[1] D. Formenti, F. Ferretti, F. Korbinian Scharnagl, M. Beller, Chem. Rev. 2019, 119, 4, 2611–2680.
[2] V. Petrelli, G. Romanazzi, C. Mortalo, C. Leonelli, M. Zapparoli, E. De Giglio, C. D. Calvano, M. M. Dell'Anna, P. Mastrorilli, Molecular Catalysis 2023, 544, 113050, 1 – 20.

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TEC-PO-001

Dry Reforming of Methane of recycled platinum on CeO_2

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Due to the continuous emissions of greenhouse gases (GHG) in the atmosphere because of anthropogenic activities, it is very important to reduce their concentration using several approaches. One of the best ways is to use the dry reforming of methane (DRM) reaction that consumes GHG to obtain syngas, a mixture of H_2 and CO. DRM is promoted using catalysts, often based on Pt or other critical raw materials (CRMs) for EU[1]. To face CRM issue, we fabricated Pt/CeO_2 catalysts with 2%wt of Pt by direct impregnation of the CeO_2 support with the leachate HCl based solution of Spent Automotive Diesel Oxidation Catalysts submitted to a mild hydrometallurgical recycling process, without purification of the leachate solution[2], which contains H_2PtCl_6 complexes as Pt precursors. A synthetic leachate Pt/CeO_2 solution was also prepared for comparison. CeO_2 has been chosen because of its widely accepted positive influence on the conversion of the products[3]. The results obtained from the catalytic tests were very encouraging, as shown in Fig.1, where the conversions of CO_2 and CH_4 are reported for the Pt/CeO_2 catalysts obtained from commercial Pt precursors. The ratio of H_2/CO was 0,9 at T=850 °C. Lower conversion efficiency was found in case of the real leachate solution. Catalysts were characterised by TPR, TGA, XRF, XRD, SEM and Raman Spectroscopy.

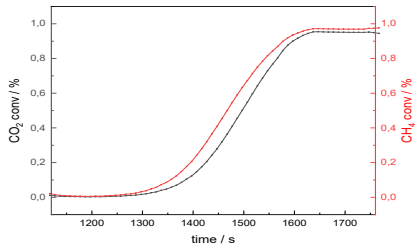

Figure 1: conversions of CO_2 and CH_4.

References:

[1] ML Grilli, et. al, Crystals 2023, 13 (4), 550-580.
[2] Z. Du, et al., Journal of Physical Chemistry C 2021,125, 18684–18692.
[3] I. Yakoumis, et al., J. Sustain. Metall. 2020, 6, 259-268.

TEC-PO-002

Liposomal Nanoplatforms for Targeted Drug Delivery and Diagnostics

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Liposomes, phospholipid-based nanocarriers, have become integral components of nanomedicine, offering a versatile platform for targeted drug delivery and imaging applications. These nanoparticles can be considered an ideal candidate to obtain a robust versatile and biocompatible nanoplatform that can be exploited for a variety of applications and targets, thanks to their biocompatibility and functionalization strategies[1].

With this in mind, we've been developing different liposome-decorated systems in which a biomarker-specific macromolecule is properly attached to the lipidic nanoparticle. This is feasible through a variety of functionalization techniques, resulting in a nanoplatform that may be customized with macromolecules of interest, being antibodies, peptides etc.

Our research has mostly focused on the use of target-specific peptides, that show fewer side effects than other biomolecules. These can selectively bind to the target, allowing the liposome to exploit its purpose, which is either to release a drug at its site of action if used as a drug delivery system or to detect the presence of its target in a sample if used as a diagnostic tool. Specifically, we have been working on the design and engineering of liposomes functionalized with epitopes specific for CD38 receptor involved in multiple myeloma[2].

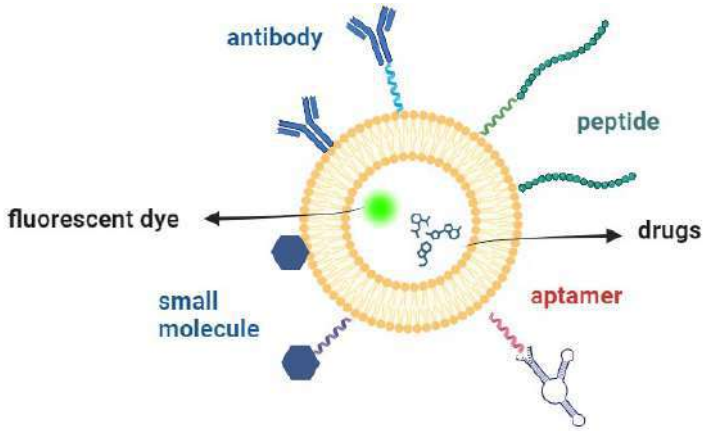

Figure 1: possible strategies for the engineering of liposomes.

References:

[1] H. Nsairat, D. Khater, Heliyon 2022, e09394.
[2] D. T. Omstead, F. Meija, J Hematol Oncol 2021, 13, 145.

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TEC-PO-003

Carbon nanotubes as advanced catalysts and catalytic supports in hydrocarbon oxidation processes

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Carbon nanotubes (CNTs) have gained substantial importance in catalysis due to their unprecedented properties[1]. Functionalization of CNTs is another advantageous approach for modifying the interaction between the support, catalyst, and guest molecules[2]. In this study, carboxylated MWCNTs were functionalized with copper(II) ions (MWCNT-COO-Cu) and then coated with dissolved *N*-hydroxyphthalimide (NHPI) in an ionic liquid (IL) ([emim][$OcOSO_3$]). The resultant catalytic system represented both the SCILL (solid catalyst with an ionic liquid layer) and SILP (supported ionic liquid phase) systems; therefore, it was identified as a novel SCILL-SILP hybrid catalytic system (Figure 1). The catalysts were evaluated for solvent-free oxidation of ethylbenzene using molecular oxygen as a greener oxidant. The recyclability and reusability of the MWCNT-COO-Cu and the SCILL-SILP hybrid catalytic system were thoroughly investigated[3]. In the subsequent study, novel SILP and SCILL-SILP hybrid catalytic systems were synthesized by coating NHPI dissolved in various ILs onto MWCNTs and MWCNT-COO-Cu, respectively. The effect of lipophilicity of ILs on the catalytic activities of the SILP systems was investigated. Furthermore, the recyclability and reusability of the catalytic systems were thoroughly investigated.

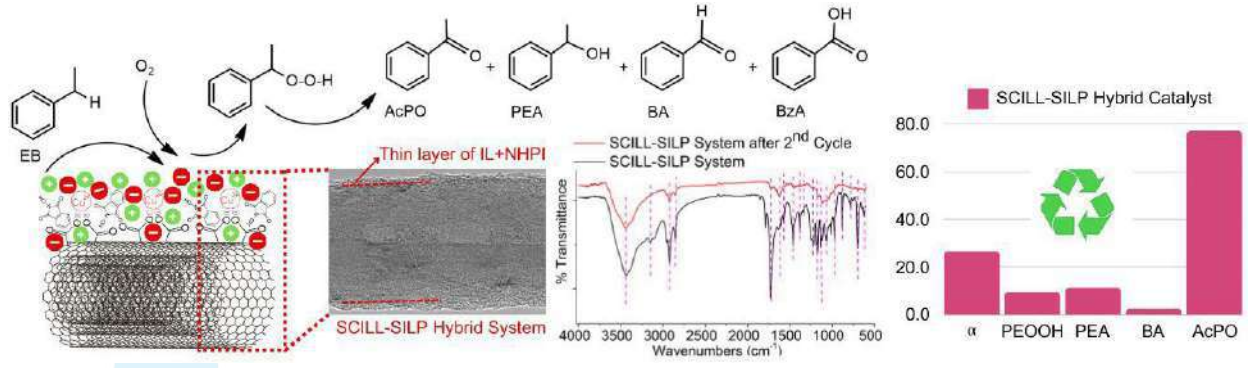

Figure 1: SCILL-SILP hybrid catalytic system for the aerobic oxidation of ethylbenzene.

References:

[1] S.U. Azam, B. Orlińska, Applied Catalysis A: General 2023, 668, 119465.
[2] S. Rathinavel, K. Priyadharshini, D. Panda, Materials Science and Engineering: B 2021, 268, 115095.
[3] S.U. Azam, K. Peckh, B. Orlińska, Chemical Engineering Journal 2023, 457, 141207.

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TEC-PO-004

Light-breakable mesoporous silica coated upconverting NPs for NIR-triggered drug release

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Light, especially near-infrared (NIR) radiation, offers a non-invasive method with high spatiotemporal resolution for triggering drug delivery, facing challenges such as carcinogenic risks and limited tissue penetration of UV light. Lanthanide-doped upconverting nanoparticles (UCNPs) provide a solution by converting NIR to UV light. Despite promising, their low upconversion quantum yield necessitates high laser powers and prolonged irradiation, posing overheating risks to tissues. To overcome this, strategies like core surface passivation and coating UCNPs with photolabile drug carriers (either mesoporous silica (UCNP-MS) or polymeric coatings) have been adopted. UCNP-MS, emerging as a robust carrier, still faces challenges like high power and long exposure times for drug release. Unlike unchanged UCNP-MS systems during drug release, polymer-coated UCNPs with UV-breakable bonds disintegrate structurally, enabling drug release for only hydrophilic molecules. This study introduces UCNPs encapsulated with a thin, UV-breakable MS shell, merging MS's scalability with an efficient drug release mechanism of a thin breakable coating.

More in detail, we present the one-step synthesis of a nanocomposite consisting of $LiYbF_4:Tm^{3+}@LiYF_4$ UCNP coated with an UV-sensitive mesoporous organosilica shell. We demonstrate that a thin shell can be easily broken under NIR light exposure at 1 W/cm^2, significantly lower than traditional systems. Loading the mesopores with the hydrophobic vitamin D3 precursor, 7-dehydrocholesterol (7-DH), results in the release of contents upon shell breakage. Vitality tests on HeLa cells confirm the nanoparticles' safety. Their internalization is assessed by conventional confocal and non-linear optical microscopy via up-conversion luminescent emission, in which the sequential absorption of two or more low-energy photons in the infrared promotes the absorption into a high-energy state, enabling a correct drug delivery. The system's tunability, enabled by its simple synthesis and low-power operation, opens new avenues for NIR-triggered drug release via UCNP, making it a scalable, flexible, and translational option.

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TEC-PO-005

Development of sensors for halogenated pollutants

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Access to clean and safe drinking water is essential for human health and well-being, but it is increasingly threatened by the presence of various contaminants, such as iodine. Iodine is a common disinfectant used in water treatment, but it can also cause adverse health effects, such as thyroid dysfunction, at high concentrations[1]. Therefore, the development of sensitive and selective sensors for the detection of iodine in water is of great importance for ensuring the safety and quality of drinking water.

Hexamethonium salts have emerged as promising porous materials for iodine capture due to their unique properties, such as high surface area, structural flexibility and chemical selectivity (Figure 1)[2,3].

The work has been organized in several key steps, including the synthesis and characterization of hexamethonium-based sensing layers, the development and optimization of the sensor design and fabrication process, and finally the testing and validation of the sensors with real water samples. Overall, the successful optimization of these sensors could have significant implications for water quality monitoring and public health, and could lead to new technologies for water treatment and purification.

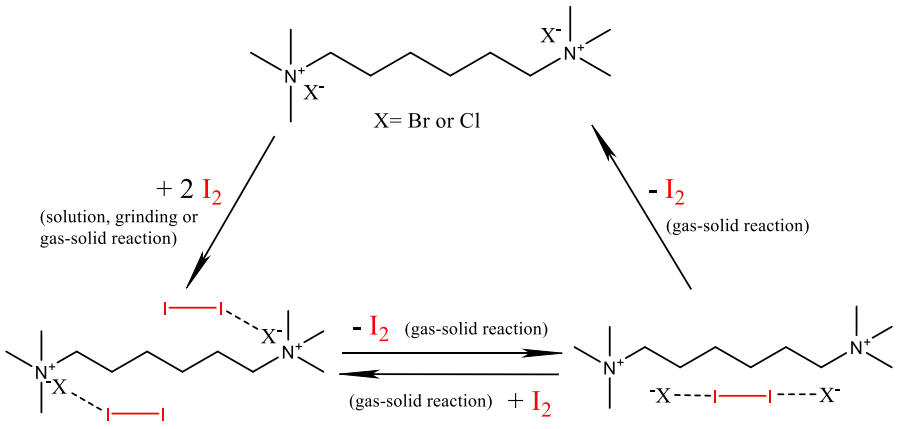

Figure 1: Synthesis of tetrahalide dianions by thermally induced deiodination reactions of the bis(I_2) adducts and other interconversion reactions involving hexamethonium halides.

References:

[1] A. M. Leung, L. E. Braverman, Consequences of excess iodine; Nature Reviews Endocrinology, 2014, 10, 136-142.
[2] A. Abate, P. Metrangolo, et al., Dimensional encapsulation of iodine in an organic salt crystal matrix; Chem. Commun., 2010, 46, 2724-2726.
[3] P. Metrangolo, G. Resnati, An adaptable and dynamically porous Organic Salt Traps unique Tetrahalide Dianions; Angew. Chem. Int. Ed., 2013, 52, 13444 –13448.

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TEC-PO-006

Bio-Extracted Feather Keratin-based Functional Materials

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In 2019, global poultry meat production reached 130 million tons, with Europe contributing 13.4 million tons annually, resulting in 3.1 million tons of feather waste.[1] Despite this abundance, the current recovery of valuable raw materials, particularly keratin, from feathers remains minimal. Existing technologies repurpose only a fraction of feathers, mainly as low-nutrient animal feed or organic fertilizers, while the majority is incinerated or landfilled. This not only represents a loss of a renewable resource but also poses environmental and health risks.[2]

Implementing eco-friendly approaches to managing feather waste could mitigate biological hazards and enable the valorization of keratin-based materials. These materials have shown potential in various high-end applications, including biomedical ones, offering a sustainable alternative to conventional resources.[3,4] As part of the KARATE project, we developed new technologies for converting waste feather fractions into high-value materials aligning with a circular economy approach. Our primary objective is to reduce the environmental impact of the poultry supply chain, while driving innovation. Specifically, we isolated a novel microbial strain capable to efficiently degrade feather wastes to extract keratin enzymatically. The resulting peptide and protein samples were fully characterized, with a particular emphasis on their self-assembly properties. These samples were subsequently engineered to create innovative keratin-based materials with substantial added value.

Figure 1: Illustration of keratin enzymatic extraction from feather waste and keratin-based materials production.

References:

[1] Poultry, EU. https://agriculture.ec.europa.eu/farming/animal-products/poultry_en
[2] A.A. El-Gindy, Z.M. Ibrahim, H.M. Aziz, H.I. Mohamed, Biocatal. Agric. Biotechnol. 2023, 53, 102883.
[3] A. Shavandi, T.H. Silva, A.A. Bekhit, A.E.A. Bekhit, Biomater. Sci. 2017, 5, 1699-1735.
[4] J. Sun, G.M. Santiago, F. Yan, W. Zhou, P. Rudolf, G. Portale, M. Kamperman, ACS Sust. Chem. Eng. 2023, 11, 1985−1994.

Acknowledgements: Fondazione Cariplo is gratefully acknowledged for funding the KARATE project (2022-0437).

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TEC-PO-007

Fluorinated lipids for development of gene delivery carriers

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RNA based therapies have gained strong interest for the treatment of various diseases, but their in vivo applications require delivery systems to prevent the degradation of the nucleic acid (NA), facilitate cellular uptake and enable NAs release. Lipid nanoparticles (LNPs) have already been used in the clinic to deliver NAs as vaccines against SARS-CoV-2 and treatment for polyneuropathy.[1] Aiming to enhance LNPs efficiency as NA carriers, we developed fluorinated ionizable lipids, which will be used for the preparation of LNPs to promote encapsulation of NAs, improve interaction with cellular membranes and encourage intracellular NA release.[2] Furthermore, the inclusion of a fluorinated tag makes the obtained LNPs active in ^{19}F-MRI, hence potentially traceable in vivo.[3] Here we will describe the synthesis and characterization of two distinct ionizable lipids with different polar heads, focusing on their behavior in physiological conditions with regard to self-assembly and their impact on LNPs structure.

References:

[1] X. Hou, T. Zaks, R. Langer and Y. Dong, Nat. Rev. Mater. 2021, 6, 1078-1094
[2] J. Lv, H.Wang, G. Rong and Y. Cheng, Acc. Chem. Res. 2022, 55, 722-733
[3] B. L. Bona, O. Koshkina, C. Chirizzi, V. Dichiarante, P. Metrangolo and F. Baldelli Bombelli, Acc. Mater. Res. 2023, 4, 71-85

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TEC-PO-008

Eco-design of cellulose nanocrystal through ESCAPE method at lab-scale

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Sustainability is becoming more and more the compass to drive the design of materials and processes. From this perspective, cellulose can be considered a sustainable natural source for the development of innovative materials due to its renewability, biodegradability, and interesting mechanical properties. Moreover, the possibility to cleave its hierarchical structure opens the way to the production of nanocellulose. Cellulose nanocrystals (CNC) find applications in different fields, such as packaging, cosmetics, energy storage and nanocomposites production.[1] However, synthetic procedures could be impactful in terms of energy demand.

Herein, CNC were obtained through two processes, the first one based on the standard and widely used H_2SO_4-treatment[1], the second following a claimed "greener" process which foresees the use of the oxalic acid/choline chloride deep eutectic solvent (DES)[2]. For each process, CNC were produced and characterized.

The sustainability of both lab-scale processes was assessed using the "ESCAPE"[3] tool. The sustainability was evaluated in terms of embodied energy (EE) and carbon footprint (CF), keeping track of the local energy mix and comparing it to foreign energy mixes. The DES-based production was found to be more sustainable, primarily due to its lower purification time and higher mass recovery. These results allowed for the identification of the most impactful steps in the synthesis process, particularly the purification step and water usage. Consequently, targeted improvements in these steps allowed to reduce the overall environmental impact without affecting the morphology of final products.

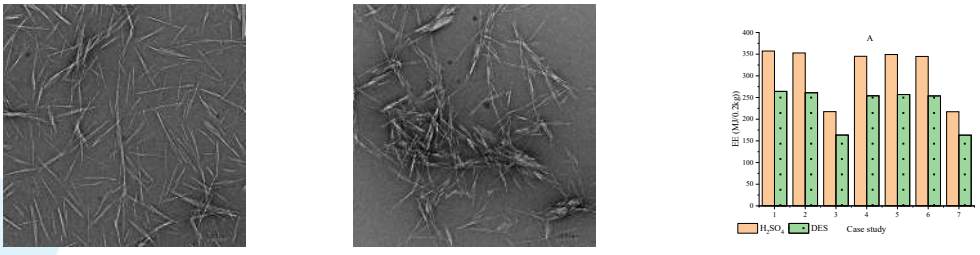

Figure 1: TEM of CNC-H_2SO_4 (left), CNC-DES (centre), total EE of CNC production (right)

[1] Habibi, Y. et al., *Chem. Rev.,* **2010**, *110* (6), 3479–3500
[2] Douard, L. et al., *ACS Sustain. Chem. Eng.,* **2022**, *10* (39), 13017–13025
[3] Ducoli, S. et al., *Sustain. Mater. Technol.,* **2023**, *38* (September)

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TEC-PO-009

Barrier properties of cellulose nanofibers-based coating agents in paper industry

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Nowadays, packaging materials are mostly based on fossil-derived products which, differently from paper, are characterized by high barrier properties against water, water vapour, oxygen and oil. However, the non-biodegradability of petroleum-based materials has given rise to environmental concerns, promoting the development of cellulose-based materials. Cellulose is the most abundant biopolymer on Earth, which has a wide range of applications thanks to its renewability, non-toxicity and biodegradability.[1] Moreover, the hierarchical structure of this polymer allows the extraction of nanoscale constituents combining an enzymatic or chemical pre-treatment with a mechanical treatment, such as homogenization or ultrasonication.[2,3] In the last decade, nanocellulose has become one of the emerging sustainable materials that can be employed in packaging industry. Indeed, the ability to form a dense network of hydrogen bonds allows nanocellulose to be a potential coating agent able to enhance barrier properties of paper. Furthermore, due to the presence of a large number of hydroxyl groups, nanocellulose can be functionalized, giving the possibility to tune its hydrophilic nature.[1] 2,2,6,6-tetramethylpiperidine-1-oxyl (TEMPO)-mediated oxidation is the most commonly applied chemical treatment which leads to the regioselective conversion of C6 primary hydroxyls to carboxylic groups.[3] On the other hand, enzymatic hydrolysis of cellulose, conducted with endoglucanase, is used to obtain nanofibers bearing hydroxyl groups on C6.[2]

The aim of this work is to compare barrier properties of different nanocellulose-based coating agents. The formulation of coating dispersions varies in different factors: pre-treatment, concentration, pH, degree of oxidation of TOCNF and number of cycles of homogenization. The effect of cross-linking agents and functionalization with lipophilic moieties were also investigated. The application mode used was the spray coating. Barrier properties against oils and water were examined *via* KIT test and $COBB_{60}$ test, respectively and the results obtained, notably in oil resistance properties, are promising.

a) b)

Figure 1: a) Non-coated and coated paper; b) $COBB_{60}$ test on coated paper

References:

[1] A. Ferrer, L. Pal, M. Hubbe, 2017, *95*, 574 – 582.
[2] P. G. Stampino, L. Riva *et al.*, 2021, *26*, 2558 – 2578
[3] A. Isogai, T. Saito, H. Fukuzumi, 2011, *3*, 71 – 85.

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TEC-PO-010

A branched fluorinated dendrimer as microRNA carrier in amyotrophic lateral sclerosis murine *in vitro* models

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In recent years, gene therapy has emerged as a promising approach for the treatment of motorneuron diseases, such as amyotrophic lateral sclerosis (ALS), a fatal neurodegenerative disease characterized by motor neuron loss associated with muscle atrophy[1].

microRNAs (miRNAs) are small non-coding RNAs that modulate gene expression and they are key molecules in the onset of muscle atrophy[2]. Yet, the delivery of Nucleic Acids (NAs) inside the cell is a challenging task. Cationic lipids and polymers, particularly cationic dendrimers, have shown to be promising as gene delivery vectors due to their ability to complex NAs and protect them from degradation. In this context, some of us have recently developed FJD_2N, a novel gene delivery vector based on a fluorinated Janus-type dendrimer[3] bearing four terminal ammonium groups. This molecule is able to self-assemble in aqueous solution forming positively charged micelles that are able to interact with the negatively charged phosphate groups of NAs forming dendriplexes[4]. This carrier was tested on cells derived from G93A-SOD1 mice, a purported model of ALS. Immunofluorescence and molecular analysis displayed a good carrier cellular internalization, no cytotoxic effects on proliferation, as showed by caspase expression levels and a significant modulation of the selected miRNA on the target genes implicated in cell regeneration.

Based on these results, this new vector appears to be a promising carrier for gene delivery applications but further *in vitro* tests on a larger scale are needed to ultimately understand its complete functioning.

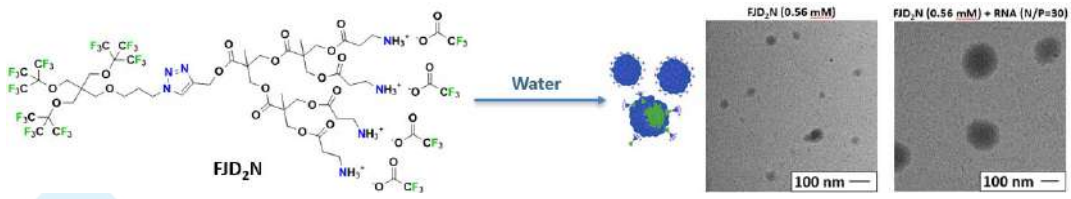

Figure 1: Chemical structure of FJD_2N and self-assembly behaviour in water. Images collected via cryoTEM analysis[4].

References:

[1] S. Marcuzzo *et al.*, *Exp Neurol*, vol. 231, no. 1, pp. 30–37, Sep. 2011
[2] E. Giagnorio *et al., J Cell Sci,* vol. 134, no. 12, Jun. 2021
[3] M. Rosati *et al., Macromolecules*, vol. 55, no. 7, pp. 2486–2496, Apr. 2022
[4] F. Baldelli *et al.,* Non-Viral Vectors for Gene Therapy. WO2023170543A1, September 14, 2023.

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TEC-PO-011

Tailoring the Properties of Low Dimensional Perovskites through Fluorination

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In recent years, perovskites have found use in numerous fields beginning with photovoltaics and expanding to light-emitting applications and other optoelectronic devices[1]. Despite the competing costs and efficiencies, the presence of defects, both at the surface or in the bulk, is critical for the long-term stability and considerably limits perovskite efficiency. Several strategies have been developed to overcome these limits. Among them, perfluoroalkyl-methyl imidazolium ionic liquids have been applied as passivating agents due to their ability to self-assemble on perovskite surface, resulting in the formation of ordered structures and higher film quality with fewer def ects[2,3]. Furthermore, the presence of highly fluorinated saturated molecular fragments in the resulting Low Dimensional Halide Perovskites (LDHPs) can bestow additional water-repellent properties and superior stability compared to fully hydrocarbon-based cations[2].

In this work, imidazolium cations functionalized with linear perfluoroalkyl chains were applied for the synthesis of new LDHPs. A combination of structural and thermal characterization allowed to study effects of perfluoroalkyl chains on the properties of perovskites. Indeed, fluorous-fluorous interactions and segregation of fluorinated moieties have been demonstrated to induce the formation of ordered structures in perovskite containing fluorinated imidazolium cations, resulting in a thermotropic liquid crystalline behavior. In addition, instead of Pb, a non-toxic metal such as Sn, has been utilized for the same reactions and the obtained LDHPs also showed a liquid crystalline behaviour. Collectively, these results may pave the way for a new class of halide perovskite-based soft materials.

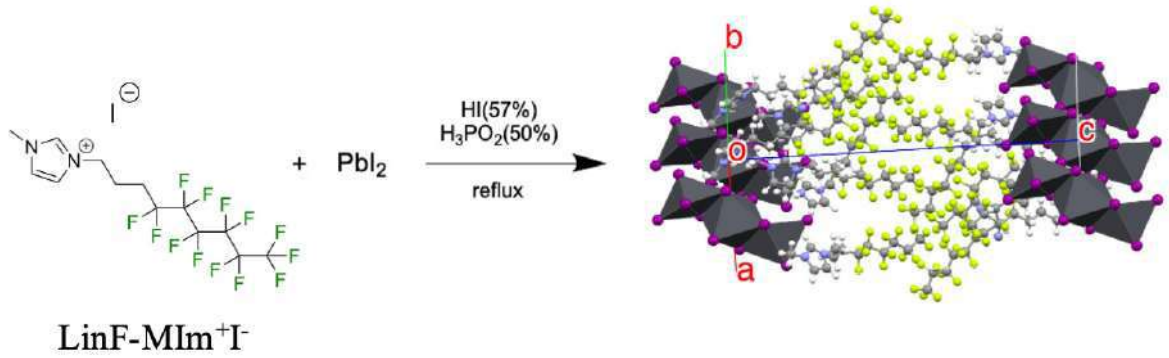

Figure 1: Crystal structure of the $(Pb_3I_{12})^{6-}(LinF\text{-}MIm)^{+}_6$ Low-Dimentional Perovskite (LinF-MIm=Linear Perfluoroalkyl-Methyl Imidazolium). Colour code: gray=C, white=H, blue=N, yellowish green=F, purple=I.

References:

[1] P. Docampo and T. Bein, Accounts of Chemical Research, 2016, vol. 49, no. 2, pp. 339–346, 2016.
[2] X. Li et al., ACS Applied Materials & Interfaces, 2021, vol. 13, no. 3, pp. 4553–4559, 2021.
[3] T. Niu et al., ACS Energy Letters, 2021, vol. 6, no. 4, pp. 1453–1479, 2021.

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TEC-PO-012

From Nature's Blueprint: Electrospinning of a Resilin-derived Brominated Heptapeptide

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Resilin, an elastomeric protein found in arthropods, possesses remarkable mechanical properties such as high resilience and elasticity, making it an attractive candidate for bioinspired materials. However, translating these unique properties in synthetic materials has remained a challenge, primarily due to the protein's intricate structure and extensive amino acid sequence.[1] In our recent work, we focused on the modification of resilin consensus sequence SDSYGAP through bromination of the tyrosine residue.[2] This minimal alteration induced peptide self-assembly due to the increased supramolecular stability conferred by bromine atoms,[3] resulting in a robust three-dimensional network of fibrils within a hydrogel matrix which exhibited elastic properties absent in the wild-type sequence. Building upon these findings, this study explores the combination of this modified peptide with other biomaterials, such as gelatin, and the fabrication of nanofibrous mats through electrospinning. This technique offers precise control over scaffold morphology and architecture, enabling tunable mechanical properties and excellent biocompatibility. We successfully produced electrospun nanofibers with uniform morphology, showing good stability in water and a strain-hardening behaviour characteristic of biological tissues, highlighting the potential of the fabricated scaffolds for various biomedical applications. Furthermore, the brominated heptapeptide scaffolds demonstrated antioxidant activity, attributed to the inherent properties of the peptide sequence. This study presents a promising avenue for the development of biomimetic materials with tunable mechanical properties and added functionalities,[4] inspired by nature's design principles.

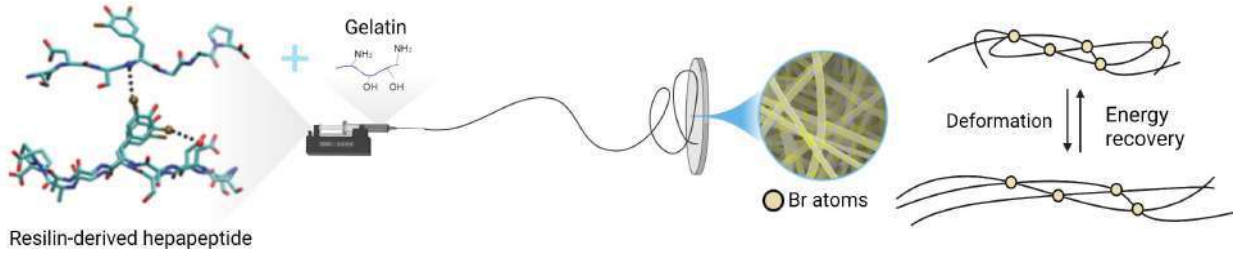

Figure 1: Design principles of the electrospun scaffolds based on the resilin-derived brominated heptapeptide combined with gelatin.

References:

[1] R. Balu, N. Dutta, A. Dutta, N. Choudhury, Nature Communication 2021, 12 (149).
[2] A. Pizzi, L. Sori, C. Pigliacelli, A. Gautieri, C. Andolina, G. Bergamaschi, A. Gori, P. Panine, A. M. Grande, M. Linder, F. Baldelli Bombelli, M. Soncini, P. Metrangolo, Small 2022, 18 (32).
[3] A. Pizzi, C. Pigliacelli, G. Bergamaschi, A. Gori, P. Metrangolo, Coordination Chemistry Reviews 2020, 411.
[4] Peptide composites with antibiofouling properties, Italian Patent application, filed on January 2024, Owners: Politecnico di Milano, Inventors: Pierangelo Metrangolo, Claudia Pigliacelli, Lorenzo Sori, Monica Soncini, Lorenza Draghi, Elisa Marelli.

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TEC-PO-013

Synthesis of nanostructured nonlinear optical materials for quantum sources

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The development of nanostructured nonlinear optical (NLO) materials play an increasingly key role in photonics, due to their advanced functionalities. NLO processes in solid-state materials are widely used for generating quantum light, including single photons, entangled-photon pairs, and quadrature-squeezed states. The ability to generate NLO processes in nanostructures should allow improving the efficiencies pointing toward the realization of photonic sources operating at the nanoscale. The design and the development of nonlinear nanostructured materials with large nonlinearities should satisfy some technological and economical requirements, among them the compatibility with contemporary optical fiber telecommunications and with chip-scale semiconductor technology. Glassy and/or crystalline nanostructured materials whit significant NLO properties obtained by sol-gel represent a remarkable alternative to traditional NLO materials due to the intrinsic versatility of the synthetic technique that allows to finely tune the NLO properties of the final material by means the process parameters and is easily integrable with other technologies, such as those used to obtain quantum photonic devices. In this work sol-gel nanomaterials belonging to Nb_2O_5-SiO_2 and ZrO_2-SiO_2 binary oxide systems, with variable contents of high polarizable element, will be synthesized using cost-effective sol-gel routes inspired to sustainability and circularity criteria of Green Chemistry, such as the use of green solvents, safe, cheap and available materials, and energy-efficient protocols. The final goal will be the synthesis of NLO nanostructured materials in form of powders or transparent thin film containing the active component, in amorphous or crystalline form, embedded in a silica matrix. These materials will be subjected to proper drying and heat treatment programs to give film/gel-derived materials with amorphous and/or crystalline nanostructuring.

TEC-PO-014

TEMPO-functionalised polyethyleneimine as a versatile material for various applications

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The nitroxyl radical 2,2,6,6-tetramethylpiperidin-1-oxyl (TEMPO) has been widely investigated due to its ability to participate in redox reactions.[1] In this work, aiming for the synthesis of novel versatile materials, different TEMPO-derivatives were synthesised and subsequently grafted to polyethyleneimine (PEI). The obtained PEI-TEMPO polymer was used as is or in the production of new materials to take advantage of the radical's properties both for biomedical and chemical applications. In particular, PEI is recognised as the golden standard for non-viral gene delivery. In this case PEI-TEMPO is used to obtain polymeric nanoparticles and polyplexes with nucleic acids able to mitigate the intrinsic cytotoxicity of PEI thanks to the protective antioxidant activity of TEMPO radical. In the field of material science, TEMPO is already employed for the oxidation of alcohols to aldehydes and carboxylic acids, and thus extensively used in the pre-treatment of cellulose to facilitate the production of nanofibers (TOCNFs)[2]. In this context, TEMPO-PEI structures are explored for the preparation of heterogeneous catalysts with the aim of innovating the process of cellulose oxidation. All the synthesised structures were completely characterised by NMR, EPR, and FT-IR techniques, successfully obtaining performing materials.

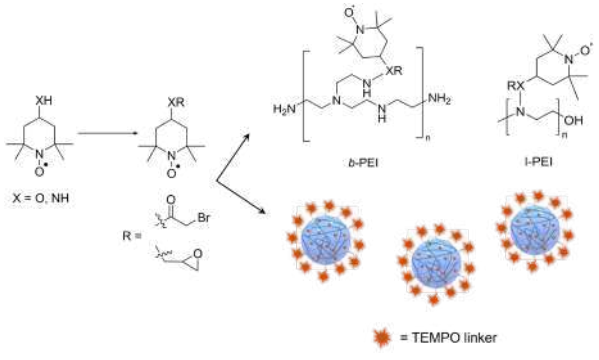

Figure 1: reaction scheme for TEMPO-based linkers and polymers

Acknowledgment: PRIN 2022 - 20227XZKBY - Superoxide responsive redox-active systems and nano smart materials to target ferroptosis – FEROX

References:

[1] B. P. Soule, F. Hyodo, K. Matsumoto, N. Simone, J. Cook, M. Krishna, J. Mitchell, 2007, *42* (11), 1632–1650.
[2] A. Isogai, T. Saito, H. Fukuzumi, 2011, *3* (1), 71–85.

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TEC-PO-015

Exploring water-polysaccharide interaction in icing conditions

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The formation of ice on exposed surfaces causes serious problems to the safety and operation of instruments and facilities. Active methods of ice removal can be costly and energy consuming. Thus, research focused on passive methods, such as superhydrophobic and liquid-infused porous surfaces (know with the acronyms SLIPS or LIS), which however can lose hydrophobicity in humid conditions or due to degradation.[1] Moreover, superhydrophobic coatings are usually made of fluorinated materials, intrinsically hydrophobic, but also potentially hazard for the environment and human health.[2] Surfaces infused with a hydrophilic lubricating layer may be an alternative strategy for functional icephobic coatings, allowing the formation of a liquid water layer on the surface which enables ice sliding.[1] In this context, polysaccharides, that are soft hydrophilic absorbent materials, non-toxic and biodegradable, may be of particular interest.[3] Hence, an electrolyte hydrogel of chitosan, an abundant polysaccharide, was physically crosslinked and infused with different amounts of salted water (Fig. 1). A 10-fold reduction of ice adhesion with respect that on aluminum and glass in the same conditions was obtained, due to the exploitation of the colligative properties of water preventing ice nucleation at the ice-hydrogel interface. This is a bio-based and cost-efficient strategy to reach easy ice detachment in humid marine environments, with potential application in offshore platforms and ships.[4]

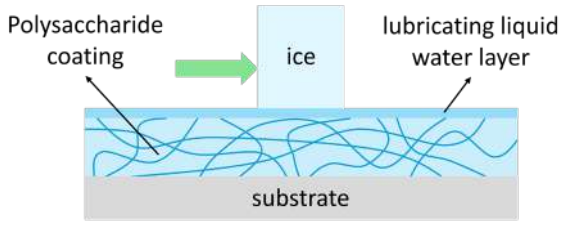

Figure 1: Scheme showing the substrate, the polysaccharide coating, an ice block, a pushing force, and the lubricating liquid water layer at the interface between ice and coating that facilitates ice detachment in freezing conditions.

References:

[1] S. Ozbay, C. Yuceel, H.Y. Erbil, ACS Appl. Mater. Interfaces 2015, 7, 22067 – 22077.
[2] I. Tagliaro, S. Seccia, B. Pellegrini, S. Bertini, C. Antonini, Carbohydrate Polymers 2023, 302, 120424 – 120433.
[3] S. Petroni, I. Tagliaro, C. Antonini, M. D'Arienzo, S.F. Orsini, J.F. Mano, V. Brancato, J. Borges, L. Cipolla, Mar. Drugs 2023, 21, 147 – 202.
[4] I. Tagliaro, V. Radice, R. Nisticò, C. Antonini. Chitosan electrolyte hydrogel with low ice adhesion properties. Submitted

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TEC-PO-016

Fluoropolymer recycling: Solutions for circularity applied to fluorinated materials

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Fluoropolymers and fluorinated materials (*e.g.*, PVDF, PFPE, fluoro and perfluoroelastomers, perfluorosulfonic resins, etc.) are characterized by the presence of carbon-fluorine bonds which lends outstanding characteristics of fluorinated materials, such as thermal and chemical resistance and stability, dielectric, surface and rheological properties, barrier and permeation attributes. For these reasons, fluorinated materials are crucial chemicals in industry and everyday life and play an important and unique role in key applications such as Batteries, e-mobility, renewable energy, hydrogen economy, water purification membranes, connectivity and life solutions to address sustainability goals

A swift transition to a full circular economy is a topic of primary importance for the sustainability of fluorinated materials.

Different recycling technologies can be applied to meet this target exploiting complementary approaches such as mechanical recycling, physical, and chemical recycling (*e.g.*, depolymerization, pyrolysis, mineralization). Selected technical approaches are investigated and described as sustainable solutions to address circularity of fluoropolymers and materials.

Acknowledgements: Syensqo is acknowledged for funding the research project “Fluorine Mineralization in Fluoropolymers” and partially funding a scholarship PNRR 117, under the 39° cycle of the PhD course in “Industrial Chemistry and Chemical Engineering” of Politecnico di Milano for the project “Mineralization and Recycling of Fluorinated Molecules, Polymers, and Materials”.

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TEC-PO-017

Hydroxylated hexagonal boron nitride as filler for polymeric composites

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Introduction

Two-dimensional hexagonal boron nitride (hBN) has attracted tremendous attention over the last few years, thanks to its stable structure and its outstanding properties, such as mechanical strength, thermal conductivity, electrical insulation, and lubricant behavior. As carbon materias, boron nitride has many allotropic forms, of which the most stable is the hexagonal multilayered structure.

hBN has many similarities with its carbon counterpart, graphene. Indeed, the material has many appealing properties, such as thermal and chemical stability, thermal conductivity, and biocompatibility.

Results

In this work, innovative strategies for the chemical modification of hBN are reported.

Starting from a deep study of the material, three approaches were designed for the sustainable insertion of -OH functional groups, mainly on the edges of hBN. The modification of its solubility parameter was also achieved.

The possibility to tune its solubility parameter was exploited in order to introduce this reinforcing filler in two divergent matrices an elastomer matrix (Styrene-butadiene rubber, S-SBR and 1,4 *cis* isoprene, NR) and a biopolymer (chitosan, CS).

Alongside with the chemical modification a reduction of the staked layers has been induced through the application of mechanical energy by dry and wet methods.

S-SBR based rubber composites were characterized through static and dynamic mechanical tests. This work demonstrates that hBN can also improve the rheological and mechanical properties of elastomer composites when used to partially replace silica.[1]

Chitosan-based suspensions, papers and aerogels were also prepared: composites were characterized by means of infrared spectroscopy, thermogravimetric analysis, and X-Ray diffraction.

References:

[1] Magaletti, F., Prioglio, G., Giese, U., Barbera, V., & Galimberti, M. (2023). Hexagonal Boron Nitride as Filler for Silica-Based Elastomer Nanocomposites. Nanomaterials, 14(1), 30.

TEC-PO-018

Antimicrobial and chemical characterization on waste glass activated with KOH or NaOH at low molarity

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The pressing need to decrease global CO_2 emissions is driving research and advancement in creating new materials and technologies that have a minimal carbon footprint, while still providing beneficial properties and long term durability[1]. Alkali-activated materials have shown great potential not only because of their performance, but also because various types of waste and by-products can be used in their production, resulting in both environmental friendliness and cost effectiveness. Sustainability can be further enhanced by minimizing the use of additives and/or their concentration, i.e. alkaline activators with low molarity.

Glass waste was alkaline activated with 2.50 M KOH or NaOH solutions. Fourier transform infrared spectroscopy was used to study the covalent bonds in the hardened materials. Leaching tests (EN12457) were also carried out to assess the possible presence of metals from the starting materials. In addition, antimicrobial activity was evaluated using the Kirby-Baur method[2,3]. Four microbial strains were used for this purpose, namely *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus* and *Enterococcus faecalis*. The result was a well-formed material with interesting antimicrobial activity.

Fundings: PRIN 2022 PNRR project #P2022S4TK2 GLASS-based TREAtments for Sustainable Upcycling of inorganic RESidues (GLASS_Trea.S.U.Res).

References:

[1] Y. Liu, C.Shi, Z. Zhang, N. Li, Resources, Conservation and Recycling. 2019, 144, 297–309.
[2] S.K. Adhikary, A. D'Angelo, V. Viola, M. Catauro, P. Perumal, Energy, Ecology and Environment 2023 in press.
[3] I. Blanco, A. Latteri, G. Cicala, A. D'Angelo, V. Viola, V. Arconati, M. Catauro, Molecules 2022, 27, 979.

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TEC-PO-019

Mechanochemical synthesis of fluorinated perovskites $KCuF_3$ and $KNiF_3$

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This study focuses on the solvent-free mechanochemical synthesis of two fluorinated perovskites, $KCuF_3$ and $KNiF_3$, that can be seen as a practical green alternative to the classical solvothermal synthesis.[3]The process has been optimized to find the refined milling time at constant rotational speed.[4] The main outputs of the process are $KCuF_3$ and $KNiF_3$ in the desired crystalline phase[2], which are present after 6 hours of milling. Other crystalline phases have been found at greater milling durations for Cu- and Ni-based perovskites, known as K_2CuF_4 and K_2NiF_4, respectively. The fluorinated perovskites were characterized by using X–Ray Diffraction Spectroscopy (XRD), X–Ray Photoelectron Spectroscopy (XPS) and Scanning Electron Microscopy (SEM), confirming the selective formation of the fluorinated perovskites. The mechanochemical route was also compared to a new mild solvothermal method. The promising results coming from this innovative method opened the research to the use of solvent–free mechanochemical syntheses as suitable approach also in the field of crystal engineering.

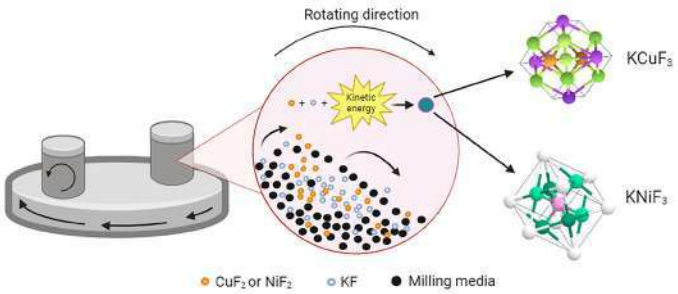

Figure 1: A graphical illustration of the synthetic approaches for the two fluorinated perovskites, KCuF3 and KNiF3.

References:

[1] Sun, S.; Lu, M.; Gao, X.; Shi, Z.; Bai, X.; Yu, W. W.; Zhang, Y.; Advanced Science 2021, 210-268.
[2] Zhang, Y.; Liu, Y.; Zhou, J.; Wang, D.; Tan, L.; Yi, C.; Chemical Engineering Journal 2022, 134-266.
[3] Zhang, M.; Wang, Z.; Mo, M.; Chen, X.; Zhang, R.; Yu, W.; Qian, Y.; Materials Chemistry and Physics 2005, 373–378.
[4] Schlem, R.; Burmeister, C. F.; Michalowski, P.; Ohno, S.; Dewald, G. F.; Kwade, A.; Zeier, W. G.; Advanced Energy Materials 2021, 11

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TEC-PO-020

Chelating agents in geopolymers

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Alkali activation is a room temperature process for consolidating aluminosilicate powders of various types. The resulting 3D aluminosilicate network is a good fixative for heavy metal ions and provides high mechanical strength to the final ceramic-like solid. In such treatments, physical encapsulation, ion exchange, and the formation of the gel structure were found to form compounds to stabilise heavy metals[1]. In addition, a unique three-dimensional zeolite-like cage structure can often occur at cryptocrystalline stage and has been shown to trap anions and organic macromolecules together with heavy metal cations[2].

This work investigated the addition of chelating agents (hydroxyapatite, tartaric acid, etc) to improve to the stabilisation of heavy metals in metakaolin-based geopolymer. The first individuated wastes are galvanic sludges and tannery wastewaters. The metakaolin powder was mixed with NaOH 8 M and sodium silicate solution, then the chelating agent and wastes were added at different percentages. The final consolidated material was tested for the geopolymerisation process by FT-IR and for the encapsulation efficiency by toxic leaching tests. The combination of geopolymer gel formation and the presence of the chelating agent resulted in the stabilisation and inertisation of not only heavy metal cations but also anions at room temperature.

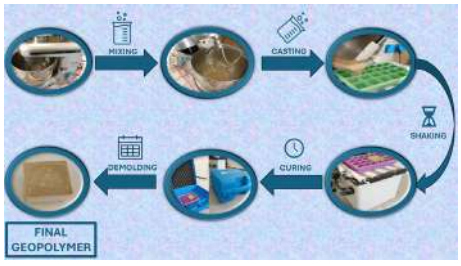

Figure 1: Preparation procedure of geopolymers

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References:

[1] G. Boldrini, C. Sgarlata, I. Lancellotti, L. Barbieri, M. Giorgetti, M. Ciabocco, S. Zamponi, M. Berrettoni, C. Leonelli, Sustainable Environment Research, 2021, 31(1), 33.
[2] M. Giorgetti, M., Berrettoni, G. Aquilanti, G. Boldrini, I. Lancellotti, C. Leonelli, Materials Letters, 2020, 270, 127741.

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TEC-PO-021

Towards Sustainable Mobility: Innovation in Polymer Binders for High-Performance EV Lithium Battery Technology

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Lithium-ion batteries (LIBs) have become indispensable energy-storage devices for various applications, ranging from portable electronics to electric vehicles and renewable energy systems. The performance and reliability of LIBs depend on several key components, among which the role of the binder for the electrodes, often overshadowed by the active materials used, is also crucial for long-term durability.

Binders provide no electrochemical benefits to the electrodes, but function to interconnect the active materials and carbon additive and adhere the electrode slurry to the metal current collector foil, preserving the electrode integrity.

Polyvinylidene fluoride (PVDF) binder is the polymer of choice because of its chemical and electrochemical stability, coupled with high mechanical strength, high strain and heat resistances, and good processability. Despite several advantages, PVDF usually has low cohesive force with the current collector because of the non reactive functional groups tethered onto the PVDF backbone, resulting in low adhesion to the metal foil.

Syensqo, former part of Solvay group, has taken advantage of its expertise in fluorine chemistry and polymerization technologies for designing a new generation of PVDF polymers, designed for use as binder and is especially tailored for high-demanding xEV battery applications, where it is necessary to guarantee best performance during battery operation. The combined effect of several polymer parameters has been studied showing how the reinforced intermolecular interactions between polymer, active materials and current collector result in increased performance in terms of adhesion and chemical resistance in the electrolyte and can influence the binder crystallinity. This can ultimately influence the final properties of lithium-ion batteries.

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TEC-PO-022

Issue of nanomaterial migration in food packaging.

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The target of food packaging experts is to leverage the merits of nanomaterials (NMs) to obtain sustainable and efficient solutions. However, along with the functional properties of NMs, safety concerns exist in their application in food contact materials (FCM). The toxicological studies have shown the negative impacts on human health due to nanoparticle (NP) exposure through inhalation, skin contact, or ingestion[1]. Based on accumulated migration data, regulatory bodies of the US and EU have laid down specific protocols for migration measurement, but these accumulated data refer to only chemical compounds. The application of theoretical and experimental models developed for ions and molecules requires a significant revision when dealing with nanoscale products. A model based on Stokes-Newton equation to predict specific migration has been proposed by Simoneau C[2]. However, it ignores the chemistry of the surrounding environment and the possibility of dissolution. It only considers the theoretical diffusion phenomenon based on the polymer's dynamic viscosity, the diffused particles' size, and the exposed area. Utilizing ICP-MS analysis methods for monitoring elemental concentrations can aid in evaluation. However, details about the migrant's form (dissolved species or single particles) are not retained when the sample undergoes the inductively coupled plasma. SP-ICP-MS can solve this issue since it can distinguish the migrant form, but the issue with this technique is that it requires a uniform liquid base, indicating that either the sample needs to be digested or the NMs need to be extracted. Similar to traditional ICP-MS, SP-ICP-MS is probably not as effective for organic NMs because the polymer matrix might have a very similar carbon-based composition. AgNPs have been detected in a migration solution by TEM/EDS. Still, distinguishing between diffusion or in situ synthesis of AgNPs is not clear. Enzyme-linked immunosorbent assay (ELISA) was used to quantify nano gelatin in fruit juices[3]. This approach requires developing antibodies specific to only the target NMs. Since different NMs have different enzyme-linked antibodies, the problem arises with no scope for comparison. In summary, most studies on nanomaterial migration have high variance and are mostly based on metallic nanoparticles and their oxides; the data available on NMs, such as nanocellulose, nanochitin, nanoclays, etc., which have a high potential in the food packaging application, are very scarce. The objective of this poster presentation aims to highlight these issues. Solutions that are currently available and ones that could be conceivable suitable for FCM will be analysed highlighting the opportunities and criticalities related to their use. Furthermore, the initial findings on nanocellulose migration from barrier coated paper-based substrates will be outlined.

References:

[1] Xuan, L.; Ju, Z.; Skonieczna, M.; Zhou, P. K.; Huang, R. **2023**, *4* (4).
[2] Simoneau, C. *EU Directive 2002/72/EC*; 2010.
[3] Dehalu, V.; Weigel, S.; Rebe, S.; Grombe, R.; Löbenberg, R.; Delahaut, P. **2012**, *403* (10), 2851–2857.

TEC-PO-023

Sustainable Perspectives in Life Cycle of Lithium Batteries

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In 2022, a global LIBs manufactured capacity of 1.5 TWh was estimated. This is expected to increase to 4 TWh by 2025 and reach 6.8 TWh by 2030, with China producing 76% of global capacity and leading the market, whose total value is projected to increase from 46.2 billion dollars in 2023 to 189.4 billion dollars in 2032[1,2]. These figures do not take into account supply shortages which, nowadays, are increasingly more likely and have implications not only on the economic level (causing the increase of LIBs cost of production), but also on the geopolitical one since the majority of materials sources usually lies under politically unstable countries. Therefore, the Li-ion batteries (LIBs) penetration in the automotive market makes more urgent the boosting of zero-waste battery recycling. This can play a crucial role in developing a circular economy through the recovery of Critical Raw Materials, as well as non-metallic components back to use. LIBs are complex devices and do not only contain metals and graphite, but also valuable fluorinated materials. For example, fluorinated lithium salts organic solutions (e.g.: 1.0M LiPF6 in EC/DMC) are used as electrolytes; poly(vinylidene fluoride) (PVDF) is the benchmark binder for the state-of-the-art cathodes, due to its outstanding properties, such as safety, chemical stability, good adhesion to the current collectors and excellent free-standing performances[3-7]. In recent years, the recycling technologies for LIBs entered in a new stage focused on the development of i) advanced pre-treatment processes to separate all the valuable battery components, and ii) more sustainable metallurgical approaches, with the aim to reduce the energy consumption in the subsequent metallurgic processes.

The recovered materials can be used to prepare and assemble a new cell using the recovered separator and characterized to evaluate the effective feasibility of the whole recycling process. The work here presented is now progressing in the frame of RENOVATE EU funded project, with several valuable Partners, especially including Polytechnic of Milan.

References:

[1] International Energy Agency, URL: iea.org/data-and-statistics/charts/lithium-ion-battery-manufacturingcapacity-2022-2030, (accessed October 202.
[2] V. Marpu, J. Prakhar, P. Yerukola, Allied Market Research, Report A01071, 2023N.
[3] K. Aleksandrov, H.-J. Gehrmann, M. Hauser, H. Mätzing, D. Pigeon, D. Stapf and M. Wexler, Chemosphere, 2019, 226, 898e906
[4]B. Ameduri and H. Hori, Chem. Soc. Rev., 2023, 52, 4208
[5] B. Ameduri, J. Fluorine Chem., 2023, 267, 110117
[6] B. Ameduri, Macromol. Chem. Phys., 2020, 221, 1900573
[7] T. Nshizirungu, M. Rana, M.I.H. Khan, Y.T. Jo, S.-J. Park, J.-H. Park, J. Environ. Chem. Eng., 2023, 11, 109160

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TEC-PO-024

SUPREME – Sustainable nanoparticles enabled antimicrobial surface coatings

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As observed during the last catastrophic pandemic, the spread of harmful pathogens can be fast and facilitated by high traffic surfaces and crowded places, highlighting the importance of an economically and environmentally sustainable solution for antimicrobial surfaces as a potential strategy to mitigate the spread of disease outbreaks.[1] Nanoparticles (NP_s) filled coatings, with recognised effectiveness against bacteria, viruses, and fungi, are valuable candidates for developing antimicrobial surfaces and minimising the surface adhesion of pathogens.[2, 3] However, due to the many technical challenges, including difficulty to develop nano-coatings with a long-term antimicrobial capability, durability under real conditions and safety assurance, their application at industrial level is still limited.

The SUPREME project aims to develop a platform of efficient and multifunctional antimicrobial nano-coatings, building upon bespoke TiO_2 NP_s, that have demonstrated an exceptional antimicrobial ability at lab scale (TRL3).[2, 3, 4] Two sustainable routes: 1) customised core/shell and advanced functional NP_s and 2) hybrid fibre-NP_s (using sustainable bio-based cellulose materials and NP_s) will be pursued.[5, 6, 7] The production of the SUPREME coating will follow a sustainable-by-design approach, that considers both toxicity and environmental impact. The scaling-up of the nano-coating production and their validation according to the industrial requirements from different market segments (e.g., textile) will enable to reach the TRL6 by the end of the project. The SUPREME consortium consists in 18 partners from 8 EU countries (UK, IT, ES, GR, BE, MT, NL and NO), including research centres, universities, a National Institute, small and medium-sized enterprises (SME_s) and large companies.

Next Technology Tecnotessile (NTT) is involved in technical activities regarding the evaluation of different coating application technologies on textile-based substrates (WP6), including plasma treatments for increasing the adhesion of the coatings on the surface (WP2). The WP6 also aims to implement the design principles and the proof-of-concept nano-coating systems produced by WP2 and verified by WP3-4 in industrial applications.

References:

[1] J. A. Otter, S. Yezli, G. L. French, Infect Control Hosp. Epidemiol 2011, 32, 687-699.
[2] I. Kitsou, P. Panagopoulos, Th. Maggos, M. Arkas, A. Tsetsekou, Appl. Surf. Sci. 2018, 441, 223-231.
[3] I. Kitsou, P. Panagopoulos, Th. Maggos, A. Tsetsekou, Appl. Surf. Sci. 2019, 473, 40-48.
[4] I- Kitsou, M. Arkas, A. Tsetsekou, SN Appl. Sci. 2019, 1, 1557.
[5] K. Chatterjee, S. Sarkar, K. J. Rao, S. Paria, Adv. Colloid Interface Sci. 2014, 209, 8-39.
[6] V. Binas, D. Venieri, D. Kotzias, G. Kiriakidis, J. Materiomics 2017, 3, 3-16.
[7] A. Segkos, I. Sakellis, N. Boukos, C. Drivas, S. Kennou, K. Kordatos, C. Tsamis, Nanoscale 2020, 12, 10254-10264.

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TEC-PO-025

Sustainable rubber composite Materials by Dynamic covalent networks and BIO-fillers

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The concept of flexible electronics, evolving over decades, saw significant strides with the introduction of conductive polymers, organic semiconductors, and amorphous silicon. These materials enable devices to bend, roll, fold, and stretch, distinguishing them from conventional electronics. The pursuit of novel materials and manufacturing techniques for high-performance, scalable electronic devices on flexible substrates is ongoing.[1,2]

Addressing escalating environmental concerns, recyclable elastomeric materials, particularly Dynamic Covalent Polymer Networks (DCPNs), show promise. [3,6]

However, the lack of reversibility in current covalent coupling reactions in rubber compounds hinders recycling efforts. This research project aims to advance recyclable elastomeric materials for flexible electronics by preparing composites with reversibly cross-linked elastomers and bio-fillers. Modified liquid rubbers for reversible curing and functionalized bio-fillers such as lignin for compatibility will be synthesized. The Diels-Alder reaction is used as the reversible system.

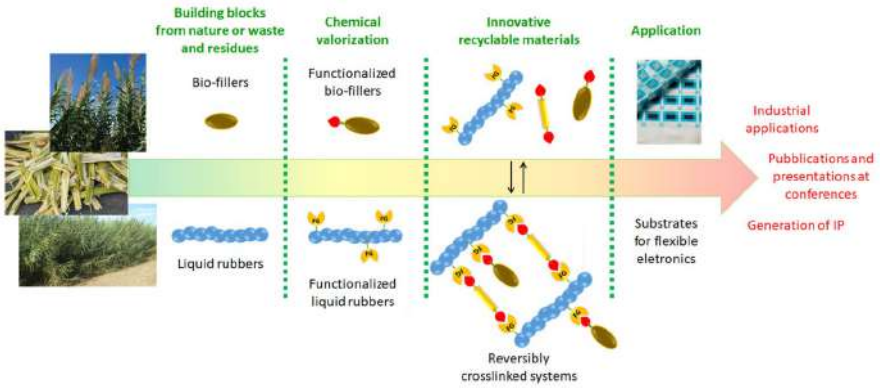

Figure 1: Overview of the research performed

References:

[1] M. P. Cenci et al. *Adv. Mater. Technol.* 2022, 7, 2001263
[2] D. Corzo et al. *Frontiers in Electronics*, 2020, 1: 594003
[3] N. Zheng et al. *Chem. Rev*. 2021; 121, 1716
[4] P. Chakma et al. *Angew. Chem. Int. Ed.* 2019; *58*, 9682
[5] Jiang Q et al. *Polymers*. 2022; 14, 1380
[6] Zou W K et al. *Adv. Mater.* 2017; 29, 1606100

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TEC-PO-026

Recycling of Permanent Magnets with Phosphonium Based Ionic Liquids

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Due to the limited availability of primary ore deposits and supply risk, research attention is being drawn towards the recovery of Rare Earth Elements (REEs) from secondary sources[1,2]. Raw materials play a fundamental role in the current and future technologies necessary for achieving sustainable development goals as outlined in the UN 2030 Agenda. Notably NdFeB and SmCo magnets, as secondary solid wastes, are significantly rich in REEs such as Nd, Sm, and Dy[3]. Current hydrometallurgical processes for the recovery of the REEs from aqueous solutions have some interesting advantages but require the use of significant amounts of toxic volatile organic compounds[4]. Ionic liquids (ILs) have many potential applications since they present many advantages such as negligible vapor pressure, reusability, and high thermal stability[5].

In this work, we assess the performance of phosphonium based ILs ($[P_{66614}][Dec]$ and $[P_{66614}][Cl]$) for separation of REEs from transition metals from magnets after HCl leaching. It was found that bivalent ions are extracted from highly acidic media, while REEs prefers neutral pH in both ILs. After extraction, stripping of metals from ILs was performed with various media. The water phase was measured by ICP-OES to quantitatively determine metal concentrations after extraction and stripping and magnet composition after leaching.

Acknowledgements:

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AK and AM acknowledge the PhD programme on Green topics (Action IV.5, DM 1061/2021, cycle XXXVII) carried out with co-financing from the European Union - ESF REACT-EU, PON Research and Innovation 2014-2020, UniUD

References:

[1] E. Yamada, H. Murakami, S. Nishihama, K. Yoshizuka, Sep. Purif. Technol 2018, 192, 62-68.
[2] R. K. Jyothi, T. Thenepalli, J. W. Ahn, P. K. Parhi, K. W. Chung, J.-Y Lee, J. Clean. Prod. 2020, 267, 122048.
[3] S. Papagianni, A. M. Moschovi, K. M. Sakkas, M. Chalaris, I. Yakoumis, Appl. Chem. 2022, 2, 199-212.
[4] M. Busato, A. Lapi, P. D’Angelo, A. Melchior, J. Phys. Chem. B 2021, 125, 6639-6664.
[5] K. M. Docherty, C. F. Kulpa Jr, Green Chem. 2005, 7, 185-189.

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TEC-PO-027

Prospective life cycle assessment of the progression of Perovskite/silicon tandem solar cells from the lab to upscaled solar applications

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In their R&D phase, perovskite/silicon tandem solar cells have continued to demonstrate excellent power conversion efficiencies (PCEs) while promising low-cost manufacturing[1]. With prospects for further enhancements, this technology has been pushed closer to market entrance. Nevertheless, for a photovoltaic technology to reach commercialization, factors such as high efficiency, scalability, long-term stability, cost competitiveness, and environmental friendliness need to be considered. Bifacial perovskite/silicon tandem solar modules offer a promising pathway toward greater stability and energy yield compared to the monofacial perovskite/silicon tandems. The bifacial configuration exploits the extra photons that originate from reflected and scattered light from the ground (albedo), resulting in a current larger than that producible by the monofacial configuration, enabling a higher performance[2]. There has been a growing interest in the development and deployment of bifacial solar cells; however, estimates show that they are expected to reach a meaningful market share within the next ten years[3]. It is therefore crucial to evaluate the environmental impacts and anticipate the mitigation of potential critical issues of bifacial perovskite/silicon tandem solar cells alongside technological advancements to guide their development in an eco-design perspective.

In this study we use the prospective life cycle assessment (PLCA) approach[4] allowing the use of multiple upscaling scenarios to assess emerging technologies at the laboratory scale with a future-oriented perspective (large-scale or industrial scale). Using the UpFunMatLCA scheme[5] to generate scenarios, we perform a systematic and comprehensive analysis taking into account the scalability of material and the processing steps of the tandem solar cell. Results highlight the possible implications of future perovskite/silicon tandem design choices and processes from an environmental perspective. Early awareness of the environmental hotspots will be essential to support the technological development before commercialization.

References:

[1] M. J. Kipyator, F. Rossi, L. Vesce, A. Di Carlo, R. Basosi, M. L. Parisi and A. Sinicropi, *Sustainable Energy & Fuels*, 2024, 10.1039.D3SE01182H.
[2] M. De Bastiani, A. S. Subbiah, M. Babics, E. Ugur, L. Xu, J. Liu, T. G. Allen, E. Aydin and S. De Wolf, *Joule*, 2022, **6**, 1431–1445.
[3] International Technology Roadmap for Photovoltaic (ITRPV), 2023.
[4] S. Cucurachi, C. Van Der Giesen and J. Guinée, *Procedia CIRP*, 2018, **69**, 463–468.
[5] S. Weyand, K. Kawajiri, C. Mortan and L. Schebek, *J of Industrial Ecology*, 2023, **27**, 676–692.

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TEC-PO-028

A Multivariate Statistical Approach to Monitor the Synthesis of Polyurethanes

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Diisocyanates, due to the presence of two functional groups –N=C=O, are commonly used for the synthesis of polyurethanes (PUs), in combination with an appropriate polyol. Physical, chemical and mechanical properties of PUs can be modulated by varying the nature of the diisocyanate compounds. In this study, two kinds of acrylate polyurethanes (PUAs) were synthesized: one using isophorone diisocyanate (IPDI), with an aliphatic R group, the other using 2,4-toluene diisocyanate (TDI), with an aromatic R group. As shown in Figure 1, in the first step, the diisocyanate compound reacts with a polyol to obtain an urethane prepolymer with two terminal –N=C=O groups; in the second step, the as-obtained urethane prepolymer is functionalized with an hydroxy methacrylate derivative.

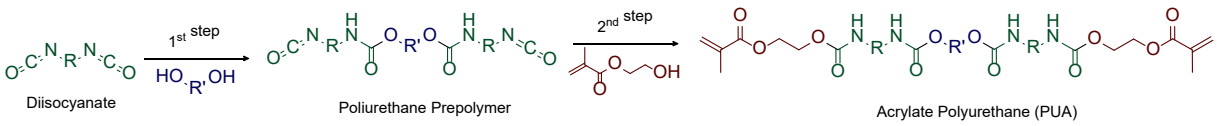

Figure 1: Synthetic pathway of the preparation of PUs with methacrylate as end groups (PUA).

The aim of this study was the application of a methodology, faster than the conventional titration method[1], for the quantification of the free isocyanates in the first step of the prepolymer synthesis. IR spectra were recorded, in the wavenumber range between 1800 and 2100 cm^{-1}, on calibration solutions and on aliquots collected from the reaction batch at different times. Then, a multivariate statistical approach was applied to build a calibration model, able to monitor the rate of decrease of the diisocyanate reagent. Results were in line with those obtained through the conventional method.

References:

[1] H. Madra, S.B. Tantekin-Ersolmaz, F. Seniha Guner, 2009, Monitoring of oil-based polyurethane synthesis by FTIR-ATR, 28, 773-779.

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TEC-PO-029

A circular approach to flexible electronics: biobased chain extenders for the control of the macrostructure of recycled polyesters

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Recycled PET, chosen as the polyester for mechanical recycling, underwent regradation utilizing a dianhydride derived from a biobased C6 building block. The biobased derived component was sourced from a 2-pyrone, extracted from lignocellulosic materials to produce mellophanic dianhydride (MEDA)[1], as illustrated in Figure 1. MEDA represents an alternative to the conventional oil-based pyromellitic dianhydride[2]. In the context of mechanical recycling of rPET, MEDA functioned as a chain extender. Chemical and rheological characterization of the recycled materials was performed.

This study, conducted as part of the European ECOTRON[3] project, specifically addressed the end-of-life considerations of polymers employed as substrates for flexible printed electronics, emphasizing circular, biobased, and biodegradable solutions. The key principles applied to the substrate in this research were:

- Recycle the used materials for integration into new products.
- Incorporate renewable, biobased, or plant-derived chemicals to reduce the use of fossil-based chemicals.

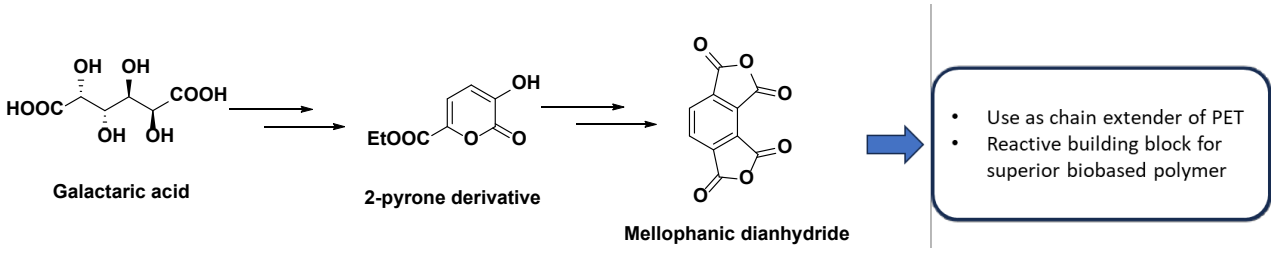

Figure 1: Chemical structure and synthetic path of MEDA; specific objectives are also reported.

The authors would like to thank ECOTRON project for the support provided for this work.

References:

[1] Truscello, Ada, et al. "Biosourced Aromatic Derivatives in the Upcycling of Recycled PET: Mellophanic Dianhydride as a Chain Extender." ACS Sustainable Chemistry & Engineering (2023).

[2] Odet, Félix, et al. "Influence of Chain Extenders on Recycled Standard and Opaque PET Rheology and Melt-Spun Filament Properties." ACS Applied Polymer Materials 4.11 (2022): 8290-8302.

[3] European Union's Horizon Europe research and innovation program under grant agreement No 101070167

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TEC-PO-030

Adducts of few layers graphene with 2-pyrones: one pot functionalization and exfoliation

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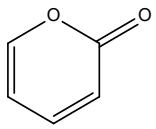
Since the 1990s, the escalation of environmental apprehensions has propelled the development of green chemistry, with the primary aim of reducing the use of hazardous substances.

Galactaric acid, from fruit peels, is crucial in organic chemistry and polymer synthesis. 2-Pyrones, or α-pyrones, are unsaturated heterocyclic compounds with a C-6 atom containing an oxygen atom and a carbonyl group at the α position. (Figure 1).[1]



2*H*-pyran-2-one

Figure 1: Chemical structure of 2H-pyran-2-one.

They represent a versatile class of structural compounds found in numerous biologically active metabolites. Their chemical versatility is explained by the resonance of 2-pyrone, which exhibits partial aromaticity. 2-pyrones react as dienes and can undergo typical reactions such as the Diels-Alder cycloaddition.

A huge amount of research has been focused on graphene due to its high surface area, exceptional mechanical strength and high charge carrier mobility[2]. Graphene is being developed mainly in the electronic field, whereas few layers graphene (FLG) are finding applications in the material field.

In this work, FLG were prepared by exploiting the edge functionalization with 2-pyrones, promoted by the mechanical energy of a high shear mixer (HSM). One pot functionalization and exfoliation were obtained, in water as the dispersion medium. Adducts of FLG were prepared by mixing a high surface area graphite (HSAG) and 2-pyrone in deionized water, in the HSM. The grafted 2-pyrone was supposed to promote the exfoliation.

The adducts were characterized by means of X-ray diffraction, UV, IR and Raman spectroscopy, investigating the degree of exfoliation.

References:

[1] Margani, F., Magrograssi, M., Piccini, M., Brambilla, L., Galimberti, M., & Barbera, V. (2022). Facile edge functionalization of graphene layers with a biosourced 2-pyrone. ACS Sustainable Chemistry & Engineering, 10(13), 4082-4093.

[2] Galimberti, M., Barbera V., Guerra S., Conzatti L., Castiglioni,,C., Brambilla L., and Serafini A. Biobased Janus molecule for the facile preparation of water solutions of few layer graphene sheets. RSC Adv 5, 81142–81152 (2015).

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TEC-PO-031

Protein-based Nanocomposites: from Insect-mediated bioconversion of Organic Waste to Electro-conductive Bioplastics

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Starting from the Organic Fraction of Municipal Solid Waste (OFMSW) as a feeding substrate for the insect Black Soldier Fly (BSF), this research aims to derive functional materials from its proteins, hence contributing to close a circular economy model for the full valorization of OFMSW. Specifically, a BSF protein-based bio-nanocomposite material enriched with a functionalized Conductive Carbon Black (CCB) for flexible electronics applications is here presented.

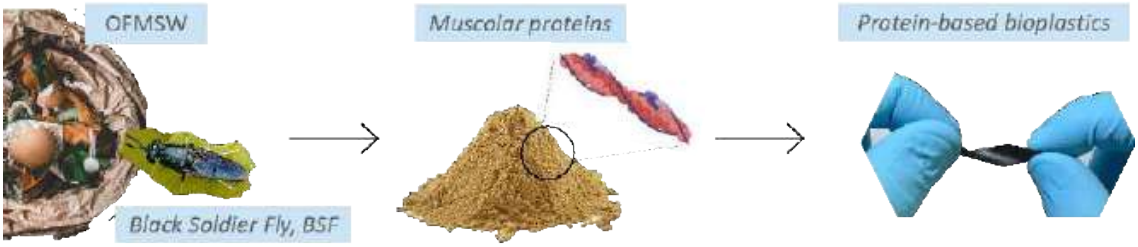

Figure 1: Circular electro-conductive nanocomposite bioplastic from BSF reared on the OFMSW.

The BSF insect proteome was deeply characterized through SDS-PAGE and LC-MS/MS, disclosing a prevalence of muscular proteins. TGA, WA-XRD analyses, and Hansen solubility tests were utilized for the characterization of the filler. Kraus plots and electrical conductivity measurements, together with associated mathematical models, served as practical tools to evidence stronger filler-polymer interactions after functionalization of CCB with the pyrrole methodology [1]. Obtained composites are flexible and mechanically robust, with conductivity values up to 0.9 S/m. Taken together, these findings not only support the development of green flexible electronics, but also contribute to the valorization of the OFMSW, aligning with European policies of circular economy [2].

References:

[1] V. Barbera et al., Nanomaterials 2019, 9, 1–23
[2] Rifiuti e riciclaggio. https://ec.europa.eu/environment/topics/waste-and-recycling_it

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TEC-PO-032

Adducts of graphene layers with pyrrole derivatives of 2-pyrone as catalysts for water remediation

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Pyrroles are essential compounds in biological systems and are utilized in drug synthesis and material chemistry. They are typically formed through the Paal-Knorr reaction, in which 1,4-dicarbonylic compounds react with amines. Here we present a sustainable approach to the synthesis of *N*-substituted pyrrole derivatives *via* the reaction of primary amines with 3-hydroxy-2-pyrones.[1] These latter compounds are easily prepared from renewable sources and can effectively mask 1,4-dicarbonylic functionalities, enabling the efficient synthesis of substituted pyrrolic rings (**Figure 1**).[2]

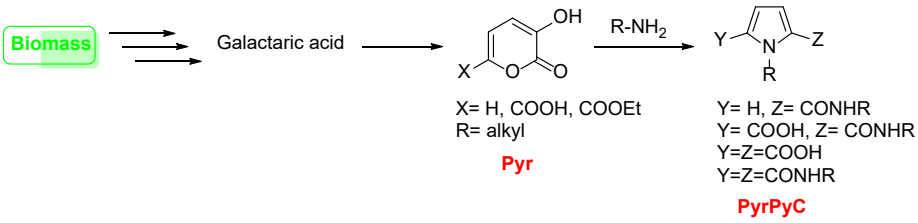

Figure 1: synthesis of green pyrrole derivatives (PyrPyC).

Based on the research conducted by the research group,[3] these pyrroles have been employed to decorate graphene layers with the aim of obtaining catalysts for sustainable water remediation (**Figure 2**), through the catalytic ozonation of recalcitrant pollutants.[4]

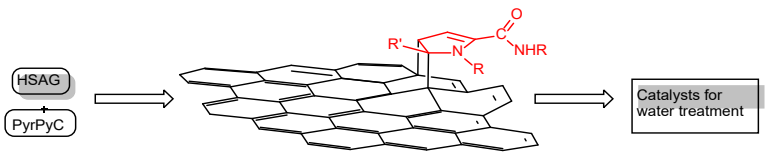

Figure 2: Preparation of catalysts for water remediation.

References:

[1] G. Leonardi, A. Truscello, G.I.C. Righetti, G.G. Mondrone, L. Mascheroni, A. Citterio, R. Sebastiano, 2022, ACS Sustainable Chemistry & Engineering, 10(38), 12763-12770.
[2] G. Leonardi, J. Li, G.I.C Righetti, A. Truscello, M. A., C. Gambarotti., G. Terraneo, R. Sebastiano, 2020, European Journal of Organic Chemistry, 2020 (2), 241-251.
[3] V. Barbera, A. Bernardi, A. Palazzolo, A. Rosengart, L. Brambilla, M. Galimberti, 2018, Pure and Applied Chemistry, 90(2), 253-270.
[4] F. Bernat-Quesada, J. C. Espinosa, V. Barbera , M. Alvaro, M. Galimberti, S. Navalon, H. Garcia, 2019, ACS sustainable chemistry & engineering, 7(20), 17443-17452.

TEC-PO-033

Protein-based compostable films: from chemical modification to application in flexible electronics

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Bio-based materials, such as proteins, are considered the most promising candidates for next-generation flexible electronics due to their high sustainability and variety of chemical structures, which can be depolymerized and recycled into monomers, offering the possibility of reducing and minimizing the future environmental impact of electronics.[1,2]

In this work, zein was selected as the starting protein, and flexible films were developed. Therefore, some physical and chemical modifications were designed and performed based on the native structure of the protein. Two routes were explored: (i) thermoreversible Diels-Alder reactions and (ii) thermosets from bio-based acrylics. Computational studies have been carried out for the design of cross-linkers of different lengths for the Diels-Alder (DA) reaction between zein (diene) and a cross-linker molecule (dienophile). The reversibility was checked through the retro-diels alder reaction.[3] Bio-nanocomposites based on proteins and chemically functionalized carbon allotropes (such as carbon nanotubes, graphene, and conductive carbon black) have been developed and studied.

The samples were characterized by DSC, FT-IR, SDS-PAGE, and NMR analysis. In addition to the mechanical properties, molecular dynamics studies were performed, which allowed us to understand the reorganization of the protein as a function of chemical modifications.

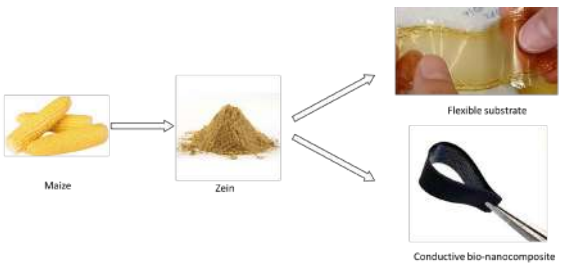

Figure 1: Schematic representation of film production: from maize to a flexible substrate and conductive bio-nanocomposite.

References:

[1] B. Kılıçarslan, I. Bozyel, D. Gökcen, C. Bayram, Macromol. Mater. Eng. 2022, 307, 2100978.
[2] V. Barbera, L. Rubino, F. Margani, M. Galimberti, P. Zalar, IT102022000013486, 2022
[3] P. Mineo, V. Barbera, G. Romeo, F. Ghezzo, E. Scamporrino, F. Spitaleri, U. Chiacchio, J. APPL. POLYM. SCI. 2015, 42314.

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TEC-PO-034

TECNOLOGIE PER LA GENERAZIONE E L'UTILIZZO DI IDROGENO VERDE ED I MATERIALI INNOVATIVI NECESSARI ALLA LORO REALIZZAZIONE

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Secondo il ben noto rapporto Brundtland [1], pubblicato nel 1987 dalla Commissione mondiale sull'ambiente e lo sviluppo (WCED), lo sviluppo sostenibile è definito come quello sviluppo che: "*soddisfa i bisogni del presente senza compromettere la capacità delle generazioni future di soddisfare i propri bisogni*". In questo quadro, la scienza gioca un ruolo fondamentale nel continuo progresso di nuove tecnologie sempre più performanti e a basso impatto ambientale e richiede lo sviluppo di nuovi materiali che ne garantiscano l'implementazione.
L'idrogeno è considerato un vettore molto efficiente e versatile per la conversione e lo stoccaggio di energia, soprattutto da fonti rinnovabili, e quindi è stato recentemente rilanciato come elemento indispensabile per la transizione energetica.

In questo intervento verranno presentati i materiali innovativi fondamentali per la conversione e lo stoccaggio dell'energia attraverso la gestione dell'idrogeno, in cui Syensqo sta puntando e investendo per contribuire allo sviluppo sostenibile. Verranno presentate due diverse tecnologie per la conversione dell'energia legate all'idrogeno che impiegano tali materiali innovativi: la cella a combustibile o *fuel cell* (PEM FC) e l'elettrolisi dell'acqua (PEM WE e ALK WE). Verranno presentati e discussi i principi di funzionamento di tali tecnologie e i polimeri sviluppati in Syensqo che trovano utilizzo nei componenti di queste apparecchiature elettrochimiche, con speciali attenzione agli ionomeri per la fabbricazione delle membrane a scambio protonico (PEM) [2].

References:

[1] World Commission on Environment and Development (1987). *Our Common Future*. Oxford: Oxford University Press. ISBN 019282080X.
[2] https://www.syensqo.com/en/brands/aquivion-ion-conducting-polymers

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TEC-PO-035

Cellulose-based sorbent materials for water decontamination from pesticides: the case study of Atrazine as a representative model compound

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Atrazine is a synthetic herbicide, one of the most studied compounds in the scientific literature[1] to validate the adsorption efficiency of sorbent materials. Furthermore, its chemical structure allows synthetic modifications with the introduction of functional groups able to change its chemical-physical properties.

In this work, we considered atrazine as potential model compound to predict the behaviour of a wider family of pesticides and their interaction with sorbent materials. In a first step, we conducted a cluster analysis which allowed to group pesticides onto consideration of three chemical-physical parameters. This analysis confirmed that Atrazine could be considered an ideal model compound for a high number of pesticides. Moreover, we also carried out a meta-analysis on the adopted operating conditions for pesticide (ad)sorption lab tests, aimed to understand if Atrazine could also predict the (ad)sorption behaviour of other similar compounds. Results confirmed that Atrazine could be considered a reliable model compound for describing (ad)sorption on the same class of sorbents, emphasizing the importance of solute-sorbent interactions.

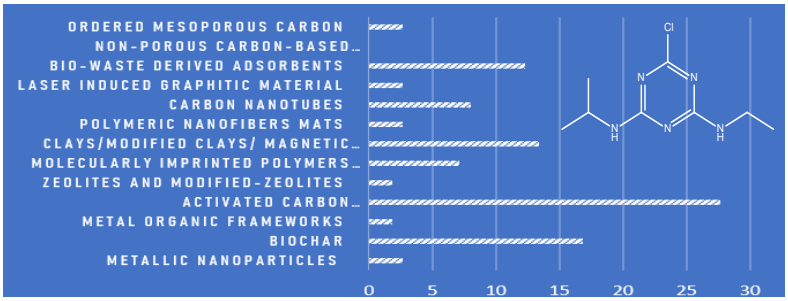

Figure 1. Percentage of Materials used in atrazine isotherm studies.

Based on these outputs, we used Atrazine to better investigate the (ad)sorbing properties and its chemical-physical interaction with new classes of cellulose-based nanostructured materials[2] and a cellulose-based commercial product. To do that, Atrazine was also chemically modified by introducing lipophilic and hydrophilic functional groups on its triazine core.

This comprehensive study allowed us to better understand the mechanisms of interaction between Atrazine and the designed cellulose-based materials, also suggesting a way to improve the sorbent for a more efficient removal of pesticides well represented by the model herbicide.

References:

[1] S. Cosgrove, B. Jefferson, P. Jarvis, Environ. Technol. Rev. 2019, 8(1), 1–24.
[2] L. Riva, A. Fiorati, C. Punta, Materials 2021, 14, 473.

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TEC-PO-036

Spectroscopy-based metabolomics for early detection of *Citrus Tristeza Virus* infection

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Metabolomics is a powerful tool for studying various aspects of plant physiology and biology, which regulate plant growth, development, and stress response. To protect themselves from pathogens, plants produce a wide range of secondary metabolites through a network of different biosynthetic pathways. The analysis of metabolomic data allows the identification of groups of metabolites, whose concentration significantly changes already at the first stages of disease. Metabolomics can be utilized as a tool to detect host-pathogen interaction and also to differentiate the type of compounds produced in resistant and susceptible phenotypes.[1]

Recently, our lab has been involved in a number of projects based on the application of spectroscopy-based metabolomics for the study of plant diseases, including *Erwinia amylovora* infections in pear[2] and *Xylella fastidiosa* infections in olive crops.[3,4] Furthermore, some important clues on the resistance phenomenon against *Xylella fastidiosa* were obtained by investigating the composition of the xylem sap of plant species characterized by a different phenotype towards Xf subspecies pauca.[5]

This study focuses on *Citrus Tristeza Virus* (CTV) infections in citrus trees. CTV is the causal agent of "tristeza", one of the most destructive viral diseases of citrus. The CTV is phloem-limited and its transmission into new geographic areas occurs by the introduction of infected plants or budwood, with subsequent local dispersal in a semi-persistent mode by several aphid species.[6] In this study, a combined approach by nuclear magnetic resonance (NMR) and hyperspectral reflectance (HSR) spectroscopies is used. NMR is the most robust and non-destructive technique for the elucidation of unknown compounds: as it is not selective, it allows for an unbiased view of the chemical composition of the sample. HSR provides a rapid detection tool, requires limited sample preparation, and is a non-invasive technique for plant disease detection.

Among the objectives of the present study is the identification of possible biomarkers of CTV infection by NMR and subsequent correlation with specific HSR wavelengths. The latter can be advantageously exploited for the development of sensors for the early detection of CTV infections.

References:

[1] B. Bhatt, S. Shikha, S. Mathpal, G. Sharma, Phytoprotection 2022, 120, 5–14.
[2] A. Rizzuti, et al., Phytopathol. Mediterr. 2018, 57, 296–306.
[3] A. Jlilat, et al., Sci. Rep. 2021, 11, 1–11.
[4] E. Ahmed, et al., Molecules 2023, 28, 1-18.
[5] A. Surano, et al., Front. Plant Sci. 2023, 14, 1–18.
[6] A. M. Afonso, et al., Comput. Electron. Agric. 2017, 141, 340–350.

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TEC-PO-037

Scalable Ligand-Free Synthesis of High-Efficient $CsPbBr_3$ Photocatalyst for Degradation of Organic Dyes

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In recent years, cesium lead halide perovskites have made a significant breakthrough in photocatalysis due to the straightforward modulation of their chemical composition, structure, energy levels, and bandgap.[1] In this study, we propose a room-temperature supersaturated ligand-free recrystallization approach for the obtainment of $CsPbBr_3$ photocatalysts by using three different antisolvents: ethyl acetate (EA), isopropanol (IPA), and acetone (ACE).[2] The corresponding synthesized materials (namely EA-$CsPbBr_3$, IPA-$CsPbBr_3$, and ACE-$CsPbBr_3$) have morphologically, structurally, and optically been characterized and tested in the methylene blue (MB) photodegradation under visible-light irradiation ($\lambda > 420$ nm). The evaluation of the pseudo-first-order rate constants for the selected degradation revealed the best performances of the series for the EA-$CsPbBr_3$ material, highlighting the impact of synthetic conditions on the specific surface area of the photocatalyst and the efficient generation of active species (superoxide and hydroxyl radicals) in the degradation. The EA-$CsPbBr_3$ material was systematically employed in the photodegradation of differently structured organic dyes, resulting extremely efficient in degradation of model hazardous xanthene-based structures (EoB and RhB, see Figure 1). Furthermore, we observed that the EoB degradation kinetics remained unaltered for at least five times using the recovered photocatalyst after each cycle. The investigations on the photocatalytic mechanism of EoB degradation evidenced the key role of the superoxide radical along with the important contributions of injected electrons and hydroxyl radicals. In perspective, beyond the reported catalytic study, this work not only establishes the potential of $CsPbBr_3$ materials in dye degradation but also provides new insight into the impact of the synthetic methods on their photocatalytic activity.

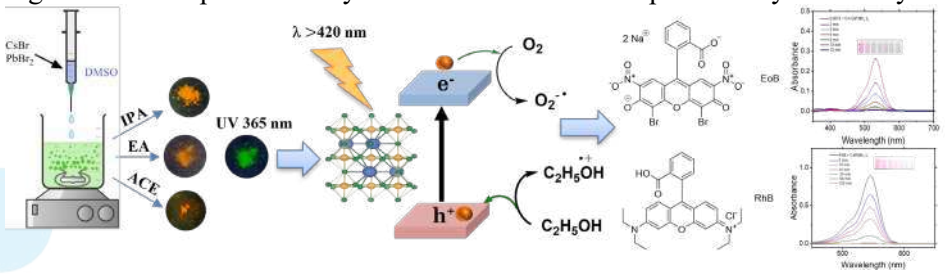

Figure 1: Schematic diagram of the synthesis process and photocatalytic mechanism of $CsPbBr_3$.

References:

[1] H. Huang, B. Pradhan, J. Hofkens, M. B. J. Roeffaers, J. A. Steele, ACS Energy Lett. 2020, 5, 1107–1123.
[2] Q. Zhang, F. Diao, Y. Wang, Inorg. Chem. 2024, 63, 1562-1574.

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TEC-PO-038

Electron-beam irradiated nanogel-based drug delivery system for cancer treatment

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Cancer remains a significant global health challenge, accounting for nearly 10 million of deaths in 2020, whose incidence and mortality cases are steadily increasing[1]. Conventional chemotherapy is the most common approach in the treatment of the disease, but it is often hindered by issues such as the lack of selectivity towards cancerous cells and the premature drug degradation. This results in the need of administering higher doses of chemotherapeutic compounds and leads to drug resistance, which commonly determines the failure of the treatment[2]. Nanoparticles respond to this issue, and the creation of drug delivery systems that can selectively target the affected cells, protect the administered drug, and increase its efficacy, is an innovation in the field of precision medicine[3]. Aqueous solutions of poly(N-vinylpyrrolidone) and acrylic acid (AA) underwent high-energy radiation-induced cross-linking to obtain nanogels. This work focused on the creation of non-immunogenic, blood-compatible, sterile, and colloidally stable systems to be eliminated through the final excretory system. Nanogels were loaded with a model chemotherapeutic drug through a redox-sensitive linker, decorated with a model targeting agent, and evaluated in 2D and 3D cellular models, to assess their applicability as modular nanosystems for precise and efficient delivery of therapeutic payloads to cancer cells.

References:

[1] Sung H, Ferlay J, Siegel RL, Bray F. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. CA Cancer J Clin. 2021 May;71(3):209-249.
[2] Vasan N, Baselga J, Hyman DM. A view on drug resistance in cancer. Nature. 2019 Nov;575(7782):299-309.
[3] Yao Y, Zhou Y, Liu L. Nanoparticle-Based Drug Delivery in Cancer Therapy and Its Role in Overcoming Drug Resistance. Front Mol Biosci. 2020 Aug 20;7:193.

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"SiciliAn MicronanOTecH Research And Innovation CEnter "SAMOTHRACE" (MUR, PNRR-M4C2, ECS_00000022), spoke 3 - Università degli Studi di Palermo "S2-COMMs - Micro and Nanotechnologies for Smart & Sustainable Communities".

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TEC-PO-039

Mitochondria-encapsulation nanotechnologies to enhance mitochondrial transplantation

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Mitochondria are dynamic cytoplasmic double-membrane organelles that generate most of the chemical energy needed to power the cell's biochemical reactions and play crucial roles in maintaining cellular signalling. Mitochondria dysfunction has been showed to be a key factor in the pathogenesis and in the progression of many diseases from cardiovascular to neurodegenerative diseases and cancer, as well as physiological conditions such as ageing[1]. Recent evidence of active transfer of mitochondria occurring between cells suggests that it is possible to deliver mitochondria to correct cellular dysfunction *in vitro* and *in vivo*[2]. Mitochondrial transplantation (also known as mitochondria replacement therapy or MRT) is therefore emerging as a promising therapy for the treatment of many pathological conditions where conventional pharmacological approaches fail, and gene therapy is not feasible[3]. Several *in vitro* techniques have been developed to improve the transfer of mitochondria and evaluate its validity[4]. With current methods, however, it is not possible to maintain the stability of the mitochondria in the long-term and/or to trace the fate of mitochondria after they have been introduced into the recipient cells and tissues. These challenges represent a stumbling block for the successful translation of this revolutionising approach to the clinical practice. Recently, chemical engineering techniques have been focused on finding a way to encapsulate mitochondria in order to improve their stability, integrity and to pilot their delivery[5-7]. Despite positive data, these methods have limitations in terms of efficiency and heterogeneity. Development of mitochondrial encapsulation technologies has the potential to advance translational application of mitochondrial transplantation and provide new ground-breaking strategies for the treatment of mitochondrial dysfunctions. In summary, limitations and future perspectives will be highlighted to address long-term stability of mitochondria while improving tissue-specific mitochondrial distribution and minimising the related immune response.

References:

[1] S. Javadov, A. V. Kozlov, A. K. S. Camara, 2020, Cells 9, 1177.
[2] N. Borcherding, J. R. Brestoff, 2023, Nature 623, 283–291.
[3] Z. Liu, Y. Sun, Z. Qi, L. Cao, S. Ding, 2022, Cell & Bioscience 12(1):66.
[4] M. D'Amato, F. Morra, I. Di Meo, V. Tiranti, 2023, International Journal of Molecular Sciences 24(3):1969.
[5] J.-C. Chang, S.-L Wu, K.-H Liu, Y.-H Chen, et al., 2016, Translational Research 170, 40-56.e3.
[6] S. Wu, A. Zhang, S. Li, S. Chatterjee, R. Qi, V. Segura-Ibarra, M. Ferrari, A. Gupte, E. Blanco, DJ. Hamilton, 2018, Advanced Science 5(3):1700530.
[7] HR. Kim, HB. Cho, S. Lee, JI. Park, HJ. Kim, KH. Park, 2023, Biomaterials. 302:122350.

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TEC-PO-040

Structure and formation thermodynamics of Cu(II) and Co(II) complexes with nitrate and chloride anions in the [C_4mim][Tf_2N] ionic liquid

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The coordination chemistry of transition metal ions in ionic liquids (ILs) attracted much attention in the last two decades, due the numerous applications, such as selective separations for hydrometallurgical processes[1], electrodepositions, energy storage and catalysis.[2] Ionic liquids (IL) are salts existing in the liquid state at temperatures < 100°C which have been considered for many applications as alternatives to classical organic solvents owing to their numerous interesting features[3]. Among the hydrophobic ILs, those based on the alkylimidazolium (C_nCmim^+) cation and bis(trifluoromethylsulfonyl)imide (Tf_2N) anion have been studied both for metal extractions, energy storage and as solvents for electrodepositions in recent years.[4] The knowledge of the metals speciation in ILs, especially in presence of common inorganic ligands (e.g. Cl^-, NO_3^-), is essential to understand their properties and behavior. In the present communication, we report our recent results on the complex formation between Cu(II) and Co(II) ions and Cl^- and NO_3^- anions in the 1-butyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide ([C_4mim][Tf_2N]) ionic liquid. Spectrophotometric titrations (Figure 1) and ITC were employed to obtain the thermodynamic parameters related to complex formation. Theoretical and spectroscopic studies were employed to obtain structural information.

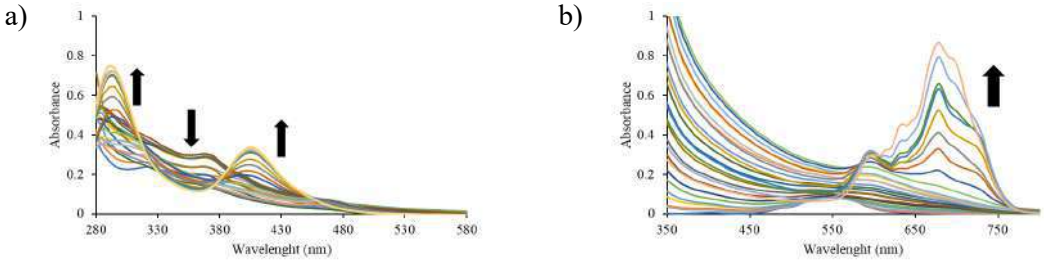

Figure 1. Spectrophotometric titration of a) Cu^{2+} and b) Co^{2+} with Cl^- in dry [C_4mim][Tf_2N]

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References:

[1] M.R. Asrami, N.N. Tran, K.D.P. Nigam, V. Hessel, Sep. Purif. Technol. 2021, 262, 118289.
[2] Singh, S. K., & Savoy, A. W. J. Mol. Liq. 2020, *297*, 112038.
[3] S. Zhang, N. Sun, X. He, X. Lu, X. Zhang JPCRD 2006, *35*(4), 1475-1517.
[4] M. Busato, P. D'Angelo, A. Lapi, M.Tolazzi, A. Melchior J. Mol. Liq. , 2020, 299,112120

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TEC-PO-041

Formulation of new biodegradable films for food packaging based on Polybutylene Succinate (PBS)

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Food waste, marine and environmental pollution are global problems that have been of particular interest to the scientific community in recent years. The increase in world population and the consequent consumption of non-reusable materials are amplifying these problems.

In this communication we present a series of bioplastics, which are completely biodegradable and environmentally friendly, with the goal of replacing fossil fuel-based packaging and slowing the degradation of food.

In fact, thin films based on Polybutylene Succinate (PBS) have been prepared and different weight percentages (1.2 and 3%$_{wt}$) of extra virgin olive oil (OO) and extra virgin coconut oil (CO), were added to improve the chemical and physical properties of the polymer and slow down the aging of fruit and vegetables. Attenuated total reflectance Fourier transform infrared (ATR/FTIR) spectroscopy was used to evaluate the interactions between the polymer and oil. Furthermore, the mechanical properties and thermal behaviour of the coating films were evaluated as a function of the oil content. SEM images showed the surface morphology of the materials. Finally, food-contact tests were carried out to assess the performance of the oil-enriched films.

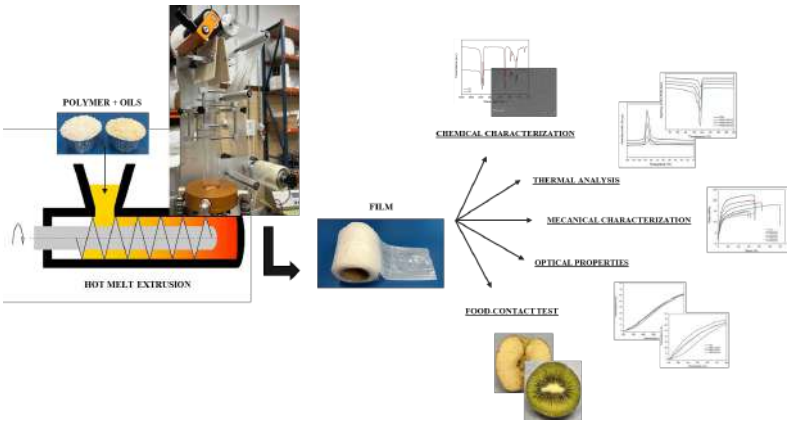

Figure 1: Flowchart of preparation of functionalized films

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TEC-PO-042

Recyclable bio-based epoxy/acrylate blends for Liquid Crystal Display 3D printing: design, preparation and characterization

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Bio-based epoxy resins are widely utilized in various application fields such as adhesives, coatings, composites, and electrical components, offering comparable performance characteristics to conventional epoxy resins, including high strength, durability, and chemical resistance [1-3]. The use of bio-based materials in 3D printing has been receiving increasing attention as a means of reducing the environmental impact of this technology, because most formulations available for stereolithography (SLA) and digital light processing (DLP) are generally non-renewable [4-6]. This study aimed to explore the potential of blending a bio-based epoxy resin with a commercial daylight-curable resin at various weight percentages to enhance the thermomechanical properties of 3D-printed parts while adhering to the working principle of LCD (Liquid Crystal Display) printers. The prepared formulations were initially characterized in terms of their thermo-mechanical properties both before and after post-treatments like photo- and thermal-curing. This procedure facilitated a comparison of the various blends based on their mechanical strength, glass transition temperature, and other pertinent properties. Upon identifying the optimal formulation, 3D-printed samples were produced using LCD printing technology. Calorimetric and morphological tests were then carried out to evaluate the thermal stability and microstructure of the printed parts. Overall, the findings of this study indicate that blending recyclable bio-based epoxy resins with commercial ones can lead to enhanced properties in additive manufactured parts. This approach has the potential to promote sustainability in 3D printing by reducing the consumption of non-renewable resources, while still meeting the standard performance required for numerous applications.

The research was partially funded by the European Union (NextGeneration EU) and MUR-PNRR project Sicilian MicronanoTech Research And Innovation Center – SAMOTHRACE (CUP E63C22000900006), Spoke 1, WP 1.6.2 and partially funded by the MUR under the grant scheme PRIN with the project TARGET "addiTive mAnufactuRing for liGhtwEight joinTs" (grant number 2020E3XL47_003, CUP E63C20011220001).

References:

[1] I. Blanco, R. Pantani, A. Pizzi, A. Sorrentino Polymers 2020, 12(8), 1721.
[2] L. Guadagno, M. Raimondo, M. Catauro, A. Sorrentino, E. Calabrese J Therm Anal Calorim 2022, 147, 5463–5472.
[3] C. Di Mauro, A. Genua, A. Mija Ind. Crops Prod 2022, 185, 115116
[4] G. Cicala, D. Giordano, C. Tosto, G. Filippone, A. Recca, I. Blanco, Materials, 2018, 11(7), 1191
[5] I. Blanco J Compos Sci 2020, 4(2), 42
[6] I. Blanco, G. Cicala, G. Recca, C. Tosto, C Entropy, 2022, 24(5), 654

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TEC-PO-043

A paper-based vapoluminescent chemosensor based on a Zinc(II) salen-type complex for the selective and sensitive detection of *n*-butylamine vapours

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Aliphatic amines are widely involved in chemical industries and their presence in food products is often related to food spoilage processes. Furthermore, aliphatic amines with short chain length (C2 – C6) possess high volatility and toxicity at low concentrations (ppm). Among them, *n*-butylamine (BA) is used in chemical industries as reactant, or intermediate in many synthetic routes. Because of its high volatility (93 mmHg at 25 °C) the main risk for human health is the inhalation. Prolonged exposure to this amine vapours can cause nausea, vomiting, and, in some cases, damage to the nervous system. For this reason, its quantitative detection is very important for human safety.

To this end, a Lewis acidic Zn(salen)-type complex[1,2] was chosen for the development of a new molecular material with vapoluminescent properties, as potential chemosensor for vapour-phase detection of BA. A paper-based sensor, fabricated by the dip-coating technique using THF solutions of the complex, was used for the quantitative detection of BA vapours. Static exposure experiments, show a linear response between 0 and 50 ppm, with a limit of detection of 2.0 ppm, below the permissible exposure limit (5 ppm) established by OSHA for BA. The effect of exposure time, exposure temperature and relative humidity on the sensor performance was also evaluated. Competitive experiments demonstrate the high selectivity of this sensor towards BA. In summary the developed paper-based sensor of the Zn(II) complex represents a simple, disposable, and cost-effective chemosensor for the selective and sensitive direct in-situ detection of BA vapours.

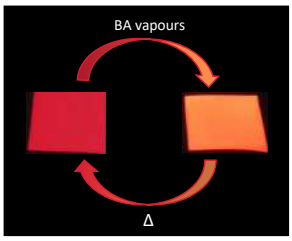

Figure 1: Fluorescence emission changes of paper-based sensor before and after exposure to BA vapours.

This research is funded by European Union (NextGeneration EU), through the MUR-PNRR project SAMOTHRACE (ECS00000022).

References:

[1] G. Consiglio, S. Failla, I. P. Oliveri, R. Purrello, S. Di Bella, *Dalton Trans*. 2009, 10426–10428.
[2] I. P. Oliveri, G. Malandrino, S. Di Bella, *Inorg. Chem*. 2014, *53*, 9771–9777.

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TEC-PO-044

Optimization of Carbon-based Electrodes for Energy Storage and Conversion

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Electrochemical energy storage and conversion devices are crucial for providing solutions to clean and green energy sectors, particularly for decarbonizing industry and long-range transport sectors. Among those devices, Metal-Air Batteries (MAB) and Microbial Fuel Cells (MFC) represent unique added values regarding sustainability, for the possibility of using oxygen from air at the cathode side and organic waste as a fuel in the case of MFC [1,2].

The critical challenges for developing MAB and MFC are the intrinsically slow kinetics of oxygen reduction at the cathode side, leading to the need to use efficient electrocatalysts. However, using critical raw materials (CRMs), such as platinum-group metals, at the cathode side jeopardizes sustainability and increases costs. By developing an efficient electrode design for MAB and MFC performance enhancement, CRM-based cathodic catalysts should be replaced with CRM-free materials [3].

This work proposes developing and optimizing iron-based air cathodes to enhance oxygen reduction at the cathode side of Zinc-Air Batteries (ZAB) and MFC. By subjecting iron phthalocyanine and carbon black pearls to controlled thermal treatments, we obtained Fe-N-C electrocatalysts with high surface area (628 m2g-1) and high oxygen reduction in both near-neutral pH and an alkaline environment. The electrocatalysts were integrated on carbon cloth and carbon paper to obtain gas diffusion electrodes, the architecture of which was optimized to maximize MFC and ZAB performance. The optimization was performed by screening different commercial carbon gas diffusion electrodes (carbon cloth and carbon paper), investigating the effect of hot pressing the catalyst layer, and the pore size of the current collector.

When assembled at the cathode side of a ZAB, the Fe-based cathode showed an excellent galvanostatic polarization discharge peak power density (PPD), outperforming the Pt/C benchmark electrocatalyst.

Moreover, the optimized electrode also showed promising features as cathode for energy recovery in an MFC: a good performance was obtained in MFC: for the Fe-based carbon paper (1028 mWm^{-2}, as PPD) as compared to a traditional electrode design based on carbon cloth (619 mWm^{-2}).

Acknowledgments:

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References:

[1] B. Ricciardi, et al., Carbon 219 (2024) 118781.
[2] W. Freitas, et al., Bioelectrochemistry, 146 (2022) 108103.
[3] W. Freitas et al., Chem. Eng. J. 465 (2023) 142987.

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Strategic metals recovery from spent lithium-ion batteries: a new technology based on microwaves

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To achieve the energy transition targets, it is estimated that by 2050 the demand for lithium, cobalt and graphite will increase by 506%, 460% and 417%, respectively. Considering that these elements are included in the list of raw materials at risk of exhaustion it is essential to recycle. This work proposes a new microwave (MW) treatment of spent lithium-ion batteries (LIBs), for strategic metal recovery (Li, Mn, Ni and Co) by carbothermic reduction, involving short treatment times[1]. The dedicated MW device, consisting of a refractory chamber and a susceptor, allows to increase the equipment thermal insulation, to recover the MW energy furnished to a carbothermal reduction reaction. Figure 1 reports the layout of the proposed recycling process based on the black mass (BM) leaching with water and environmentally friendly organic acid (L-malic acid), after the MW treatment, for the simultaneous extraction of Li (mainly in water), Ni, Co, and Mn.

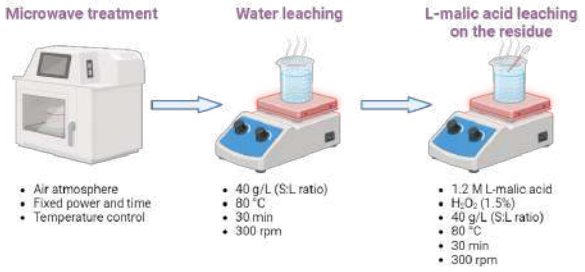

Figure 1: Scheme of the metals recovery procedure. (Figure created with BioRender.com).

The first experiments performed on LCO ($LiCoO_2$) batteries show that the MW treatment at 600 W for 5 min increased Li recovery, reaching 85%. This result encourages the development of MW technology able to reach high temperatures in a short time, compared to pyrometallurgical processes.

This study was carried out within the MICS (Made in Italy – Circular and Sustainable) Extended Partnership and received funding from Next-GenerationEU (Italian PNRR – M4 C2, Invest 1.3 – D.D. 1551.11-10-2022, PE00000004).

References:

[1] M. Scaglia, A. Cornelio, A. Zanoletti, D. La Corte, G. Biava, I. Alessandri, A. Forestan, C. Alba, L. E. Depero and E. Bontempi, Batteries, 2023, 9, 536.

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New memory-shaped materials based on PBS and PPAz for ophthalmic suture.

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Memory-shaped polymeric sutures have recently emerged as a promising innovation in ophthalmic surgery. These sutures are designed to have shape memory, allowing them to revert back to their pre-programmed shape after being stretched or deformed. This unique property allows for improved wound closure and enhanced tissue healing in surgeries, like ophthalmic ones. The ability of memory-shaped polymeric sutures to provide controlled and precise tension during the healing process significantly contributes to better surgical outcomes. Additionally, the use of this kind of sutures eliminates the need for knot tying, reducing the risk of post-operative complications such as suture slippage[1]. Furthermore, the biocompatibility and biodegradability of these sutures make them suitable for use in ophthalmic field, where long-term tissue support is not required.
In detail, a shape memory material requires a rigid phase with a sufficiently high melting point that can maintain the permanent shape, together with a soft phase that can create the temporary shape. In the present study, poly(butylene succinate), PBS, was used as the hard segment, being characterized by high crystallinity, high elastic modulus, high melting temperature and proven biocompatibility[2]. The soft segment was made of poly(propylene azelate), PPAz, a flexible aliphatic polyester with a melting point near body temperature.

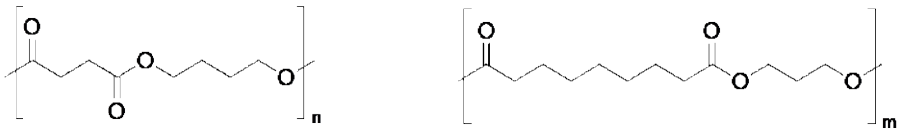

Figure 1*: Chemical structure of PBS (on the left) and PPAz (on the right).*

In this context, the synthesis of the two homopolymers (Figure 1) was carried out by a two-stage melt polycondensation process. A physical blend and a block copolymer were obtained by dissolution in a common solvent and reactive blending (for 13 minutes), respectively, from a 50:50 weight ratio of the two homopolymers. Compression moulding was then used to process the materials into films. Chemical characterisation was carried out by Nuclear Magnetic Resonance (NMR) and Gel Permeation Chromatography (GPC), while the crystallinity was analysed by Wide Angle X-ray Scattering (WAXS). Thermal analyses including Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA) were also performed. The mechanical properties of the materials were also investigated and preliminary shape memory analyses were successfully carried out. Hydrolytic degradation and cell viability studies were also performed.

References:

[1] T. A. Kuznetsova, B. G. Andryukov, N. N. Besednova, T. S. Zaporozhets, A. V. Kalinin, J. Mar. Sci. Eng., 2020, 481.
[2] M. Gigli, M. Fabbri, N. Lotti, R. Gamberini, B. Rimini, A. Munari, Eur. Polym. J., 2016, 75, 431-460.

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Cellulose-based nanosponges as efficient sorbent materials for minimizing disinfection by-products in drinking water

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Nowadays, there is a growing awareness of the impact that climate change is having not only on the quantity of water, but also on its quality. Among the several implications that this phenomenon generates, a critical aspect refers to the provision of safe drinking water to guarantee human health security. In fact, worldwide both surface water and groundwater are the predominant sources for drinking water supply. The continuous increase of background natural organic matter (NOM), chemicals and microbial contaminants due to climate change asks for the development of more efficient and specific treatments for their removal.

For these reasons, disinfection of drinking water before distribution could take on an increasingly important role in the upcoming years for providing a microbially safe water. However, disinfection by-products (DBPs) can be formed, depending the presence on natural organic matter (NOM), which is one of the main DBPs precursors, representing in turn an additional risk for human health.

Among the different approaches suggested to overcome this issue, the development of effective adsorption-based processes to remove NOM before disinfection is a promising route. In the last decade, we have developed a new class of cellulose-based nanoporous materials which resulted particularly effective for the decontamination of wastewater and seawater from a wide range of both heavy metals[1] and organic contaminants.[2] They result from the covalent cross-linking between cellulose nanofibers and polyamine polymers.[3]

Herein we report a purposely designed new family of cellulose nanosponges (CNS) for NOM sorption before undergoing disinfection of water intended for human consumption, as part of the results obtained within the ongoing EU project SafeCREW (Climate-resilient management for safe disinfected and non-disinfected water supply systems), funded by the European Union under grant agreement No 101081980.

The removal efficiency by CNS has been verified on water matrices spiked with custom NOM solutions, resulting even higher than that measured with both micro- and meso-porous powdered activated carbons, selected as referent adsorbing materials.

References:

[1] A. Fiorati, G. Grassi, A. Graziano et al., J. Clean. Prod. 2020, 246, 119009.
[2] L. Riva, N. Pastori, A. Panozzo et a., Nanomaterials, 2020, 10, 1570.
[3] C. Esposito, G. L. Russo, L. Riva et al., Env. Poll. 2023, 334, 122169.

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TEC-PO-048

Photocatalytic Degradation of recovered micro/nanoplastics by membrane processes

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Plastic pollution has become one of the most global graves environmental issues for their impact on the environment and on human beings[1]. The significant and continuous increase of plastics waste require an implement strategy for the reduction/elimination of plastic pollutants. In this work an innovative system that combines the membrane separation and the photocatalytic process for the treatment of polyester-polluted water is proposed (Figure 1). The complete recovery of fibres from water and the almost complete recovery of the initial performance of the membrane used (CA 2 kDa NF) with a cleaning efficiency of 98% and a low fouling index (16%) was obtained. Preliminary photocatalytic tests on some polyester fibres, recovered by a membrane process, showed a decrease in their length and in the weight, the photocatalytic decomposition was confirmed also by py-GCMS characterization[2], highlighting the potential of the photocatalytic process to degrade micro/nanoplastics. The obtained results suggested that the photocatalytic process can be tuned to allow the decomposition of micro/nanoplastics avoiding the use of dangerous and costly methods such as the thermal process that can produce toxic by-products. Future work will be directed toward the optimization of an integrated separation/photocatalytic process for the treatment of micro/nanoplastics from polluted water.

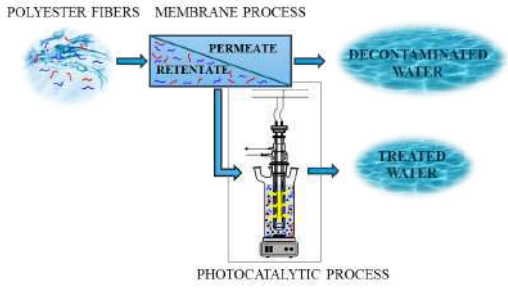

Figure 1: Scheme of the recovery by membrane and photocatalytic decomposition of polyester fibres.

References:

[1] T. Poerio, E. Piacentini, R. Mazzei, Molecules 2019, 24, 4148.
[2] T. Poerio, C. Lavorato, A. Severino, B. Russo, R. Molinari, P. Argurio, A. Figoli, Available at SSRN: https://ssrn.com/abstract=4763919 or http://dx.doi.org/10.2139/ssrn.4763919.

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TEC-PO-049

PVDF coated membrane for improved saline water treatment

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MEloDIZER is a European project, funded by the European Union under the Horizon Europe programme, with the overall aim of providing the necessary step to transform membrane distillation (MD) into products that benefit industry and society[1].

To do this, the heart of the research will focus on providing high-performance membranes and modules through the use of components (such as polymers, solvents, functionalization materials, etc.) that can be used on a large scale but which at the same time are sustainable (replacing current potentially harmful materials with non-harmful ones and following the principles of green chemistry)[2]. The best design of this technology, when combined with the most appropriate mix of renewable energy resources, will be the key to its effective application in different fields, both in industry and on a domestic or community scale.

To this end, two different paths were followed in the creation of new membranes. The first involves the creation of flat PVDF-based membranes through the use of non-toxic solvents instead of classic solvents (e.g. N-butylpyrrolidone with the trade name Tamisolve). The second path involved the study of the coating of commercial PVDF membranes in order to improve MD performance. Fluorinated oligomer (PFPE) was chosen as the coating, with the trade name Fluorlink®. Fluorolinks were selected for their high chemical resistance, water-oil repellency, tendency to increase hydrophobicity and chemical energy, and low surface tension[3].

The performance of PVDF membranes was evaluated in MD devices where different concentrations of salt were used as feed. Specifically, direct contact and vacuum membrane distillation were used to test coated and uncoated membranes. When the PFPE coating is present on the PVDF membranes, an improvement in hydrophobicity was achieved. For example, in the case of the commercial PVDF membrane, the contact angle increases from 132 to 150°. These results indicate an improvement in the wetting resistance of the membranes during long-term MD tests (membrane tested for 60 hours without wetting). In fact, in the case of 0.6M NaCl solution as feed, the flow obtained with the coated membrane appears more stable than the uncoated membrane (average flow of 8.42 and 8.14 L/m^2*h, respectively). Furthermore, salt rejections range from 99.99 to 100% for the uncoated membrane and 100% for the coated membrane. The results obtained, within the Melodizer project, encourage the implementation of high-performance membranes and modules in strategic membrane distillation applications, thus providing the decisive step for the success of MD.

References:

[1] https://www.melodizer.eu/.
[2] Zou D., Nunes S.P., Vankelecom I.v, Figoli A. Lee Y.M. Green Chem., 2021, 23, 9815-9843
[3] Figoli A., Ursino C., Galiano F., Di Nicolò E., Campanelli P., Carnevale M.C., Criscuoli A., Journal of Membrane Science, 2017, 522, 192–201

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Microwave assisted synthesis of polypyrrole-polyketone copolymers for electrochemical applications as anion exchange membranes

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As the core component of alkaline fuel cells (AFC), anion exchange membranes (AEMs) have to withstand a strongly reactive alkaline environment[1]. Among the proposed polymeric material proposed not only to show good chemical stability but also to provide high ion conductivity, polypyrrole-polyketone copolymers enjoy an easy synthetic procedure and a low-cost starting material, polyketone[2,3]. A drawback in the application of the Paal-Knorr reaction to link the amino (then turned into ammonium) functionality is the need for long reaction times when using conventional heating systems. We studied the possibility to reduce reaction time and energy consumption by applying alternative heating/reaction modes, in particular with the use of a microwave reactor. Here we report the preparation of some derivatives characterized by heterocyclic ammonium groups, prepared by varying the amine/PK molar ratio to influence the degree of functionalization, f (Figure 1). The polymers have been cast to produce anion exchange membranes after quaternization and anion exchange.

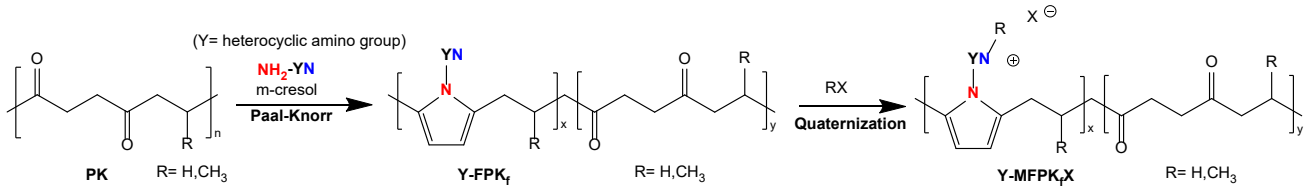

Figure 1: Synthetic scheme for the copolymer preparation (f = degree of functionalization).

The membraned have been characterized to understand their chemical composition, thermal and conduction properties proving the efficacy of the devised synthetic procedure in obtaining AEMs with promising ion conductivity.

References:

[1] P. Sgarbossa, G. Crivellaro, F. Lanero, G. Pagot, A.R. Alvi, E. Negro, K. Vezzù, V. Di Noto, Membranes for Fuel Cells in "Electrocatalysis for Membrane Fuel Cells: Methods, Modeling, and Applications", Wiley Ed. 2023, 227-285.
[2] G. Nawn, K. Vezzù, G. Cavinato, G. Pace, F. Bertasi, G. Pagot, E. Negro, V. Di Noto, Advanced functional materials 2018, 1706522.
[3] A.R. Alvi, K. Vezzù, G. Pagot, P. Sgarbossa, G. Pace, V. Di Noto, Macromolecular Chemistry & Physics 2022, 223, 2100409.

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From flat-sheet to hollow-fiber theophylline-imprinted membranes

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The technological progress of the modern society as well as the necessity of recovery and recycling precious resources allowed the development of more and more efficient and sustainable separation materials. In this perspective, a relevant contribution comes from the employment of membrane-based separation systems. In particular, the production of imprinted membranes offers the possibility of achieving a high separation level of targeted compounds. Some example of applications are the selective separation of ions and toxic substances from wastewaters and the recovery of bioactive compounds from food matrices or other sources[1,2].

This work deals with the development of imprinted polymeric membranes for the selective recovery of theophylline (THEO) from water samples containing also the structural analogue caffeine (CAFF). Theophylline is a xanthine used in the cure of asthma, chronic obstructive pulmonary disease and chronic bronchospasm[3,4]. Firstly, flats-sheets imprinted membranes were prepared *via* the non-solvent induced phase inversion technique by dispersing different amounts of a pre-synthesized imprinted polymer in a modified poly(ether ether ketone) (PEEK-WC) polymer solution. Molecular recognition investigations carried out in aqueous environment permitted to assess the specific recognition properties of the imprinted membranes with respect to the simple (PEEK-WC)-based membranes and the non-imprinted membranes prepared under the same operating conditions. Starting from these results, the phase inversion technique was also applied for producing novel hybrid hollow-fiber imprinted membranes containing the 5% of THEO-imprinted polymer with respect to the (PEEK-WC). Membranes were prepared at two different compositions of bore fluid and using water as the non-solvent.

References:

[1] L. Donato L, I.I. Nasser, M. Majdoub, E. Drioli, Green chemistry and molecularly imprinted membranes, Membranes, 2022, 12, 472, https://doi.org/10.3390/membranes12050472.
[2] L. Donato, E. Drioli, Imprinted membranes for sustainable separation processes, Front. Chem. Sci. Eng., 2021, 15, 775-792.
[3] C. Algieri, O.I. Parisi, M.R. Gullo, F. Puoci, E. Drioli, L. Donato, Development of novel hybrid imprinted membranes for selective recovery of theophylline, Sep. Purif. Technol., 2018, 192, 513-519.
[4] P.J. Barnes, Theophylline for COPD, Thorax, 2006 61(9), 742-744.

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TEC-PO-052

Synthesis and characterisation of lignin-based hydrogels for the removal of emerging pollutants from wastewater

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Lignin is the second most abundant organic polymers on Earth and consists of cross-linked aromatic units called "lignols" [1]. Nowadays, most lignin is pyrolysed as biomass. However, new possibilities for its application have recently opened, including its use as a component of hydrogels for drugs removal from wastewater due to its adsorption and retention properties [2].

In this study, LS_pAAm hydrogel was synthesised from lignin sulfonate and acrylamide by a free radical copolymerisation, using N,N′-Methylenebisacrylamide as the crosslinking agent. In addition, a hydrogel with cationic functionalities (LS_pAAm_DAC) was obtained by free radical grafting with Acryloxyethyltrimethyl Ammonium Chloride (DAC) of the main chains of the copolymer LS_pAAm.

Physical-chemical characterisation of the prepared hydrogels (Infrared Spectroscopy, Scanning Electron Microscopy, Differential Scanning Calorimetry and Thermal Gravimetric Analysis) confirmed the obtainment of a porous material able to incorporate high amounts of water and, in the case of LS_pAAm_DAC, with the cation the DAC quaternary ammonium moiety.

The cationic LS_pAAm_DAC hydrogel, which showed a higher swelling degree than LS_pAAm one, was tested for the removal of the model drug Diclofenac in its anionic form (DCF-Na) and showed a Removal Efficiency of 85% after incubation with a 30 mg/L aqueous solution of DCF-Na.

The kinetic of DCF-Na removal as well as the isotherm adsorption were also studied: the removal follows a pseudo-second order kinetic whereas a linear absorption of the drug by the hydrogel is suggested.

References:

[1] Yunlong, L. et al., “Recent advances in lignin-based porous materials for pollutants removal from wastewater”, International Journal of Macromolecules 2021, 187, 880-891.

[2] Wei, S. et al., “Synthesis of a Functional Biomass Lignin-Based Hydrogel with High Swelling and Adsorption Capability towards Acid Red 73”, Environmental Science and Pollution Research 2021, 28, 51306–53120.

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TEC-PO-053

Toward green development of polymeric and hybrid nanoparticles by membrane processes

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Although technological progress has brought undeniable benefits, it has generated some issues related to the excessive exploitation of planet's resources and to the resulting effects on environment and human health. In reply to this concern, there has been a growing focus on a new concept of industrial advancement which could integrate economic growth with social and environmental responsibility, converting old technologies into new eco-friendly processes. Membrane technologies play a dominant role in offering a valid solution to the aforementioned problems and they are currently proposed as greener alternative productive processes in different field. Membrane nanoprecipitation (MN) is emerging as sustainably manufacturing method to formulate different polymeric particulate materials. The process is based on the precipitation of the polymer as a form of nanoparticles (NPs) due to the solvent- non solvent mixing at the membrane pores level; these products could find application in various sectors. MN is recognized as environmentally friendly method because allows to operate using few steps, minimizing energy consumption and waste output.[1] MN has been extensively studied to produce hydrophobic NPs, while limited literature data have been reported for hydrophilic ones. To fully explore the potentiality of the technology in this field, two case-studies will be presented in this study focus on the use of MN for the development of 1) chitosan NPs for the encapsulation of organic bioactive molecules and 2) hybrid materials in which inorganic components are enveloped within the polymeric shell. Chitosan has been selected as biopolymer material for its relevant role among the hydrogel carriers for drug delivery and because its positive charge allows electrostatic interactions with not only organic, but also inorganic compounds with the purpose of creating hybrid structures. A methodical investigation on chitosan NPs preparation by MN will be discussed examining the results in terms of uniform distribution, particle size and productivity, encapsulating a protein (BSA) as model. The MN will be also studied for the production of hybrid particles using zeolites as anionic models. The effect of the type of reagents and their concentration will be analyzed. The sustainability impactful of the process will be evaluated by calculating the energy consumption, the environmental factor (E-factor) for the two cases studies presented and the results will be compared with conventional methods used in the field.

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References:

[1] E. Piacentini, B. Russo, F. Bazzarelli, L. Giorno, Journal of Membrane Science 2022, 654, 120564.

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TEC-PO-054

Development of biofunctionalized membrane-based platforms to enhance recognition selectivity and sensitivity of sensing systems

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To achieve more selective and effective management in the detection of traces of small molecular weight micropollutant (SMWMP) in aqueous phase, the development of biosensors built on biofunctionalized membrane-based platform has attracted considerable attention. The introduction of the membrane with appropriate chemical-physical characteristics into the biosensor architecture contributes, in fact, to support the bioreceptor in a well-defined structure, regulate the analyte transport, promote the bioreceptor-analyte interaction, increase the analyte concentration, act as a microenvironment that aids the transduction of the biochemical interaction into a physical signal.

In this work, phosphotriesterase enzyme (PTE) was used as a model bioreceptor to selectively recognize the pesticide paraoxon (as SMWMP model). PTE was covalently linked on various home-made and commercial membranes (polyvinilidene fluoride - PVDF, polyvinylidene fluoride/alkali lignin - PVDF/AL, regenerated cellulose - RC, and polyamide - PA) using glutaraldehyde as crosslinker[1]. The activity and stability of the biofunctionalized membranes were monitored over time. Adsorption experiments of paraoxon (substrate) and p-nitrophenol (product) on membranes enabled us to design strategies for sensing systems.

RC and PA membranes were selected for the membrane-based sensing systems development as they showed the highest specific enzyme activity after biofunctionalization. Due to the chemical composition differences between the membranes, RC membrane showed no adsorption of either the substrate or the product, while the PA membrane adsorbed only the latter (turning yellow). A colorimetric detection is provided for both the developed platforms using two different detection instruments: a UV-Vis spectrophotometer for RC membrane and a color detector for PA membrane. The lecture will discuss the strategies investigated to enhance sensing selectivity and sensitivity.

Acknowledgments:

The authors thank for the financial support the project “Tech4You - Technologies for climate change adaptation and quality of life improvement” – Ecosistemi dell’Innovazione – PNRR M4C2.

Reference:

[1] G. Vitola, R. Mazzei, L. Giorno, Journal of Membrane Science 2021, 635, 119438.

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TEC-PO-055

Partial hydrogenation of waste cooking oil biodiesel by steel slags based iron oxides/nickel catalysts

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There are several sustainability issues that the scientific community must tackle by giving high priority to the implementation of the circular economy concept. Wastes can be reused to obtain high-value products and in this context, steel slags, due to their chemical properties, can play a significant role in catalysis by contributing to the reduction of solid wastes.[1] On the other hand, converting waste biomass, such as spent cooking oil, into valuable biofuel perfectly fits green chemistry principles and follows the attempts of the world decarbonization.[2] In this framework, the present work reports on the synthesis and characterization of new materials constituted of iron oxides and nickel nanoparticles deposited onto waste steel slags to be used as catalysts for the partial hydrogenation of FAMEs (Fatty Acid Methyl Esters) coming from waste cooking oil. The partial hydrogenation reaction aims at selectively converting all C18 polyunsaturated esters of the FAMEs mixture into C18:1 monounsaturated product, avoiding the formation of C18:0 methyl stearate (Figure 1), thus upgrading the biodiesel parameters of the whole blend.

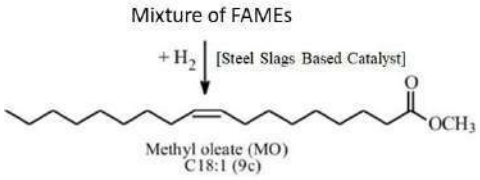

Figure 1: Hydrogenation reaction of FAMEs

The novel catalysts were characterized by Thermogravimetric Analyses (TGA), Scanning Electron Microscopy (SEM), Fourier Transform-Infrared Spectroscopy (FT-IR), X-Ray Diffraction (XRD) and Transmission Electron Microscopy (TEM) analytical techniques.

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References:

[1] M. Casiello, O. Losito, Catalysts 2021, 11, 619
[2] A.M. Fiore, G. Romanazzi, Catalysts 2022, 12, 506

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Preparation of PVDF membrane with DMI green solvent for membrane distillation

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Poly(vinylidene fluoride) (PVDF) flat sheet membranes were prepared by using the Dimethyl isosorbide (DMI) as the green solvent via NIPS-VIPS method. DMI is a high boiling green solvent that possess good physical/chemical properties for the casting membrane. The PVDF membranes were prepared at the temperature of 120 ºC to obtain the completely homogeneous solution. After degassing of about 2 h, the casting solutions were casted by the casting knife on the glass, with the air gap of 250 μm at the temperature of 90 ºC in a climate chamber, where the relative humidity is 65% and the temperature is 25 ºC [1]. A series of membranes were prepared by varying the exposure time in the humidity, which is 0, 1, 1.3 and 2.5 mins, respectively. The membranes were characterized in terms of thickness, porosity, contact angle, mechanical strength and SEM morphologies. The membranes were applied in direct contact membrane distillation (DCMD) operations. Feed temperatures were set at around 40, 50 and 60 ºC respectively for pure water membrane distillation tests. Fluxes were increased with feed temperatures. Results achieved until now showed that, the membrane prepared under 1.3 mins in the humidity chamber presented high fluxes at around 13 L/m^{2}h, and rejections above 99.9% in the 0.6 M NaCl solution DCMD test, which is operated at the feed temperature of 40 ºC and permeate side temperature of 15 ºC.

References:

[1] F. Russo, F. Galiano, F. Pedace, F. Aricò, A. Figoli, ACS Sustainable Chem. Eng. 2020, 8, 659 – 668.

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Effective Cu/Steel Slag catalyst for nitroarenes reduction in aqueous medium

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The application of waste materials as catalysts holds significant relevance in the field of sustainable chemistry and green synthesis. Steel slags are a waste-product of the steel manufacturing process, originating from the extraction of molten steel from contaminants in steel production furnaces.[1] This slag material exists in a molten liquid state as a solution of silicates and oxides, which undergoes solidification upon cooling. Its chemical composition typically comprises calcium, silicon, iron, aluminium, magnesium, and their oxides. Given to their extensive composition, alkaline characteristics, and good mechanical properties, herein steel slags were chosen as valuable catalyst support for an important organic reaction, such as the reduction of nitroarenes. Copper was selected as the active component for catalysis among transition metals, due to its high level of activity, abundance, and relatively moderate cost.[2]

A novel Cu/SteelSlags catalyst was obtained by mixing copper sulphate pentahydrate ($CuSO_4 \cdot 5H_2O$) solution and sieved steel slags powder for 2 hours. The precipitation of copper hydroxide onto steel slags occurred without the addition of any further alkaline compound. The transformation of the active component from copper (II) to copper (0) nanoparticles occurred in-situ under reductive reaction conditions, as evidenced by TEM analyses and by the change of the colour of the catalyst from blue-grey to black.

Catalyst revealed active, selective and recyclable in nitroarene reduction to anilines at room temperature in the presence of $NaBH_4$, as the reductant, in deionized H_2O as the solvent in few hours. Cu/SteelSlags material was characterized by FT-IR, XRD, PXRF, TGA, SEM and TEM techniques before and after the catalytic cycles.

References:

[1] M.M. Dell'Anna, G. Romanazzi, et al., Aquat. Ecosys. Health Manag.2021, 23, 474 – 482
[2] D. Formenti, F. Ferretti, et al., Chem. Rev. 2019, 119, 2611–2680

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TEC-PO-058

Exploring Anticancer Potential: Utilizing 3-Hydroxyflavone and Ethyl Gallate as Platinum Coordinators in Biological Systems

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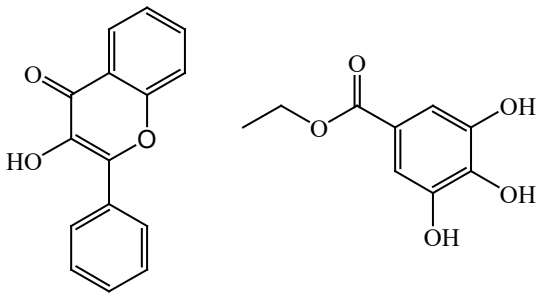
Cisplatin, a widely-used chemotherapy agent, has significant drawbacks, including severe side effects like kidney damage and nerve toxicity. Finding a new platinum drug with better efficacy and fewer side effects remains a key goal in cancer treatment.[1]

The strategic substitution of ligands within cisplatin, incorporating moieties characterized by both biological activity and anticancer potential such as flavones, represents a compelling direction of inquiry. In pursuit of this objective, our research group has synthesized novel complexes aimed at realizing this dual functionality.[2]

3-Hydroxyflavone (3-Hfl) and ethyl gallate (etga) exhibit notable antioxidant, anti-inflammatory, and anticancer properties, making them highly appealing candidates for inclusion as ligands in platinum derivatives. This highlights their potential significance in biomedical research and therapeutic development.[3]



a b

Figure 1: a: 3-Hydroxyflavone (3-Hfl) and b: ethyl gallate (etga)

Acknowledgements: The National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) is acknowledged for financial support (PhD fellowship).

References:

1. I. Kostova, *Frontiers in Anti-Cancer Drug Discovery, Volume (1)*, 2011, **1**, 298-339.
2. V. Vergaro, M. M. Dell'Anna, H. R. Shahsavari, F. Baldassarre, D. Migoni, P. Mastrorilli, F. P. Fanizzi and G. Ciccarella, *Nanoscale Advances*, 2023, **5**, 5340-5351.
3. V. Censi, A. B. Caballero, M. Perez-Hernandez, V. Soto-Cerrato, L. Korrodi-Gregorio, R. Perez-Tomas, M. M. Dell'Anna, P. Mastrorilli and P. Gamez, *Journal of Inorganic Biochemistry*, 2019, **198**, 110749-110761.

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TEC-PO-059

Microwave assisted biodiesel production from waste cooking oil using steel slags as catalyst

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Nowadays, it is vital to find an alternative source of fuel to oil. This presentation deals with the development of an innovative catalytic system for biodiesel synthesis starting from waste biomass (waste cooking oil, WCO) in the presence of waste material (steel slags) as the catalyst.
The importance of this issue is well documented by the presence of many reports on both the use of WCO as a feedstock[1] and a waste as the catalyst[2]. Recently, the use of steel slags as active and selective catalyst for the synthesis of fatty acid methyl esters (FAMEs) by transesterification of soybean oil in methanol under conventional heating (120°C) has been reported to take several hours (12 h) to reach completion[3].
In this study, microwave (MW) irradiation protocols were developed for fast and low energy consuming biodiesel synthesis from WCO in the presence of steel slags. After some preliminary tests, the reaction conditions were investigated and optimized by setting a design of experiment. Time, temperature and catalyst weight were set as factors. The almost quantitative conversion of WCO could be achieved in only 18 min at 134°C. The recyclability of the catalyst and the variations of its structure during cycles were also investigated. Steel slags were characterised by Scanning Electron Microscopy (SEM), Total X-ray Florescence (TXRF), X-Ray Diffraction (XRD) and Thermogravimetric Analysis (TGA).

Acknowledgements: This work has been supported under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 – Call for tender No. 3138 of December 16, 2021 of the Italian Ministry of University and Research, funded by the European Union – NextGenerationEU [Award Number: CNMS named MOST, Concession Decree No. 1033 of June 17, 2022, adopted by the Italian Ministery of University and Research, CUP: D93C22000410001, Spoke 14 "Hydrogen and New Fuels"].

References:

[1] a) L. Nascimento, A. Ribeiro, A. Ferreira, N. Valério, V. Pinheiro, J. Araújo, C. Vilarinho, J. Carvalho, Energies, 2022, 15, 116; b) A. M. Fiore, G. Romanazzi, C. Leonelli, P. Mastrorilli, M. M. Dell'Anna, Catalysts 2022, 12, 506.
[2] W. Nabgan, A. A. Jalil, B. Nabgan, A. H. Jadhav, M. Ikram, A. Ul-Hamid, M. W. Ali, N. S. Hassan, RSC advances, 2022, 12.3: 1604-1627.
[3] M. Casiello, O. Losito, A. Aloia, D. Caputo, C. Fusco, R. Attrotto, A. Monopoli, A. Nacci, L. D'Accolti, Catalysts 2021, 11, 619.

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KEYNOTE LECTURE

Michele Parrinello, Istituto Italiano di Tecnologia

TEO-KN-01

Do we really understand catalysis?

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The transition to a green economy depends critically on the development of efficient catalysts that could for instance help in sequestrating CO2 or producing H2. To reach this goal a detailed understanding of the catalytic mechanism would be of great value. Unfortunately, most industrial catalysis takes place at temperatures and pressures, so high that both experimental and theoretical investigations are challenging. Current theories cannot explain the extreme durability and stability of industrial catalysts under these conditions. In our view the root of this difficulty lies in a static view of the catalytic process in which the catalyst is only seen as a static platform for reaction. We argue instead that industrial catalysts are dynamical entities that, under reaction conditions evolve forming reactive sites with the reagents. Recent technical development, driven by machine learning methodologies, allow realistic and accurate atomistic simulations to be performed. These simulations are validating such a complex dynamical picture, and we find in our simulations that efficient catalysts are better described as functional materials. We focus our attention on the synthesis and cracking of NH3. The final purpose of these studies is twofold. On the one hand one wants to reduce the remarkably large carbon footprint of ammonia production which account for 4% of the global CO2 emission. On the other, having in mind a hydrogen-based economy indicating ways of dissociating ammonia into its constituents nitrogen and hydrogen so as to allow using ammonia to store and transport hydrogen.

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TEO-OR-001

Accurate reduced cost VRC-TST rates for barrierless reaction by means of DFT geometry optimizations, coupled cluster composite methods, and difference-dedicated multireference contributions

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Recent theoretical and hardware developments have turned computational investigations into valuable assets for every chemist's toolkit. Advanced versions of Transition State Theory (TST), Variational Transition State Theory (VTST), and Variable Reaction Coordinate Transition State Theory (VRC-TST)[1] are at the forefront of addressing the complexities of chemical kinetics. While both approaches mitigate the non-recrossing approximation, their effectiveness strongly hinges on the quality of the underlying potential energy surface, with this aspect being particularly daunting for VRC-TST, which relies on a Monte Carlo (MC) phase-space sampling. In this regard, existing strategies are based on *geometric* and *electronic* mono-dimensional *on-the-fly* corrections. The first aims to alleviate the implications of adopting asymptotic fragment structures during MC, whereas the latter tries to overcome the inaccuracy of cheap quantum chemical models. However, this protocol hides intricacies. First, acquiring accurate *reference potentials* can be prohibitive, and establishing the most effective *low level* model for the MC sampling is neither a straightforward nor a black-box process. Second, applying *geometric* corrections may not fully account for the coupling of the reaction coordinate with transitional and conserved modes[2]. Here, we propose an efficient yet accurate solution to these problems. After the acquisition of a suitable wave-function for the single-reference high-spin state by employing the Pisa composite scheme (PCS),[3] the *reference potential* is obtained by adding the energy difference between the high- and low-spin states (*spin-splitting* correction)[4] computed by the Iterative Difference Dedicated Configuration Interaction (I-DDCI)[5] or its perturbative version (I-DDCI-PT2) presented here for the first time. This embodies a rapid basis-set convergence, reduced number of doubly excited configurations, and lack of intruder states interferences. Then, the *geometric* issue is tackled by relaxing the conserved modes during the MC, ensuring they closely match the values of a set of reference geometries. On these partially optimized geometries, the sampled energy is derived at a *low level*, which reduces the electronic correction relative to the *reference potential*. A black-box framework simplifies the time-consuming selection of the appropriate exchange and correlation functional[6].

References:

[1] Y. Georgievskii and S. J. Klippenstein, J. Chem. Phys. 2003, 118, 5442–5455.
[2] J. Zheng, S. Zhang and D. G. Truhlar, J. Phys. Chem. A 2008, 112, 11509–11513.
[3] V. Barone, L. Crisci and S. Di Grande, J. Chem. Theory Comput. 2023, 19, 7273–7286.
[4] C. F. Goldsmith, L. B. Harding, Y. Georgievskii, J. A. Miller and S. J. Klippenstein, J. Phys. Chem. A 2015, 119, 7766–7779.
[5] J. Miralles, O. Castell, R. Caballol and J.-P. Malrieu, Chemical Physics 1993, 172, 33–43.
[6] L. Crisci, S. Di Grande, C. Cavallotti and V. Barone, J. Chem. Theory Comput. 2023, 19, 7626–7639.

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TEO-OR-002

Non-equilibrium dynamical effects on excited states within polarizable environment: perspectives from an open quantum system approach

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The accurate simulation of environment effects in the formation and relaxation of electronic excited states (ES) is still a challenge for theoretical chemistry: from one hand, the time dependent non-equilibrium effects can play a major role for ES properties, from the other, the QM approach used to calculate the excitation can describe in different ways the polarization response of the environment.[1,2] Recently[3] the time dependent problem of a solute described by Quantum Chemistry within an environment represented as a polarizable continuum model (PCM) has been reconsidered in terms of the open quantum systems (OQS) theory.[4] This method can be also extended to polarizable QM/MM approaches, due to the similar formalism with continuum models.[2]

In this talk I will discuss how using a non-Markovian stochastic Schrödinger equation (SSE) formulation,[5] comprehensive picture of the electronic energies and the coupling between solute and environment electronic dynamics is provided, ranging from the limit where the solute electronic dynamics is much faster than the embedding one to the opposite case. [6]

It proves to be a unifying theoretical framework[3] able to describe the delayed solvent response due to the solute charge density reorganization evolving in a time regime. It naturally includes polarization and dispersion interactions, paving the way for development of empirical but effective simpler protocols [7,] that can be used in different applications ranging from biophysics[8] to optoelectronics[9,10].

References:

[1] C. A. Guido, D. Jacquemin, C. Adamo and B. Mennucci, *J. Chem. Theory Comput.* **2015**, 11, 5782-5790.
[2] C. A. Guido and S. Caprasecca, *Int. J. Quantum Chem.* **2018**, 119, e25711.
[3] C. A. Guido, M. Rosa, R. Cammi and S. Corni *J. Chem. Phys.* **2020**, 152, 174114.
[4] H. P. Breuer and F. Petruccione, *The Theory of Open Quantum Systems* (Oxford University Press, 2002).
[5] P. Gaspard and M. Nagaoka, *J. Chem. Phys.* **1999**, 111, 5676.
[6] H. J. Kim and J. T. Hynes, *J. Chem. Phys.* **1992**, 96, 5088.
[7] C. A. Guido, A. Chrayteh, G. Scalmani, B. Mennucci, D. Jacquemin *J. Chem. Theory Comput.* **2021**, 17, 5155-5164.
[8] M. Bondanza, B. Demoulin, F. Lipparini, M. Barbatti, B. Mennucci, *J. Phys. Chem. A* **2022**, 126, 6780-6789.
[9] C. A. Guido, F, Zinna, G. Pescitelli, J. Mater Chem C, **2023**, 11, 10474-10482.
[10] E. Salvi, D. Padula, C. A. Guido, **2024**, *submitted*.

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TEO-OR-003

Real-Time and Strong Coupling between Molecules and a Continuum Environment

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We present here a recently developed real-time approach for accounting for the non-equilibrium interaction between a continuum environment and a molecular system described by the propagation of its wave-function [1] or electronic density [2] respectively at the Real-Time TDCI and TDDFT levels.We reformulated the Boundary Element Method (BEM) for the the description of the molecule-environment interaction using a diagonal representation for the frequency-dependent response matrices. We show that our "diagonal" formulation is equivalent to (i) the Polarizable Continuum Model [3] if the BEM approach is formulated to describe the interaction between a molecule placed in a vacuum cavity within a dielectric medium sourrounding it (ii) an analogous approach developed to describe the response of plasmonic excitations in metallic nanoparticles [4] close to the molecule of interest. In addition, the diagonal approach clearly highlights the connection between BEM-based and multipolar-based description of the interaction potential [1].Moreover our approach provides "equations of motion" in the time domain for the fictitious degrees of freedom (polarization charges) describing the molecule-environment time-dependent interaction that we derived both for a Debye, Drude-Lorentz and general (numeric) continuum response [1,5,7].At last we have exploited the features of the diagonal BEM formulation to quantify the quantum coupling between a plasmon in the medium and an exciton in the molecule [7,8].

References:

[1] S.Pipolo, S. Corni and R. Cammi, JCP 2017, 146, 064116.
[2] S.Pipolo, S. Corni, JPCC 2016, 120, 28774.
[3] S.Corni, S. Pipolo and R.Cammi, JPCA 2015, 119, 5405.
[4] J.Tomasi, B.Mennucci and R.Cammi, Chem. Rev. 2005, 105, 2999.
[5] S.Corni and J.Tomasi, JCP 2001, 114, 3739.
[6] G. Dall'Osto, G. Gil, S. Pipolo, S. Corni JCP 2020, 153, 184114
[7] J. Fregoni, T. S. Haugland, S. Pipolo, T. Giovannini, H. Koch, S. Corni, Nano Lett. 2021, 21, 6664
[8] S. Pipolo, C.A. Guido, S. Corni, in preparation.

TEO-OR-004

Tackling size and complexity of Metal-Organic Frameworks from cheap hybrid DFT methods

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The chemical versatility and modular nature of Metal–Organic Frameworks[1,2] (MOFs) make them unique materials for a wide range of possible applications[3-10]. However, from a computational view point, ab initio modeling of MOFs is a challenging and demanding task, in particular, when the system reaches the size of giant MOFs as MIL-100[11] and MIL-101[12] with several thousand atoms in the unit cell. Here, we show how such complex systems can be successfully tackled by a recently proposed class of composite electronic structure methods revised for solid-state calculations[13]. These methods rely on HF/density functional theory hybrid functionals (i.e., PBEsol0, HSEsol and r2SCAN0) combined with a double-zeta quality basis set. They are augmented with semi-classical corrections to take into account dispersive interactions (D3 scheme[14]) and the basis set superposition error (gCP[15]). The resulting methodologies, dubbed "sol-3c," are cost-effective yet reach the hybrid functional accuracy. Here, sol-3c methods, implemented in the CRYSTAL code[16], are effectively applied to predict the structural, vibrational, electronic, and adsorption properties of some of the most common MOFs. Calculations are feasible even on very large MOFs containing up to 3700 atoms in the unit cell as MIL-100 and MIL-101, with small-scale computing resources (e.g. 80 cores). We propose to use our composite methods for the routine In Silico screening of MOFs targeting properties beyond plain structural features.

References:

[1] J. R. Long, et al., Chem. Soc. Rev. 2009, 38, 1213–1214.
[2] S. R. Batten, et al., Pure Appl. Chem. 2013, 85, 1715–1724.
[3] S. Ma, et al., Chem. Commun. 2010, 46, 44–53.
[4] H. Li, et al., Mater. Today 2018, 21, 108–121.
[5] M. A. Nasalevich, et al., CrystEngComm 2014, 16, 4919–4926.
[6] P. Kumar, et al., TrAC, Trends Anal. Chem. 2015, 73, 39–53.
[7] V. Stavila, et al., Chem. Soc. Rev. 2014, 43, 5994–6010.
[8] M. R. Ryder, et al., ChemPlusChem 2018, 83, 308–316.
[9] P. Horcajada, et al., Nat. Mater. 2010, 9, 172–178.
[10] P. Horcajada, et al., Chem., Int. Ed. 2006, 118, 6120–6124.
[11] G. Férey, et al., Angew. Chem. 2004, 116, 6456–6461.
[12] G. Férey, et al., Science 2005, 309, 2040–2042.
[13] L. Donà, et al., J. Chem. Phys. 2019, 151, 121101.
[14] S. Grimme, et al., J. Chem. Phys. 2010, 132, 154104.
[15] H. Kruse, et al., J. Chem. Phys. 2012, 136, 154101.
[16] A. Erba, et al., J. Chem. Theory Comput. 2023, 19, 6891−6932.

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TEO-OR-005

From Theory to Practice: DFT Insights into Anharmonicity Effects on Vibrational Spectra in Solid-State Chemistry

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We introduce a computational tool for the quantum-mechanical simulation of anharmonic infrared (IR) and Raman spectra of materials.[1] The approach, implemented in the CRYSTAL software,[2] stems from a Taylor's expansion of the potential energy surface (PES) on the basis of normal modes up to cubic and quartic terms. The PES can be sampled with four different numerical schemes at the level of density functional theory (DFT). Anharmonic states are obtained by solving nuclear Schrödinger's equation with either the vibrational self-consistent field (VSCF) or vibrational configuration interaction (VCI) methods. Nuclear quantum effects (NQEs) are thus fully accounted for.[3] IR intensities are computed numerically through a Barry phase approach or analytically through a coupled-perturbed (CP) approach. Raman intensities are computed analytically via the CP approach.

A variety of anharmonic features of vibrational spectra of materials can be simulated, including band shifts, combination bands, overtones, resonances (first order Fermi, second-order Darling-Dennison), and hot bands. We showcase the effectiveness of the approach on the description of a first-order Fermi resonance (FR) in CO_2 dry ice: a challenging test-case given that the FR occurs in the Raman spectrum, requires NQEs, and involves two- and three-mode couplings.[4] Fundamental mechanistic differences with respect to the well-know FR in molecular CO_2 are addressed. This application represents the first quantum-mechanical, periodic description of FR in dry ice.

References:

[1] Mitoli, D., Maul, J., & Erba, A., J. Phys. Chem. Lett., 2024, 15, 888-894.
[2] Erba, A., Desmarais, J. K., Casassa, S., Civalleri, B., Donà, L., Bush, I. J., Searle, B., Maschio, L., Edith-Daga, L., Cossard, A., Ribaldone C., Ascrizzi, E., Marana, N. L., Flament, J.-P., & Kirtman, B., J. Chem. Theory Comput., 2023, 19, 6891-6932.
[3] Markland, T. E., & Ceriotti, M., Nat. Rev. Chem., 2018, 2, 0109.
[4] Cardini, G., Salvi, P. R., & Schettino, V., J. Chem., Phys., 1989, 91, 3869-3876.

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TEO-OR-006

A time averaged semiclassical approach to IR spectroscopy

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Semiclassical vibrational spectroscopy is based on the evolution of classical trajectories and is able to reproduce quantum effects with good accuracy at the cost of a reasonable computational effort.[1-5] Nevertheless, semiclassical vibrational power spectra do not simulate all the features of the experimental IR spectra, since intensities in power spectra are not directly related to IR absorptions. Therefore, we developed a new semiclassical approach to the calculation of molecular IR spectra, by employing the time average technique upon symmetrization of the quantum dipole-dipole autocorrelation function.[6,7] We tested the accuracy of this new method on a few simple analytical systems and small molecules in the gas phase. In particular, spectra in the limit of infinite or zero temperature were investigated. Overall the method features excellent accuracy in calculating absorption intensities and provides estimates for the frequencies of vibrations in agreement with the corresponding power spectra.

References:

[1] R. Conte, A. Aspuru-Guzik, and M. Ceotto, *J. Phys. Chem. Lett.* 2013, 4, 3407.
[2] G. Bertaina, G. Di Liberto, and M. Ceotto, *J. Chem. Phys.* 2019, 151, 114307.
[3] C. Aieta, M. Micciarelli, G. Bertaina, and M. Ceotto, *Nat. Comm.* 2020, 11, 4384.
[4] A. Rognoni, R. Conte, and M. Ceotto, *Chem. Sci.* 2021, 12, 2060.
[5] R. Conte, C. Aieta, G. Botti, M. Cazzaniga, M. Gandolfi, C. Lanzi, G. Mandelli, D. Moscato, and M. Ceotto, *Theor. Chem. Acc.* 2023, 142, 53.
[6] A. L. Kaledin and W. H. Miller, *J. Chem. Phys.* 2003, 118, 7174.
[7] A. L. Kaledin and W. H. Miller, *J. Chem. Phys.* 2003, 119, 3078.

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TEO-OR-007

Exploring Photoinduced Non-Equilibrium Dynamics and Spectroscopy through AIMD Simulations and Wavelet Transform

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Modern scientific research heavily relies on time-resolved vibrational spectroscopic techniques, specifically infrared (IR) and Raman spectroscopies for probing the intricate photoinduced non-equilibrium dynamics of molecular systems and elucidating the underlying mechanisms driving various chemical reactions and biological processes.[1,2] In this contribution we will present an innovative computational approach combining *ab-initio* molecular dynamics (AIMD) with transient vibrational analysis, establishing a time-dependent density functional theory (TDDFT)-based protocol.[3] This protocol offers a groundbreaking capability: the simultaneous description of transient IR and Raman active vibrational modes. To achieve this, we incorporate recent advancements in assessing higher-order TDDFT properties and employ multiresolution time-frequency analysis techniques based on the Wavelet Transform of specific time-series extracted from AIMD simulations, pushing the boundaries of vibrational spectroscopy. To demonstrate the practical utility of our protocol, we will show representative case studies in gas and in condensed phase where we applied these methodologies for investigating the complex interplay between time resolved signals and excited state photodynamics .[4] Through the meticulous analysis of vibrational signatures, we gain a deeper understanding of how nuclear motions act as mediators in the photodynamics of diverse photo-active systems, shedding light on the molecular mechanisms governing these processes. In summary, our computational approach, grounded in TDDFT and advanced vibrational analysis techniques, marks a paradigm shift in the study of ultrafast chemical processes.[5] It allows researchers to delve into the transient structural dynamics of molecules in real time, bridging the gap between theoretical predictions and experimental observations in materials and systems of biological interest.

References:

[1] M. Maiuri et al., *J. Am. Chem. Soc.* 2020, 142, 1, 3–15; S. Mukamel, *Annu. Rev. Phys. Chem*. 2000, 51, 691-729.
[2] E. T. J. Nibbering et al., *Annu. Rev. Phys. Chem.* 2005, 56 337-367; C. Fang et al., *Annu. Rev. Phys. Chem.* 2020, 71, 239-265.
[3] N. Rega, *Theor. Chem. Acc.* 2006, 116, 347-354, A.Petrone et al., *J. Am. Chem. Soc.* 2014, 136, 14866-14874; M.G. Chiariello *J. Chem. Theory Comput.* 2020, 16, 10, 6007-6013.
[4] F. Coppola et al., *J. Phys. Chem. A* 2022, 126, 40, 7179-7192; F. Coppola et al., *Chem. Sci.* 2021, 12, 8058-8072; M.G. Chiariello et al., *Phys. Chem. Chem. Phys.* 2019 21, 3606-3614; F. Coppola et al., *J. Phys. Chem. A* 2024, 128, 9, 1620–1633; R. Carfora, F. Coppola, A. Petrone, N. Rega - *manuscript in preparation.*
[5] A. Petrone et al., *Chem. Phys. Rev.* 2022, 3, 021307.

TEO-OR-008

Excited-state dynamics in Non-Fullerene Acceptors for Organic Photovoltaics

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The efficiency of organic photovoltaics (OPVs) has exceeded 19% with the introduction of non-fullerene electron acceptor (NFA) materials such as Y6 and its derivatives. Despite this progress, a lack of understanding hampers further advancements in material design. This presentation centers on a computational-experimental characterization of application-relevant NFAs. I will discuss how first-principles-based model Hamiltonians and state-of-the-art non-adiabatic molecular dynamics simulations[1,2], which couple the electron-nuclear motion, allow for the accurate reproduction of experimental optical properties in large molecular aggregates and provide important insights. For example, the interplay of charge transfer excitations and Frenkel exciton states in some NFAs was identified as responsible for the broadening and red shift in the absorption spectrum from solution to solid state, contrasting common causes like J-aggregation. These simulations, along with evidence from transient absorption spectroscopy and magnetic resonance spectroscopy, enabled the disentanglement of the complex excited state dynamics in these systems[3]. I will discuss a set of strategies based on our understanding of the solid-state packing's influence on NFA properties for intelligent material design to enhance OPV performance.

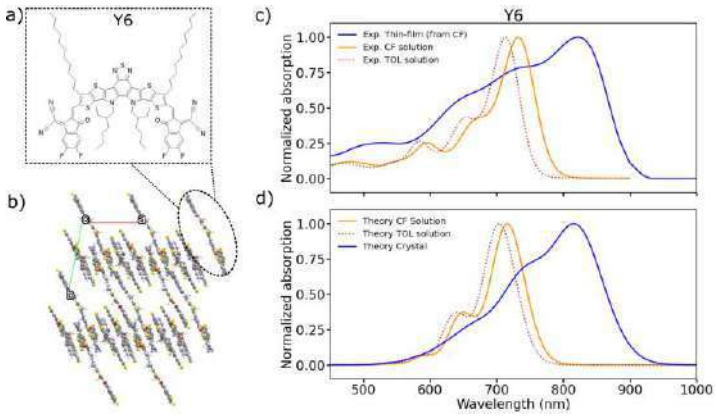

Figure 1: Molecular and **b)** single-crystal structures of Y6, respectively. **c)** Experimental absorption spectra of Y6 in TOL (dashed brown line) and CF solution (solid orange line). **b)** Computed absorption spectra in the same solvents.

References:

[1] Giannini et al. Nat. Commun. (2022) 13, 2755
[2] Giannini et al. Nat. Mat. (2023) 22, 1361
[3] Giannini et al, (2024) arXiv:2312.04459

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TEO-OR-009

Computational modeling of gas-phase reactions: the role of intersystem crossing in the reaction between O(^{3}P) and pyridine

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Spin-forbidden processes, such as intersystem crossing (ISC) occur on longer time scales than those where the spin is conserved, thus they are recognized as secondary processes. The entity of these phenomena can be tuned and, as an example, ISC is enhanced in presence of heavy atoms, like transition metals, bromine, or iodine.

In a recent paper,[1] the discovery of a dominant ISC that controls the reaction between atomic oxygen O(^{3}P) and pyridine (C_5H_5N) was reported. This ISC occurs in the presence of only light atoms (H,C,N,O) making the process relevant in atmospheric chemistry, as well as in combustion processes, and astrochemistry. The discovery was made thanks to a joint theoretical and experimental study of the title reaction, in the gas phase. In particular, the experimental data from crossed molecular beams for the reaction show that the reaction C_5H_5N+O(^{3}P) forms a 98% isomer with molecular formula C_4H_5N (pyrrole or one of its isomers) together with the CO molecule. These products belong to a singlet surface, while the reactants are on the triplet surface, thus testifying the importance of the spin-forbidden channel controlled by the ISC between the triplet and singlet surfaces. This is large contrast with the isoelectronic system benzene+O(^{3}P), where the entity of the ISC is in the order of 30% [2]. The ISC was characterized using accurate computational approaches, which have been used to uncover the reaction networks, the geometries at the ISC, the various products (about 30) and the kinetic of the process at moderate-low temperatures.

The key features of this new ISC were interpreted using frontiers orbitals and other energetic considerations, opening the way towards the characterization of this ISC in other reactions where one of the reactants bears an N-atom.

References:

[1] P. Recio, S. Alessandrini, G. Vannuzzo, G et. al., Nat. Chem. 2022, 14, 1405-1412.
[2] G. Vanuzzo, A.Caracciolo, T. K. Minton, N. Balucani, P. Casavecchia, C. de Falco, A. Baggioli, C. Cavallotti J. Phys. Chem. A 2021, 125, 8434-8453.

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TEO-OR-010

Shining Light on Inverted Singlet-Triplet Emitters

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The inversion of the lowest singlet and triplet excited states, observed in several triangle-shaped organic molecules containing conjugated carbon and nitrogen atoms, is an astonishing result that implies the breakdown of Hund's rule.[1] The phenomenon attracted interest for its potential toward triplet harvesting in organic LEDs. On a more fundamental vein, the singlet-triplet (ST) inversion sheds new light on the role of electron correlations in the excited-state landscape of π-conjugated molecules.[2-5] Relying on the celebrated Pariser-Parr-Pople model, the simplest model for correlated electrons in π-conjugated systems, we demonstrate that the ST inversion does not require triangle-shaped molecules nor any specific molecular symmetry.[6] Indeed, the ST inversion does not require strictly non-overlapping HOMO and LUMO orbitals but rather a small gap and a small exchange integral between the frontier orbitals.

References:

[1] Aizawa, N. et al., Nature 2022, 609, 502
[2] Ehrmaier, J. et al., J. Phys. Chem. A 2019, 123, 8099
[3] Ricci, G. et al., ChemPhysChem 2021, 22, 553
[4] Pollice, R. et al., Matter 2021, 4, 1654
[5] Bhattacharyya, K., Chem. Phys. Lett. 2021, 779, 1388
[6] Bedogni, M. et al., J. Chem. Theory Comput. 2024, 20, 2, 902-913

TEO-OR-011

Ultrafast excited-state dynamics of Luteins in the major light-harvesting complex LHCII

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Carotenoid pigments are known to present a functional versatility when bound to light-harvesting complexes. This versatility originates from a strong correlation between a complex electronic structure and a flexible geometry that is easily tunable by the surrounding protein environment. In this work, we investigated how the different L1 and L2 sites of the major trimeric light-harvesting complex (LHCII) of green plants tune the electronic structure of the two embedded luteins, and how this reflects on their ultrafast dynamics upon excitation. By combining molecular dynamics and quantum mechanics/molecular mechanics calculations, we found that the two luteins feature a different conformation around the second dihedral angle in the lumenal side. The s-cis preference of the lutein in site L2 allows for a more planar geometry of the π-conjugated backbone, which results in an increased degree of delocalization and a reduced excitation energy, explaining the experimentally observed red shift. Despite these remarkable differences, according to surface hopping simulations the two luteins present analogous ultrafast dynamics upon excitation: the bright state S_2 quickly decays (in ~50 fs) to the dark intermediate S_x, eventually ending up in the S_1 state. Furthermore, by employing two different theoretical approaches (i.e., Förster theory and an excitonic version of surface hopping), we investigated the experimentally debated energy transfer between the two luteins. With both approaches, no evident energy transfer was observed in the ultrafast timescale.

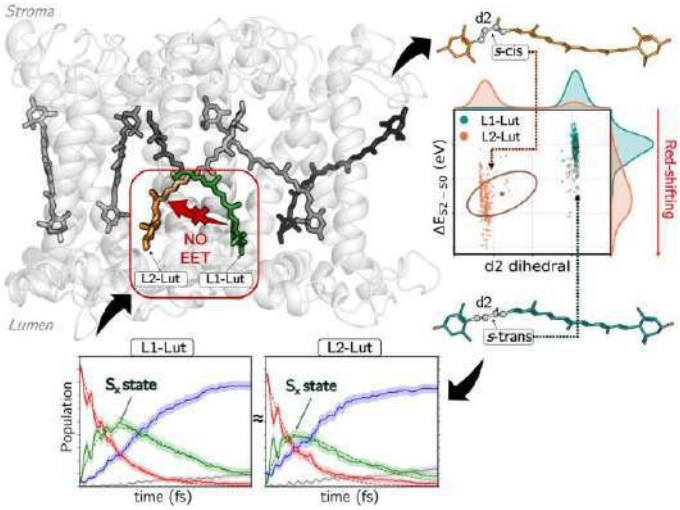

Figure 1: Graphical abstract.

References:

[1] Pedraza-González, L., Accomasso, D., Cupellini, L., G., Granucci, B., Mennucci. Photochem Photobiol Sci 2024, 23, 303-314.

TEO-OR-012

The nature of carotenoid S* state and its role in the nonphotochemical quenching of plants

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Light-harvesting complexes (LHCs) of oxygenic photosynthetic organisms serve a dual function in photosynthesis. Under low-light conditions LHCs absorb sunlight and transfer the excitation energy to the reaction center, whereas in high-light situations they switch to a quenched state, dissipating the excess of the absorbed energy as heat to avoid photodamage. While the processes underlying the light-harvesting function are now rather well known, the quenching mechanisms of LHCs are still under debate. In CP29, a minor LHC of plants (Figure 1), spectroscopic investigations have proposed that quenching mainly occurs via excitation energy transfer (EET) from specific chlorophylls to a debated carotenoid S* state of lutein (Lut).[1,2] In this work, we performed simulations of the nonadiabatic excited state dynamics for Lut in CP29. Our simulations indicate that the minor s-trans conformer of Lut in CP29 shows all the spectroscopic features ascribed to the S* state, and the EET quenching by Lut is more energetically favored for the s-trans conformer, compared to the dominant Lut s-cis conformer. These findings allow us to elucidate the nature of the quencher S* state and to associate it with a specific carotenoid conformation.[3]

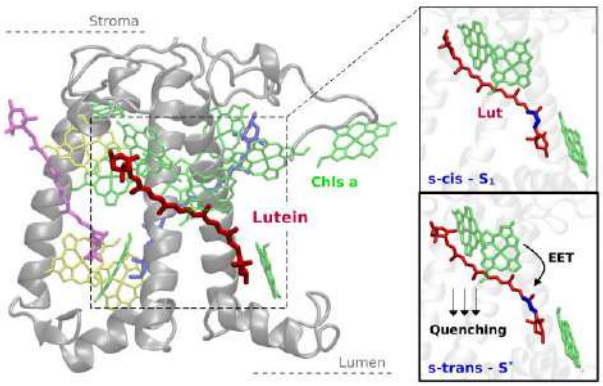

Figure 1: Side-view of CP29 and its L1 site for both Lut s-trans and s-cis conformers.

References:
[1] V. Mascoli et al., Chem 2019, 5, 2900–2912.
[2] S. Sardar et al., J. Chem. Phys. 2022, 156, 205101.
[3] D. Accomasso et al., Nat. Commun. 2024, 15, 847.

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TEO-OR-013

Multiscale Modeling of the Photoinduced Enantioselective Radical Cyclization of α-Chloroamides in Flavin-Dependent Ene-Reductases

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Photobiocatalysis has recently emerged as a valuable strategy for conducting chemical reactions that are challenging with conventional organic chemistry tools. This approach involves the use of photenzymes, i.e. enzymes that absorb light to promote substrate transformation. The photexcitation of these catalysts enables access to electronic excited states with different properties compared to the ground state, thus providing new reaction modes. Additionally, the chiral active sites of these enzymes can control the stereoselective outcomes of these processes.

While there are only few natural photoenzymes, irradiating non-natural photoenzymes, which are enzymes dependent on cofactors with latent photochemical properties, can broaden the range of available catalysts. Notably, Todd Hyster and coworkers discovered that the photoexcitation of flavin-dependent ene-reductases (EREDs) can facilitate non-natural transformations involving radical intermediates, such as the 5-exo-trig radical cyclization of alkene-tethered α-chloroacetamides to yield a chiral γ-lactam.[1] Specifically, they found that two enzymes from this family, the triple mutant T36A-K317M-Y343F of *Gluconobacter oxydans* ene-reductase (GluER-G6) and the Old Yellow Enzyme 1 (OYE1), produce opposite enantiomers.[1,2]

We present a computational study of this reaction catalyzed by GluER-G6, employing a multiscale approach based on Molecular Dynamics (MD), Quantum Mechanics (QM), and the Perturbed Matrix Method (PMM)[3]. Firstly, we focused on the initial step, namely the mesolytic cleavage of a C-Cl bond triggered by photoexcitation. We observed that productive mesolytic cleavage occurs only in certain conformations of the substrate, while the others undergo back electron-transfer. Then we addressed the subsequent radical cyclization step using the same tecniques. On the base of our results, we proposed an enatioinduction scenario in which the relative stability of prochiral transition states is not determined by direct interaction with the protein but is rather dependent on a degree of freedom within the substrate, which is controlled by the enzyme through conformational selection.[4]

References:

[1] K. F. Biegasiewicz, S. J. Cooper, X. Gao, D. G. Oblinsky, J. H. Kim, S. E. Garfinkle, L. A. Joyce, B. A. Sandoval, G. D. Scholes, T. K. Hyster, Science 2019, 364, 1166 - 1169.
[2] B. T. Nicholls, D. G. Oblinsky, S. I. Kurtoic, D. Grosheva, Y. Ye, G. D. Scholes, T. K. Hyster, Angew. Chem. Int. Ed. Engl. 2022, 61, e202113842.
[3] A. Amadei, M. D'Alessandro, M. D'Abramo, M. Aschi, J. Chem. Phys. 2009, 130, 084109.
[4] M. Capone, G. Dell'Orletta, B. T. Nicholls, G. D. Scholes, T. K. Hyster, M. Aschi, I. Daidone, ACS Catal. 2023, 13, 15310 - 15321.

TEO-OR-014

Computational insight on monoterpenoids antifungal activity

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Natural terpenoids and their derivatives are raising new interest as antifungal agents, inspired by traditional medicine and plant protection strategies. Among all, thymol and carvacrol are widely investigated for their activity as antibacterial/antimycotic agents1. Recently, tailored modifications, such as acetylation or bromination, led to thymyl acetate and 4-bromothymol, respectively, which have been synthesized and purified through eco-friendly approaches2. Interestingly, 4-bromothymol antimycotic activity resulted up to 6 times higher than that of thymol on 8 yeast strains3, even in the case of acclaimed resistant species. To elucidate the 4-bromothymol mechanism of action, a thorough computational study has been performed, exploiting Quantum Mechanics (QM) and Molecular Dynamics (DM). QM afforded the characterization of the reactivity, the moieties acting as hydrogen bonds donor/acceptor in water, and the partition coefficients. MD, through the Minimum Bias Approach (MBA), showed out the "real" pose of active compounds into the simulated double layer of eukaryotic-like membrane, meanly 1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine (POPC). MBA confirmed the density alteration of the leaflet into which monoterpenoids are inserted, the shrinkage of the membrane thickness, and the alteration of the order parameter of the double layer. Overall, the computational findings were in terrific agreement with the experimental results3, and they clarified, for the first time, the mechanisms of action of thymol, carvacrol, and 4-bromothymol, likely explaining their different antimicrobial efficiency (Figure 1).

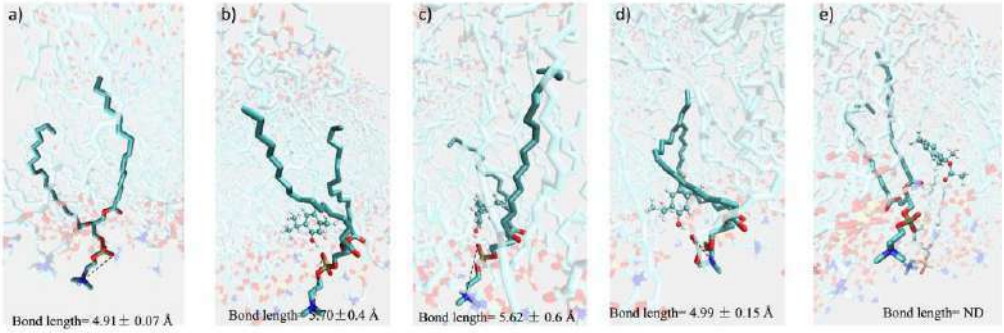

Figure 1: Analysis of the bond length in lipid between the nitro-group and the phosphate oxygen, in the presence or not of the investigated compounds, dotted line. a) POPC alone, and POPC with b) thymol, c) carvacrol, d) 4-bromothymol, e) thymyl acetate.

References:

[1] Floris, B.; Galloni, P.; Conte, V.; Sabuzi, F. Biomolecules 2021, 11, 1325.
[2] Sabuzi, F. Churakova, E., Galloni, P., Wever, R., Hollmann, F., Floris, B., Conte, V. Eur. J. Inorg. Chem. 2015, 3519–3525
[3] Y. Lyu, N. Xiang, J. Mondal, X. Zhu, G. Narsimhan, J. Phys. Chem. B 2018, 122, 2341-2354

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A Theoretical-computational Protocol for Cancer Therapy: Modeling Aptamers and their Interactions with Oncological Targets

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Breast cancer is the second leading cause of mortality in adult women, accounting for more than 500,000 deaths every year[1]. Although significant improvements in the prognosis of this tumor have been achieved, innovative strategies able to further increase the patients' survival rate are still required. Theoretical-computational approach can be of crucial importance in several stages of discovery and design of new drugs. Extra-cellular vesicles (EVs) isolated in the sera of breast cancer patients show, on their membrane, high levels of the Gremlin-1 protein[2-4] that has been associated with poor prognosis and promotion of lung metastasis. In this scenario, our research group has recently identified, through the SELEX procedure[5,6], an RNA aptamer (Ex-50T) able to selectively recognize breast cancer EVs by interacting with Gremlin-1. In this work, a theoretical-computational investigation of the structural properties of this aptamer and of its binding mechanism to Gremlin-1, is presented. In particular, a complete modeling procedure is built to obtain the tridimensional structure of Ex-50T from its primary sequence. Then, the interaction with Gremlin-1 has been modeled through molecular docking and microseconds-long molecular dynamics (MD) carried out to characterize at atomic resolution the RNA aptamer interaction with the biologically relevant forms of Gremlin-1. Our results show that an integrated computational approach spanning from bioinformatic tools to predict the 2D and 3D aptamer structure to molecular docking and MD simulations to investigate its interaction with the protein, is crucial to provide the insight necessary to understand how to chemically modify the aptamer to improve its binding with Gremlin-1. In this way, another step toward the design of more efficient and pharmacokinetically stable aptamers that might be further developed both as therapeutic and as diagnostic tools, is taken.[7]

References:

[1] *Cancer.org*
[2] R. H. Church, A. Krishnakumar, A. Urbanek et al., *Biochem J*, 2015, 466 55.
[3] S. O'Reilly *Cell Mol Life Sci*, 2021, 78 7917.
[4] N. McNamee, R. Daly, J. Crown, L. O'Driscoll, *Translational Oncology* 2022,15, 101274.
[5] C. Tuerk, L. Gold, *Science* 1990, 249, 505–510.
[6] A. D. Ellington, J. W. Szostak, *Nature*, 1990, 346 818–822.
[7] C. Quintavalle, F. Ingenito, G. Roscigno et al., *Mol. Ther. Nucleic Acids*, submitted.

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TEO-OR-016

A Machine Learning tool for Pathway Analysis in Molecular Dynamics Simulations

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Understanding molecular mechanisms, such as ligand binding, protein unfolding, and conformational changes, is crucial for deciphering complex biological processes and accelerating drug discovery. Molecular dynamics (MD) simulations, boosted by enhanced sampling methods, provide a robust computational framework to investigate dynamical events at atomistic level. However, there is a challenge in processing the large-scale data produced by MD simulations and extracting important conformations from noisy trajectories.

To address this, we developed PathDetect-SOM[1], a flexible tool for in-depth analysis of pathways sampled during MD simulations. The tool employs Self-Organizing Maps (SOMs), a well-established algorithm in unsupervised machine learning. PathDetect-SOM facilitates the visualization and interpretation of MD simulation pathways, helping in the identification of pivotal states and examination of energy landscapes. It simplifies complex molecular processes into intuitive 2D representations through geometric clustering and trajectory mapping.

Recently, we designed and implemented, an R package that extends PathDetect-SOM, providing functions to develop workflows for MD simulation analysis within the R statistical environment. This upcoming package will support reading and writing trajectories in the GROMACS format and includes a suite of analysis functions for pathway reconstruction, property mapping and network analysis.

Applications of PathDetect-SOM to different molecular mechanisms are presented, demonstrating its suitability to reconstruct pathways and to detect critical events in simulations of ligand binding[2,3], protein unfolding[4,5], and protein-protein interaction[6]. These tools facilitate the analysis of complex pathways, thus accelerating the understanding of key biological processes.

References:

[1] S. Motta, L. Callea, L. Bonati, A. Pandini, J. Chem. Theory Comput. 2022, 18, 1957 – 1968.
[2] L. Callea, L. Bonati, S. Motta, J. Chem. Theory Comput. 2021 17, 3841 – 3851.
[3] S. Motta, P. Siani, E. Donadoni. G. Frigerio, L. Bonati, C. Di Valentin, Nanoscale 2023 15, 7909 – 7919.
[4] S. Motta, A. Pandini, A. Fornili, L. Bonati J. Chem. Theory Comput. 2021 17, 2080 – 2089.
[5] E. Hendrix, S. Motta, R. F. Gahl, Y. He, J. Phys. Chem. B 2022 126, 7934 – 7942.
[6] T. Li, S. Motta, A. O. Stevens, S. Song, E. Hendrix, A. Pandini, Y. He, JACS Au 2022 2, 1935 – 1945.

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TEO-OR-017

Exploring glyoxal acetal-based electrolytes for next-generation batteries with polarizable molecular dynamics

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The demand for high-performance and sustainable energy storage solutions has led increasing research efforts towards the development of novel materials for next-generation batteries. Glyoxal acetals have been recently proposed as a promising innovation to electrolyte formulations for Li-ion batteries[1], holding as a potential solution to many problems related to the large volume changes occurring in high-capacity anode materials like Si and Si/graphite[2]. However, optimizing the formulation of the glyoxal acetals-containing electrolyte requires a fine understanding of their interaction with co-solvents and salts at a molecular scale.

Molecular dynamics (MD) is widely exploited to study local molecular properties of condensed phases which are hardly accessible to experiments. Polarizable MD force fields have shown to generally outperform fixed point-charge models in yielding a good description of structural and dynamical properties of either gas-phase, cluster-size and liquid bulk systems with a same set of parameters[3]. This holds in particular when a system is characterized by a large amount of mobile charge carriers, like in electrolytes and ionic liquids[4].

In this work we present an extension of the polarizable AMOEBA force field for the simulation of glyoxal acetals-based electrolytes for new Li-ion batteries. The force field was first validated with reference ab-initio calculations of ion-solvent and ion-ion pairs potential energy surfaces and molecular clusters formation energy in gas-phase. Calculated bulk properties were also compared to the available experimental data. The MD simulations investigated the effect of different solvent/co-solvent formulations in LiTFSI and LiFSI electrolytes, highlighting in particular the impact on ions solvation, ion-pair dynamics and ionic transport mechanisms. The results allow to elucidate the relation between the electrolyte structure and its electrochemical performances and to design practical strategies for their improvement.

References:

[1] L. H. Hess and A. Balducci, ChemSusChem, 2018, 11, 424, 1919.
[2] L. Gehrlein, C. Leibing, K. Pfeifer et al., Electrochemical Acta, 2022, 424, 140642.
[3] A. Szabadi and C. Schröder, Journal of Computatinoal Biophysics and Chemistry, 21, 4, 415-429.
[4] D. Bedrov, J.-P. Piquemal, O. Borodin et al., Chemical Reviews, 2019, 119, 13, 7940-7995.

TEO-OR-018

Computational Study of Glassy Solid Electrolytes for All-Solid-State Batteries

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The global growing demand for energy storage is pushing the research for new battery materials with improved properties. These materials must allow high performances of the batteries and guarantee a safe and ecological synthesis, usage, and disposal. Moreover, the need for raw materials whose supply comes from areas where human rights are not guaranteed must be eliminated.

All-Solid-State-Batteries (ASSB) are emerging as promising alternatives in terms of safety and energy density but new highly conductive, yet electrochemically stable Solid-State Electrolytes (SSE) must be developed. In particular, Glassy Solid Electrolytes (GSE) are gaining growing interest in the research and industrial community because of their low-cost manufacturing and robust chemical stability which can avoid the known safety problems, like fires and explosions, caused by the organic liquid electrolytes in Li-ion batteries[1].

The tremendous increase in the battery market has made lithium a critical material. Its extraction from mines comes with ethical issues and the supply chain could face a shortage in the near future. Sodium-based batteries are possible alternatives, but a huge effort is needed in the study of suitable SSE. Nowadays, the most studied GSEs for Na-ASSB are based on sulfide because of their high ionic conductivity, wide compositional range, and lack of grain boundaries[2]. Unfortunately, these materials can react with atmospheric compounds and are electrochemically unstable with electrode materials hampering their synthesis and usage. In the last decade, mixed oxy-sulfide (MOS) glasses have been demonstrated to maintain the optimal ionic conductivity of pure sulfide GSE while having the chemical and electrochemical stability of oxide-based ones[2].

This study aims to understand the atomistic structure of MOS-GSE as the link between the composition and properties of these materials. To do so, DFT ab-initio molecular dynamics (MD) simulations were performed on several Na-based MOS-GSE with increasing substitution of sulfur with oxygen. The high computational cost of this technique limits the simulation to a few hundred atoms and very short timescales that do not allow the investigation of ionic conduction mechanisms at low temperatures. To overcome these limitations the DFT data were used to train a Machine Learning (ML) potential which was applied to the MD simulations of larger simulation boxes to investigate the Na conduction.

This method has the potential to become a standard method for the accurate investigation of GSEs by means of MD simulations as it allows minimizing the ab-initio calculations and simulating large models for long timescales which makes conduction events accessible at low temperatures.

References:

[1] S. Kmiec, A. Joyce, S. W. Martin, J. Non-Cryst. Sol. 2018, 498, 177-189.
[2] S. W. Martin, Handbook of Solid State Batteries, 2015, 433-501

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TEO-OR-019

DFT and Experimental study of FeO_x/Au heterostructures: insights and relevance as electrochemical water splitting heterogeneous catalysts

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Nowadays there is an urge to transit from fossil fuels to clean energy sources: a crucial role in this process can be played by the oxygen evolution reaction (OER), hydrogen evolution reaction (HER) and oxygen reduction reaction (ORR)[1]. The main problem in the worldwide diffusion of the catalysts for these reactions is their high costs. The most efficient catalysts are in fact made of noble metals[2,3]. An alternative based on earth abundant metals would be needed and for this we propose and study FeOx /Au systems. The structure of supported FeOx layers is nonetheless still to be determined since a wide range of structures can be formed depending on the operating conditions (mainly the applied potential and the pH of the solution)[4,5].

In such framework, computational chemistry can play a relevant role in identifying conceivable structures based on Fe oxides and hydroxides with different oxidation numbers. Relevant structures have been fully analysed by considering their electron/magnetic properties and their relative stability at the operating conditions. The major interest is to establish the relationships between structure and properties in order to identify the active species taking part to the catalytic reactions.

The VASP code[6] has been used for calculations in combination with the DFT+U approach and PBEsol as functional since this computational set up guarantees a proper description of the transition metals centers and related (electro)chemical processes. Experimentally acquired STM images and water adsorption energies are used to compare theoretical data with experimental one, validating our model and highlighting different structure-reactivity-properties relationships in the three high-symmetry domains of the FeO/Au moiré.

References:

[1] Jia, H., Yao, N., Zhu, J., & Luo, W., Chem. Eur. J., 2023, 29(13), e202203073.
[2] Zhao, G., Rui, K., Dou, S. X., & Sun, W., Adv. Funct. Mater., 2018, 28(43), 1803291.
[3] An, L., Zhao, X., Zhao, T., & Wang, D., Energy Environ. Sci., 2021,14(5), 2620–2638.
[4] Yang, S., Gou, J., Cheng, P., Chen, L., & Wu, K., Phys. Rev. Mater., 2020, 4(7), 074004.
[5] Liang, J., Yu, Q., Yang, X., Zhang, T., & Li, J., Nano Res., 2018, 11(3), 1599–1611.
[6] Kresse, G., & Furthmüller, J., Comput. Mater. Sci., 1996, 6(1), 15–50.

TEO-OR-020

N-Heterocyclic Molecules for Tunable Functionalization of Oxide Surfaces

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N-Heterocyclic carbenes (NHCs) have superior properties as building blocks of self-assembled monolayers, or as carriers of functional groups to functionalise surfaces. Understanding the influence of the substrate in the molecular binding is a fundamental step before employing these ligands in technological applications. NHCs have been widely studied on metallic substrates such as Au(111)[1] or Cu(111).[2] Recently, it has been shown how, on oxidized copper, these molecules tend to bind preferentially to oxygen atoms, rather than copper atoms.[3] This is an important finding, since it is the first time that a direct bond formation between a carbene centre and an oxygen atom is observed in the context of adsorption on surfaces. Interestingly, the subsequent desorption of cyclic urea promotes the reduction of copper under relatively mild conditions.[4]

Based on these findings, it is hereby shown how NHCs can bind to oxide surfaces, recurring to Density Functional Theory calculations. The following oxidic supports are studied: MgO, cuprite, titanium dioxide in the form of rutile, and silica. Both normal carbenes and mesoionic carbenes (displaying a more pronounced electron donor character) are considered. Two different binding modes are found: i) the carbene centre binds to a metallic cation and ii) the carbene binds to an oxygen anion. Depending on the chemical nature of the oxide and the electron-donating capability of the NHC molecule, either C-metal bonds or C-O bonds are preferentially formed. In case of C-metal bond formation, the charge transfer is related to the balance between the sigma donation and pi back-donation mechanisms, where the chemical structure of NHC plays a role. When C-O bonds are formed, the NHC molecule is oxidized, with consequent reduction of the surface: this mechanism is very unfavourable on large-gap oxides such as MgO, while it is possible on reducible oxides such as TiO_2. These findings will help in designing the employ of NHC ligands to functionalize oxide surfaces.

References:

[1] C. M. Crudden et al., Nat. Commun. 2016, 7, 12654.
[2] J.J. Navarro et al., Angew. Chem. Int. Ed. 2022, 61, e202202127.
[3] J.J. Navarro et al., J. Am. Chem. Soc. 2022, 144, 16267–16271.
[4] J.J. Navarro et al., J. Phys. Chem. C 2022, 126, 17528-17535.

TEO-OR-021

Nickel Oxide/ DiRh(II,II) interface complexities dissected with ab-initio calculations

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Single-chromophore single-molecule photocatalysts have emerged as promising agents for the conversion and storage of solar energy into chemical bonds.[1-4] Recently, Turro and co-workers reported a single-molecule dirhodium photocatalyst (DiRh(II,II)) bound to nickel oxide (NiO) photocathode able to generate hydrogen from acidic solutions with red light.[5] Its unique design makes this complex also a highly promising sensitizer for Dye-sensitized photoelectrochemical cells (DSPECs) when coupled with p-type semiconductors such as NiO. The efficient development of DSPECs calls for a thorough understanding of all properties and processes occurring at the molecule/solid interface, only partially achievable by experimental techniques. In this context, this contribution presents new insights into structural and electronic features of the DiRh(II,II)/NiO interfaces from state-of-the art Density Functional Theory (DFT)-based calculations. Besides, we also compute molecule/surface electron injection rates and identify preferential charge transfer channels via the projection-operator diabatization (POD) approach.[6] Our results show that DiRh(II,II) complex interacts strongly with the NiO surface through the formation of COO-Ni bonds, leading to stable mono- or bi- anchored configurations, with the mono-anchored DiRh(II,II) complex presenting the most promising features from the electronic and charge dynamics points of view. Regarding H_2 production, we find that surface anchoring to NiO facilitates efficient charge separation but barely impacts hydrogen binding to the DiRh(II,II) complex. Overall, our findings provide valuable insights into the nature of DiRh(II,II)/NiO interactions, guiding the design of advanced catalysts (e.g. containing asymmetric ligands) with enhanced photo-electrochemical performance for applications in renewable energy conversion and storage.

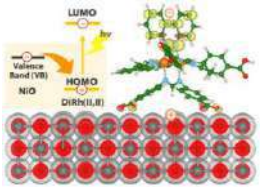

Figure 1: Schematic representation of charge transfer at NiO/DiRh(II,II) interface

References:

[1] Huang, J. Gallucci, J. C. Turro, C. Chem. Sci. **2020**, 11, 9775–9783
[2] Whittemore, T. J. Xue, C. Huang, J. Gallucci, J. C. Turro, C. Nat. Chem. **2020,** 12, 180–185.
[3] Li, Z. Leed, N. A. Dickson-Karn, N. M. Dunbar, K. R. Turro, C. Chem. Sci. **2014**, 5, 727–737.
[4] Manamperi, H. D. Moore, C. E. Turro, C. Chem. Comm. **2021**, 57, 1635–1638.
[5] Huang, J. Sun, J. Wu, Y. Turro, C. J. Am. Chem. Soc. **2021**, 143, 1610–1617.
[6] Pecoraro, A. Fasulo, F. Pavone, M. Muñoz-García, A. B. Chem. Comm. **2023**, 59, 5055–5058.

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TEO-OR-022

A DFT study on the Red-Light Photocatalytic Activation Of Pt(IV) Anticancer Drugs Using Methylene Blue

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In recent years, Salassa and colleagues have discovered new catalytic reactions in which flavins, such as riboflavin (Rf) and certain flavoproteins, mediate, under light irradiation, the transformation of Pt^{IV} prodrugs into the corresponding active Pt^{II} drugs, such as clinically-approved cisplatin, oxaliplatin, and carboplatin, with unanticipated efficiency.[1] In these photocatalytic reactions, the catalyst needs an electron source (e.g., NADH) to be reduced into the active hydroquinone form, which can rapidly convert Pt^{IV} into Pt^{II} complexes. In these bioorthogonal reactions, metal complexes act unconventionally as substrates, rather than catalysts, changing a well-established paradigm in catalysis. However, the main limitation of flavin-catalyzed reduction of Pt^{IV} prodrugs is the wavelength necessary for being photoactivated. Indeed, the absorption profile of flavins does not fall within the therapeutic window (600-900 nm), which is not conducive to optimal tissue penetration. For this reason, we have researched new photocatalysts possessing photo-redox properties similar to flavins but capable of absorbing light within the therapeutic window range. Our research has led us to study methylene blue (MB), a phenothiazine with a rich medical history and an intense absorption band between 600-700 nm. The mechanism of reduction by MB-catalysis, showed in Figure 1, has been studied using Density Functional Theory (DFT). Firstly, we explored the NADH to MB hydride-transfer mechanism both in the dark and under light irradiation for the formation of the LeucoMethylene Blue (LMB). Then, we have investigated the reduction of Pt^{IV} prodrugs by LMB, focusing on elucidating the possible activation pathways.

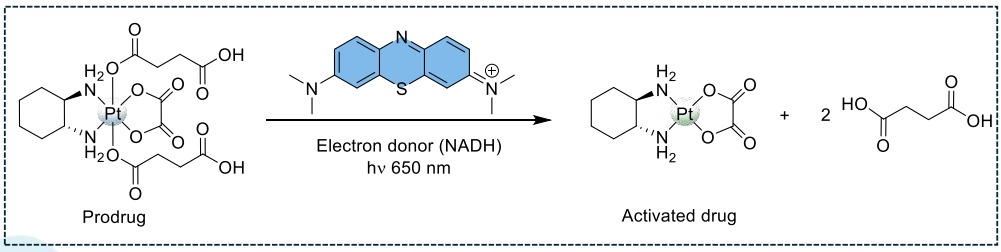

Figure 1: Catalytic reduction of PtIV promoted by MB in the presence of NADH

References:

[1] S. Alonso-de Castro, E. Ruggiero, A. Ruiz-de-Angulo, E. Rezabal, J.C. Mareque-Rivas, X. Lopez, F. Lopez-Gallego, L. Salassa, Chem. Sci. 2017, 8, 4619 – 4625.

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TEO-OR-023

Modelling Single-Atom Catalysis

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Single Atom Catalysts (SACs) are emerging as new frontier in the field. Computational chemistry offers a valid framework to access the atomistic details of electrocatalytic processes and to rationalize of even predict novel systems. Recently, a lot of attention has been dedicated to the reactions of evolution and conversion of molecular hydrogen and oxygen from or to liquid water.[1] The activity of SACs is usually rationalized or predicted using the Computational Hydrogen Electrode (CHE) approach, where the free energy of key intermediates adsorbed is used to explain the catalytic activity.[2]

In this presentation we discuss the key ingredients to model electrocatalytic processes on SACs. SACs differ substantially from metal surfaces and can be considered analogues of coordination compounds. In coordination chemistry, at variance with metal surfaces, stable complexes of hydrogen and oxygen can form.[3] We show that the same can occur on SACs and their formation may change the kinetics of the process.[4,5] We propose an approach to predict the stability of SACs under working conditions of pH and applied voltage.[6] Needless to say, the adopted DFT functional affects the accuracy of the predictions, and we show evidence suggesting that self-interaction corrected schemes should be adopted.[7] DFT numerical simulations demonstrate that these ingredients may lead to different conclusions about the activity of SACs in the water splitting reaction. This work provides an example of the important analogies between the chemistry of SACs and that of coordination compounds, and underlines the key ingredients to be accounted when attempting to provide predictions with computational frameworks.

References:

[1] L. Cao, Q. Luo, W. Liu, Y. Lin, X. Liu, Y. Cao, W. Zhang, Y. Wu, J. Yang, T. Yao, S. Wei, Nat. Catal. 2 (2019) 134.
[2]J. K. Nørskov, T. Bligaard, A. Logadottir, J. R. Kitchin, J. G. Chen, S. Pandelov, U. Stimming, J. Electrochem. Soc. 152 (2005), J23.
[3] G. J. Kubas, Chem. Rev. 107 (2007), 4152; R. H. Crabtree, Chem. Rev. 116 (2016), 8750.
[4] G. Di Liberto, L. A. Cipriano, G. Pacchioni, J. Am. Chem. Soc. 143 (2021), 40321; ACS Catalysis 19 (2022), 11682; I. Barlocco, L.A. Cipriano, G. Di Liberto, G. Pacchioni J.Catal. 417, 351 (2023).
[5] G. Di Liberto et al, Curr. Opin. Electrochem 101343 (2023); J. Power. Sources 556 (2023), 232492; Adv. Mater. 35, 2307150 (2023).
[6] G. Di Liberto, L. Giordano, G. Pacchioni ACS Catalysis 14, 45 (2024).
[7] I. Barlocco, L.A. Cipriano, G. Di Liberto, G. Pacchioni. Adv. Theo. & Simul. 6, 2200513 (2023)

TEO-OR-024

Using photons to control the properties of molecules: an *ab-initio* study

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Manipulation of matter properties using strong coupling to photons is becoming a hot research topic in physics and chemistry [1,2]. Recent experimental studies demonstrated that strong-light matter coupling in optical cavities can be used to inhibit, catalyze and increment the selectivity of chemical reactions[1].

In the past few years, a lot of progress has been made in the field, but a complete understanding of the possibilities offered by cavity QED in chemistry is still far from being achieved.

In this talk, I will present some recent studies we performed using new *ab-initio* theoretical techniques developed in the group.[3-4] The predictive potential offered by these techniques will be exploited. The effects induced by quantum fields on several chemical phenomena going from photochemistry to chemical reactivity will be analyzed and discussed.[3-5] In the last part of the talk I will also mention how the chirality [6,7] and magnetic properties [8] of molecules can be manipulated inside and optical cavity.

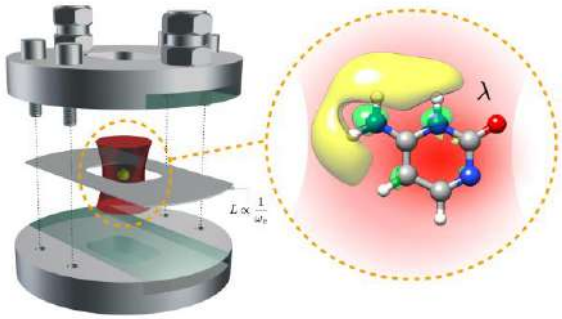

Figure 1. Chemical processes in optical cavities.

References:
[1]. T. W. Ebbesen, Acc. Chem. Res., 49, 2403, 2016.
[2]. M. Ruggenthaler, N. Tancogne-Dejean, J. Flick, H. Appel and A. Rubio, Nature Rev. Chem., 2, 0118, 2018.
[3]. T. S. Haugland, E. Ronca, E. F. Kjønstad, A. Rubio, H. Koch, Phys. Rev. X, 10, 41043, 2020.
[4]. R. R. Riso, T. S. Haugland, E. Ronca, H. Koch, Nature Commun., 13, 1368, 2022.
[5]. C. Schäfer, J. Flick, E. Ronca, P. Narang, A. Rubio, Nature Commun., 13, 7817, 2022.
[6]. R. R. Riso, L. Grazioli, E. Ronca, T. Giovannini, H. Koch, Phys. Rev. X, 13, 031002, 2023.
[7]. R.R.Riso, E. Ronca, H. Koch, arXiv:2308.06181, 2023.
[8]. A. Barlini, A. Bianchi, E. Ronca, H. Koch, arXiv:2402.10599, 2024.

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TEO-OR-025

A machine learning approach for the prediction of atomic charges of metal- organic frameworks

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Metal-organic frameworks (MOFs) are very versatile materials due to their modular structure, as the framework is formed by the combination of two secondary building units (SBUs): an inorganic unit (metal ion or cluster) and an organic ligand. As a result, a wide range of combinations are possible, thus allowing MOFs to cover a huge chemical space. High-throughput computational screening is then useful to explore all the chemical and physical properties of such materials but low-cost computational methods such as bespoke tailored force-fields are needed to speed up the calculations [1]. To this end, accurate atomic charges are crucial to predict long-range electrostatic interactions correctly. These can either be derived from quantum-mechanical calculations or generated on the fly through simplified geometric schemes or, more recently, through Machine Learning (ML) prediction models. The latter requires suitable databases of structures and properties to be used to train the ML model. Several databases of MOFs and their properties are now available such as CoReMOF [2], QMOF [3] and ARC-MOF [4].

In this work, we present the results of predicting atomic charges derived from the QMOF database. We trained different ML models by using XGBoost and RandomForest with atomic and environmental descriptors. On the one hand, the QMOF database, which contains more than 20000 cleaned-up experimental structures (< 300 atoms in the unit cell) for which DDEC charges are available, was analysed to understand how the size and composition (i.e. metal ion types) of the training dataset affects the prediction of the atomic charges. On the other hand, we built datasets with randomly extracted structures ranging from 500 to 1500 MOFs. We compared them with more balanced one with an equated composition in terms of different metal ions.

This strategy allows us to achieve good results using a reduced number of MOFs compared to the largest dataset (i.e. 1500 vs 20375 structures of the entire QMOF database) with the RandomForest ML models giving better performance to XGBoost. We were also able to predict with higher accuracy the charges of the metallic species in the node which are less abundant compared to the other species present in the structure (e.g. H, C, O and N). Based on this result, Hirshfeld-I charges were also calculated using the low-cost hybrid HF/DFT sol-3c composite methods [5] on the reduced dataset and an ML model was trained. The CRYSTAL program [6] was used to exploit the space group symmetry and the efficient parallelization of the code.

References:

[1] P. Xu, X. Ji, M. Li, e W. Lu, npj Comput. Mater. 9 (2023) 42
[2] Y. G. Chung, E. Haldoupis, B. J. Bucior, M. Haranczyk, R. Snurr, et al. (2020). CoRE MOF 2019 Dataset (1.1.3).
[3] J. Burner et al., Chem. Mater., 35 (2023) 900.
[4] A. S. Rosen et al., Matter 4 (2021) 1578–1597.
[5] L. Donà, J. G. Brandenburg, B. Civalleri, J. Chem. Phys., 156 (2022) 121101
[6] A. Erba, J.K. Desmarais, S. Casassa, B. Civalleri, L. Donà, et al. J. Chem. Theory Comput.(2023) 19, 6891−6932

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Building reactive potentials through machine learning and enhanced sampling: from methods to catalytic applications

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Machine learning potentials for atomistic simulations have enormous potential for modeling chemical reactions and materials, offering *ab initio*-like accuracy but being orders of magnitude faster than density functional theory (DFT) calculations. Unlike interatomic potentials based on fixed functional forms, they learn to reproduce energies and forces directly from large datasets of quantum-mechanical calculations.

However, many reactive processes, such as chemical reactions, occur on longer time scales than we can simulate. This makes it challenging to construct a set of reference configurations, especially if the reactions occur in a complex and dynamic environment. To address this problem, we take advantage of enhanced sampling methods such as Metadynamics. Integrating these methodologies with active learning strategies, we can construct robust and reliable potentials for studying rare events. In particular, active selection of configurations in the transition region proves critical to describe reaction rates with machine learning-based potentials accurately[1]. In addition, by leveraging efficient architectures such as equivariant graph neural networks and Bayesian approaches to measure the uncertainty, we can construct uniformly accurate potentials along the entire reaction path in a data-efficient way.

The synergistic combination of these families of approaches allows us to simulate for the first time in a realistic way the dynamics of heterogeneous catalytic processes under *operando* conditions. A revealing example is the study of the dynamics of the Fe(111) surface at high temperatures and its influence on the decomposition of N_2, which is believed to be the limiting step in the famed Haber-Bosch process[2]. At high temperatures, surface iron atoms become highly mobile, jumping between lattice sites. Consequently, active sites are continuously formed and destroyed, altering the free energy profile of adsorption and dissociation. If we also include the effect of lateral interactions with adsorbed nitrogen, we again find two different behaviours[3]. At room temperature, nitrogen atoms poison the catalyst by blocking the active sites. In contrast, at high temperatures, poisoning is greatly reduced by the surface reconstruction induced by the adsorbates with the formation of local motives that cluster the nitrogen atoms and stabilize the remaining active sites. These simulations highlight the danger of extrapolating low-temperature results to *operando* conditions and indicate that the chemical reactivity can only be inferred from calculations that take dynamics fully into account.

References:

[1] M. Yang, L. Bonati, D. Polino, M. Parrinello, Catalysis Today 2022, 387, 143-149.
[2] L. Bonati *et. al.*, Proceedings of the National Academy of Sciences 2023, 120(50), e2313023120
[2] S. Tripathi, L. Bonati, S. Perego and M. Parrinello, ACS Catalysis 2023, 14, 4944-4950

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A General Perturbative Route to Anharmonic Vibro-Rotational Spectroscopy in Internal Curvilinear Coordinates

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The quest for a reliable yet practical modelling of large molecular systems has always played a central role in the field of theoretical and computational chemistry.[1] In this framework, despite the undisputed effectiveness of static structure-property correlations and the fundamental rigid-rotor/harmonic-oscillator model, results that are directly comparable to experiment can only be achieved through a more advanced description either at the electronic or nuclear level. Among the various methods for the inclusion of anharmonic effects, the vibrational second-order perturbation theory (VPT2)[2,3] allows the effective study of medium-to-large size molecular systems.

While VPT2 can be successfully applied in many cases, it is also characterized by some intrinsic drawbacks that prevent its use in some situations, in particular when large amplitude motions (LAMs) are present. Unfortunately, variational approaches such as the vibrational configuration interaction (VCI)[4] become rapidly prohibitive as the size of the molecular systems increases. On the other hand, reduced-dimensionality methods tailored for describing one or a limited number of LAMs require an effective separation from the rest of vibrations, usually referred to as small amplitude motions (SAMs). As shown in previous studies,[5-8] the definition of a suitable set of internal coordinates able to decouple these two classes of vibration allows to treat each normal mode through the most appropriate method. Based on this premise, a general and effective VPT2 framework in terms of curvilinear coordinates was developed.

In this contribution, the versatility of internal coordinates and their application in the fields of rotational and vibrational spectroscopy will be described, starting from the calculation of transition energies, and proceeding up to thermochemistry and vibro-rotational interaction parameters. The performance of the new engine will be illustrated by its application to systems of biological and technological interest.

References:

[1] C. Puzzarini, J. Bloino, N. Tasinato, V. Barone, Chemical Reviews, 2019, 119, 8131 – 8191.
[2] H.H. Nielsen, Reviews of Modern Physics, 1951, 23, 90.
[3] M. Mendolicchio, J. Bloino, V. Barone, Journal of Chemical Theory and Computation, 2021, 17, 4332 – 4358.
[4] R.J. Whitehead, N.C. Handy, Journal of Molecular Spectroscopy, 1975, 55 356 – 373.
[5] M. Mendolicchio, J. Bloino, V. Barone, Journal of Chemical Theory and Computation, 2022, 12, 7603 – 7619.
[6] M. Mendolicchio, Theoretical Chemistry Accounts, 2023, 142, 133.
[7] C.R. Quade, Journal of Chemical Physics, 1976, 64, 2783 – 2795.
[8] A.D. Isaacson, The Journal of Physical Chemistry A, 110, 379 – 388.

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Theoretical-Computational Approaches for Ultrafast Photo-Induced Phenomena in Complex Environments

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Light induces non equilibrium time evolving molecular phenomena. The computational modelling of photoinduced processes in large systems, embedded in complex environments (i.e. solutions, proteins, materials), demands for a quantum and statistical mechanic treatment to achieve the required accuracy in the description of both the excited state energy potentials and the choice of the initial conditions for dynamical simulations.[1] On the other hand, the theoretical investigation on the atomistic scale of times and sizes of the ultra-fast photo-induced reactivity and non-equilibrium relaxation dynamics right upon excitation requests tailored computational protocols. Additional challenge is the theoretical study of the interplay between molecules at finite temperature and their related non-equilibrium time-resolved spectroscopies, such as time-resolved infrared (IR), femtosecond stimulated Raman, and transient absorption.[2]

In this work we will show several methodologies exploiting hierarchic computation schemes, where a large part of the degrees of freedom are treated explicitly to achieve the right accuracy. Additionally, part of the explicit system is described at *ab initio* level, using density functional theory, employing hybrid functionals and its time-dependent formulation (TD-DFT),[3] given the good compromise between accuracy and computational cost. Finally, we will present several theoretical-computational protocols for the accurate characterization of the photo-induce charge recombination and excitons dynamics, along with their related non-equilibrium vibrational/dynamical properties. For this aim, the time dependent electronic structure of excited electronic states and their interconnection with time-resolved spectroscopic signals in materials (dyes for light harvesting) and biological systems (photo-probes) will be analyzed.[4]

References:

[1] A. Petrone, F. Perrella, F. Coppola, L. Crisci, G. Donati, P. Cimino, N. Rega, 2022, Chem. Phys. Rev., 3 (2), 021307.
[2] P. Kukura, D. W. McCamant, R. A. Mathies, 2007, Annu. Rev. Phys. Chem., 58, 461.
[3] [3a]M. E. Casida, Recent Advances in Density Functional Methods, edited by D. P. Chong (World Scientific, 1995) pp. 155–192. [3b]R. E. Stratmann, G. E. Scuseria, and M. J. Frisch, 1998, J. Chem. Phys. 109, 8218.
[4] [4a]A. Petrone, J. J. Goings, X. Li, 2016, Phys. Rev. B, 94, 165402. [4b]G. Donati, D. B. Lingerfelt, A. Petrone, N. Rega, X. Li, 2016, J. Phys. Chem. A, 120, 7255. [4c]F. Perrella, F. Coppola, N. Rega, N., A. Petrone, 2023, Molecules, 28(8), 3411. [4d]E. Buttarazzi, F. Perrella, N. Rega, A. Petrone, 2023, J. Chem. Theory Comput., 19 (23), 8751–8766. [4e] F. Coppola, P. Cimini, U. Raucci, M. Chiariello, A. Petrone, N. Rega, 2021, Chem. Sci.,12, 8058-8072.

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Novel computational strategies for the study of chemical selectivity: Combining high accuracy and chemical insight

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In this contribution, local correlation methods,[1] advanced conformational sampling strategies,[2-3] innovative electronic structure analysis tools[4-5] and machine learning models are combined to establish accurate computational protocols for the study of chemical selectivity in complex transformations. These protocols are employed to elucidate the mechanisms that govern the selectivity of challenging processes, encompassing for example asymmetric catalytic reactions for the synthesis of important pharmaceuticals and natural products.[6] The knowledge gained is then used to identify simple rule of thumbs for the design novel catalysts with tailored selectivity, and to provide insights into their potential validity across diverse chemical scenarios.[7]

References:

[1] A. Altun, F. Neese, G. Bistoni, J. Chem. Theory Comput. 2020, 16, 10, 6142-6149
[2] D. Yepes, F. Neese, B. List, G. Bistoni, J. Am. Chem. Soc. 2020, 142, 3613-3625
[3] I. Harden, F. Neese, G. Bistoni, Chemical Science, 2022, 13, 8848-8859
[4] G. Bistoni, WIREs Computational Molecular Science, 2020, 10, e1442
[5] L. Baldinelli, F. De Angelis, G. Bistoni, J. Chem. Theory Comput. 2024, 20 1923 -1931
[6] J. A. A. Grimm, H. Zhou, R. Properzi, M. Leutzsch, G. Bistoni, J. Nienhaus, B. List, 2023, Nature, 615, 634-639
[7] Q. Li, S. M. Levi, C. C. Wagen, A. E. Wendlandt, E. N. Jacobsen, 2022, Nature, 608, 74-79

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Unravelling the complex dynamical behavior of heterogeneous catalysts during reactants exposure

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The complex dynamical behavior of industrial catalysts during their high-temperature exposure to reactants represents a critical yet frequently disregarded factor in the study of heterogeneous catalysis, which is traditionally dominated by the static active site paradigm.

Here, thanks to the progress in the construction of DFT quality machine learning (ML)-based interatomic potential and enhanced sampling techniques, we unravel the complex dynamic behavior of catalytic processes under *operando conditions* by investigating ammonia decomposition on lithium imide[1,2] (Li_2NH) and ammonia synthesis on barium hydride[3] (BaH_2). Our ML-driven molecular dynamics simulations reveal that when the catalyst is exposed to the reactants, the dynamical state of the top layers changes, inducing the formation of a few diffusive, almost liquid-like interfacial layers[1,3]. Such a modified and highly fluctuating interfacial state is responsible for catalysis. Indeed, the large fluctuations observed in the top layers of the surfaces allow a series of reactions to occur enabling ammonia synthesis or decomposition on these transition-metal-free catalysts. Once started, the process is self-sustained, with different reaction steps further contributing to the surface dynamical behavior, and therefore, to its catalytic efficiency[1].

In conclusion, our microscopic analyses underline the dynamic nature of heterogeneous catalysts, which do not merely serve as static platforms for reactions but, rather represent dynamic entities that evolve under reaction conditions. We suggest the rational design of more efficient catalysts by appropriately engineering their interfacial behavior.

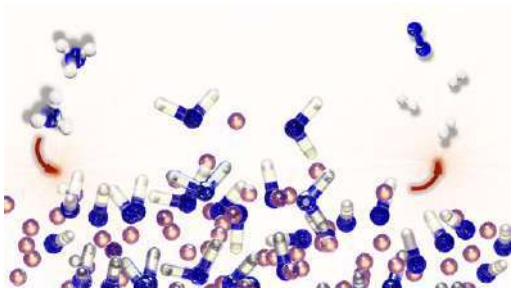

Figure 1: A representative snapshot of the Li_2NH (111) surface during ammonia exposure.

References:
[1] M. Yang, U. Raucci, M. Parrinello, Nat. Catal. 2023, 6, 829-836.
[2] F. Mambretti, U. Raucci, M. Yang, M. Parrinello, ACS Catal. 2024, 14, 1252-1256.
[3] A. Tosello, U. Raucci, M. Parrinello, manuscript in preparation.

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TEO-OR-031

A graph theory-based order parameter for the structural and dynamic characterization of supercooled water

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Our work is focused on the development of a graph theory-based order parameter for the characterization of liquids. In particular, we applied it to the delicate framework of the Liquid-Liquid Phase Transition (LLPT) in supercooled liquid water, simulated via molecular dynamics (MD). In the LLPT scenario, liquid water exists in two states, the high-density liquid (HDL) and the low-density liquid (LDL).

Despite the structural, dynamic and thermodynamic differences between the HDL and LDL state, distinguishing between the HDL and LDL state, distinguishing them even with computational methods is challenging and, therefore, several order parameters have been introduced to differentiate the two phases.

We recently proposed the Node Total Communicability (NTC) as an order parameter, testing its ability to distinguish between HDL/HDL-like and LDL/LDL-like molecules at high pressure where the coexistence line is crossed [1], and at ambient pressure, where the Widom line is crossed[2].

This descriptor, borrowed from graph theory, yields information about the local connectivity of each water molecule within a simulation box and highlights the influence of the medium-to-long range effects, allowing us to characterize the structural and dynamical behaviour of the system at the microscopic level[1,2].

We found that HDL-like forms are not homogeneous but rather characterized by the presence of high connectivity patches composed of molecules with an increased local density and mobility. Small highly connected patches are also found in the LDL phase (Fig. 1), and we hypothesize that they could function as initial sites from which the HDL phase starts forming and growing during a phase transition.

Expanding on this hypothesis, we are currently using the NTC to study and characterize the transition of an LDL system to an HDL-like composition with a spinodal-like decomposition mechanism.

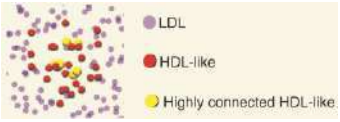

Figure 1: Visualization of highly connected patches and HDL-like patches in an LDL environment.

References:

[1] C. Faccio, I. Daidone, L. Zanetti-Polzi, Journal of molecular liquids 2022, 355, 118922.
[2] C. Faccio, N. Di Fonte, I. Daidone, L. Zanetti-Polzi, Journal of molecular liquids 2023, 392, 123425.

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TEO-PO-001

Assessing the catalytic mechanism of the horse-liver alcohol dehydrogenase with a biomimetic cofactor through a multiscale computational study

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In recent years, there has been a significant interest in redox enzymes due to their ability to exert crucial chemo and stereoselective control over the reactions they catalyze. Moreover, enzymes operate under mild conditions, making them particularly attractive for the design of green chemical processes.[1] Here, we focus on horse liver alcohol dehydrogenase (HLADH), an enzyme exhibiting a wide substrate tolerance. Specifically, in its catalytic action of the reduction reaction of ketones, the enzyme mediates the hydride transfer (HT) from NADH to the re-face of the carbonyl group, resulting in the formation of S alcohols as products.[1,2]
The utilization of biomimetic cofactors presents an appealing strategy, given their notable advantages in versatility, efficiency, and tunability. These attributes render them invaluable instruments for propelling advancements across diverse domains of chemistry and technology[1]. However, the catalytic reaction mechanisms are not yet known. In a previous study,[1] a mechanism was proposed for the reduction of 2-pentanone catalyzed by HLADH, employing 1,4-dihydro-N-benzylnicotinamide as biomimetic cofactor. Differently from the mechanism with NADH (which implies an initial, direct HT), this mechanism involves as first step the detachment of His67 from the catalytic Zn(II) metal ion center followed by formation of a complex that involves η^2-coordination of the 5,6 double bond of the biomimetic to the zinc, followed by HT. We study the catalytic mechanism of this system here using a multiscale approach, specifically the Perturbed Matrix Method-Molecular Dynamics (PMM-MD) approach.[3] By calculating the free energy changes along the possible mechanisms, we can ascertain whether the alternative mechanism (involving detachment of His67 and formation of the η^2 complex) or the direct-HT mechanism is the most thermodynamically and kinetically favorable.

References:

[1] A. Marrone et al., J. of Organom. Chem. 2021, 943, 121810
[2] C. Bruice et al., J. Am. Chem. Soc. 2001, 123, 11952-11959
[3] L. Zanetti-Polzi et al., J. Phys. Chem. Lett. 2017, 83321-3327

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TEO-PO-002

Design and set up of Machine Learning force fields of characterization and development of next generation solid state battery electrolytes

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All-solid state (ASSB) batteries are one of the most promising alternatives of Li-ion liquid technology. ASSB have several advantages[1], such as greater stability, better safety, and higher energy density[2], but also an intrinsic, and still unsolved, problem caused by their solid nature, the low ion mobility. Amorphous Lithium thiophosphates, LPS (xLi_2S-$(1-x)P_2S_5$) and their oxidised form LPSO (with Li_2O and/or P_2O_5) are among the most promising[3] electrolytes. Optimizing their performances by tuning their composition in order to achieve high ion conductivities (at least 10^{-3} S/cm to be competitive with liquid electrolytes) is an extremely complicated task because we do not yet know the structure-properties relation and the optimization process require laborious trial-and-error laboratory procedures. Using molecular modelling we can help making this process much quicker. Typically, computational approaches to electrochemistry involve ab-initio molecular dynamics (AIMD) methods, that, despite their accuracy, are very slow and computationally intensive, compared to classical molecular dynamics (MD), that instead relies on parametric force fields (FF). Classical MD calculations on LPS and LPSO are, at the moment, difficult to perform because they would need the development of a suitable FF whose analytical form is complicated due to the different states of chemical coordination that Li^+ assumes in the amorphous solid. Nevertheless, it is important for the electrochemical community to have access to a quick and efficient way to model electrolytes such as LPS and LPSO.

We have used deep learning molecular dynamics[4], to generate the FF. The deep neural network[5] has been trained using accurate ab-initio data and a deep learning force field (DLFF)[7-8] has been produced. The FF has the high accuracy[6] of the ab-inito level chosen for the training set and, being parametric, a high efficiency (classical MD level). Using this DLFF we have performed fast ed accurate simulations on model systems beyond the actual limits of AIMD. This approach will be crucial to determine electrochemical properties of LPS and optimize their composition to make this technology competitive in a large-scale industry environment.

References:

[1] Sun, Y.-K., ACS Energy Lett. 2020, 5, 3221–3223.
[2] Zhang, Z. et al., Energy Environ. Sci. 2018, 11, 1945–1976
[3] Grady, Z. A. et al., Front. Energy Res. 2020, 8.
[4] Unke, O. T. et al., Chem. Rev. 2021, 12, 10142–10186.
[5] Mo, Y. et al., Chem. Mater. 2012, 24, 15–17.
[6] He, X. et al., npj Comput Mater 2018, 4, 1–9.
[7] Wang, H. et al., Comp Phys. Comm. 2018, 228, 178–184.
[8] Zhang, L. et al., Phys. Rev. Lett. 2018, 120, 143001.

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A computational approach to the study of carbon dots for the determination of their structure and properties

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Recently, carbon dots (CDs) have emerged prominently in the family of carbon-based nanoparticles for their unique properties, such as intense photoluminescence, low toxicity, excellent biocompatibility, and easy surface functionalization[1]. In addition, they involve simple synthetic approaches that include bottom-up and top-down methods[2] that, in turn, determine the functional groups of the surface, their size, and their photoluminescence response. For all these reasons, CDs have found applications in various fields, being mostly used for biological and biomedical applications[3]. To date, a detailed understanding of the atomic-level structure of these compounds and the relationship between the structure and their properties has been only partially established[4]. Therefore, it is necessary to develop an efficient computational method to fill these gaps. Preferably, this approach should maintain an explicit description of the electronic degrees of freedom, to assess optical properties from first principles and to investigate electron density and, ultimately, the surface charge of the nanoparticle.

We present results on the application of a computational multiscale approach based on *ab-initio* DFT (Density Functional Theory) and semi-empirical (TB-DFT, tight-binding density functional theory) methods to the class of carbon dots. The advantage lies in reducing time and cost of the research compared to experimental methods, while considering a wide range of structures and maintaining a good level of accuracy. Our study begins with the CDs with an amorphous carbogenic core, the variant which is less explored in literature. Several model structures based on amorphous carbon functionalized with nitrogen or oxygen atoms, with a number of atoms ranging from 20 to 200 have been studied and will be presented.

References:

[1] D. Ozyurt, M. Al Kobaisi, Carbon Trends 2023, 12, 100276.
[2] B. Yao, H. Huang, Trends in Chemistry 2019, 1 (2), 235 – 246.
[3] J. Liu, R. Li, ACS Central Science 2020, 6 (12), 2179 – 2195.
[4] K. J. Mintz, M. Bartoli, Carbon 2021, 173, 433 – 447.

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r²SCAN derived composite methods for solid state calculations

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In the last decades, methods derived from Density Functional Theory (DFT) have been used as workhorse computational tools for many applications. Recently, there has been a growing interest in moving from the modelling of small and medium-sized systems to investigating increasingly large and complex systems. However, for systems characterized by weak bonds the current semi-local or hybrid DFT methods do not show sufficient accuracy and predictive power due to their pitfall in describing dispersive interactions. To cope with this, it would be necessary to use either the 5th-rung exchange-correlation (XC) functionals or wavefunction-based methods, which are very accurate but extremely expensive for large-scale calculations. To overcome this limitation, Stefan Grimme proposed the so-called "3c" composite methods[1] which combine DFT with semiclassical corrections to include dispersive interactions and correct for the basis set incompleteness error. After their initial application to molecules and molecular crystals, the originally proposed methods have been revised and optimized for solid-state calculations. This has resulted in a set of methods referred to as "sol-3c"[2].In this work, we have extended the existing "sol-3c" composite methods to mGGA XC functionals using the r²SCAN one[3]. The corresponding r²SCAN-based composite methods in their pure and hybrid HF/DFT variants have been developed in combination with double-ζ (sol-def2-mSVP) and triple-ζ (pob-TZVP-rev2) quality basis sets[4] specifically adapted to solids. The r²SCAN "sol-3c/pob-3c" methods were validated and tested on benchmark sets containing both intermolecular adducts (s66x7[5]), molecular crystals (X23[6], DMC8[7]) and simple inorganic solids (SS20[8]). They were then applied to the study of the energetic and structural properties of layered materials, the mechanical, electronic and vibrational properties of α-quartz, TiO2 (and its polymorphs), all-silica zeolites and the adsorption of small molecules on inorganic surfaces and meta-organic frameworks. The new methods show broad applicability with accurate results and an adjustable and affordable computational cost.

References:

[1] S. Grimme, A. Hansen, S. Ehlert, et al., J. Chem. Phys. 2021, 154 (6), 064103-064121.
[2] L. Donà, J. G. Brandenburg, B. Civalleri, J. Chem. Phys. 2019, 151 (12), 121101-121106.
[3] J. W. Furness, A. D. Kaplan, J. Ning, J. P. Perdew, J. Sun, J. Phys. Chem. Lett. 2020, 11 (19), 8208−8215.
[4] D. Vilela Oliveira, J. Laun, M. F. Peintinger, T. Bredow, Journal of Computational Chemistry 2019, 40 (27), 2364-2376.
[5] Z. M. Sparrow, B. G. Ernst, P. T. Joo, et al., J. Chem. Phys. 2021, 155 (18), 184303-184321.
[6] G. A. Dolgonos, J. Hoja, A. D. Boese, Physical Chemistry Chemical Physics 2019, 21(44), 24333-24344.
[7] A. Zen, J. G. Brandenburg, J. Klimeš, A. Tkatchenko, D. Alfè, A. Michaelides. Proceedings of the National Academy of Sciences 2018, 115 (8), 1724-1729.
[8] P. Pernot, B. Civalleri, D. Presti, A. Savin, The Journal of Physical Chemistry A 2015, 119 (21), 5288-5304.

TEO-PO-005

The effect of locally concentrated RTILs on low temperature aluminium-sulfur batteries, a computational investigation

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In modern days, battery usage is expanding since mobile systems like smartphones, electric vehicles, etc. rely on stored energy[1]. Aluminium-sulfur (Al-S) has been considered a promising energy storage device due to the theoretical capacity and the high abundance of their components. However, these batteries are notoriously flawed by sluggish ionic transport and cathode convertion rates[2]. Recently[3], a mixture of room temperature ionic liquids (RTILs) and aromatic diluents has been used showing improved ionic transport, offering high coulombic efficiency.

We have employed molecular dynamic simulations to study locally concentrated RTILS electrolytes (LCILEs). The aggregation behaviour of LCILE have an important role in the ionic transport and stripping/plating mechanism on the electrodes. The advantage of using a parametrized simulation make the dimension scales of nano-aggregations easily achievable giving us a tool to better understand the experimental results of those novel batteries.

References:

[1] M. S. Whittingham and et al. Electrical energy storage and intercalation chemistry. Sci., 192, 1976.
[2] Q. Zhou et al. Coord. Chem. Rev. 2023, 474, 214856.
[3] C. Xu et al. Angew. Chem. 136, 10, 2024.

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TEO-PO-006

Modeling Single Atom Catalysts

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Single Atom Catalysts (SACs) are considered to be the new frontier in the field, since they establish a bridge between the homogeneous and heterogeneous catalysis. Computational chemistry shows the atomistic details of electrocatalytic processes, and it is extremely helpful to rationalize of even predict systems'properties. A lot of attention has been dedicated to the reactions of evolution and conversion of molecular hydrogen and oxygen from or to liquid water.[1] The Computational Hydrogen Electrode (CHE) approach is the key to predict the activity of SACs, where the free energy of key intermediates adsorbed is used to explain the catalytic activity[2], or even predict the reaction mechanism.

In this presentation we discuss a computational screening of Single Atom Catalysts (SACs) bound to titanium nitride (TiN), an emerging supporting matrix. The catalysts were tested against the Hydrogen Evolution Reaction (HER), based on density functional theory (DFT). We explore the role of fundamental ingredients to consider for a reliable screening of SACs. Namely, the formation of H_2-complexes[3,4] besides the classical H* one has an important impact on the predicted HER activity. Also, the results indicate that one needs to adopt self-interaction corrected functionals[5], including the Hubbard parameter on d electrons. Once unconventional intermediates in a self-interaction corrected scheme, the number of potential good catalysts for HER is strongly reduced, since the formation of unconventional intermediates lead to thermodynamic barriers. This study highlights the importance of including the key ingredients for the prediction of new systems, as the formation of unconventional intermediates and the adoption of self-interaction corrected functionals[5]. Also, this study highlights some interesting candidate deserving more dedicate work.

References:

1. L. Cao, Q. Luo, W. Liu, Y. Lin, X. Liu, Y. Cao, W. Zhang, Y. Wu, J. Yang, T. Yao, S. Wei, Nat. Catal 2.2 (2019) 134-141.
2. J. K. Nørskov, T. Bligaard, A. Logadottir, J. R. Kitchin, J. G. Chen, S. Pandelov, U. Stimming, J. Electrochem. Soc. 152 (2005), J23.
3. G. J. Kubas, Chem. Rev. 107 (2007), 4152-4205; R. H. Crabtree, Chem. Rev. 116 (2016), 8750-8769.
4. G. Di Liberto, L. A. Cipriano, G. Pacchioni. JACS 143.48 (2021) 20431-20441.
5. I. Barlocco, L.A. Cipriano, G. Di Liberto, G. Pacchioni. Adv. Theo. & Simul. 6.10 (2023), 2200513.

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TEO-PO-007

First-principles insights on solid-state transitions in Mn-based layered oxides as high energy cathodes for Na-ion batteries

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Layered Transition Metal Oxides (Na_xTMO_2) hold promise as high-energy cathode materials for Na-ion batteries[1]. Their general structure consists of TMO_6-octahedra 2D slabs sandwiched between Na layers, wherein the arrangement and packing of oxide layers define distinct material morphologies such as P2- and O3- structures[2]. While mixed transition metal oxides in this class of cathodes have shown promising performances and enhanced anion redox activity[3,4], ongoing research aims at improving their long-term stability, which is often hampered by solid-state phase transitions occurring during Na^+ insertion and extraction cycles, with structural collapse and significant capacity loss. Understanding and controlling these structural transformations is therefore of outmost importance to boost the electrochemical performance of layered oxides.

Employing the solid state nudged elastic band (ss-NEB) method[5] combined with state-of-the-art density functional theory (DFT) calculations, we address the prototypical case of P2 ↔ P2'/OP4 transitions in Na_xMnO_2[6]. We provide an atomic-level perspective on the glide-driven processes in these compounds, confirming the key role of Cooperative Jahn-Teller effects (CTJE) and Na^+ ordering at low state of charge as driving forces for these phase transitions[7]. Moreover, we highlight the utility of the ss-NEB method in finely charactering these subtle processes. Leveraging the same methodology, we also elucidate how partial substitution of Mn with Ni extends the of P2 phase, delaying the direct transition from P2 to O2 at higher voltages.

In conclusions, our new structural and electronic insights will provide a solid scientific framework for designing new layered transition-metal oxides with enhanced stability for long term battery operations.

References:

[1] S. Fang, D. Bresser, S. Passerini, Adv. Energy Mater., 2021, 10, 1902485.
[2] X. Xiang, K. Zhang, J. Chen, Adv. Mater., 2015, 27, 5343–5364.
[3] K. Zhang, D. Kim, Z. Hu, et al., Nat. Commun., 2019, 10, 5203.
[4] A. Massaro, A. Langella, A. B. Muñoz-García, M. Pavone, J. Am. Ceram., 2023, 106, 109-119.
[5] D. Sheppard, P. Xiao, W. Chemelewski, D. Duane Johnson, G. Henkelman, J. Chem. Phys., 2012, 136, 074103.
[6] C. Wang, L. Liu, S. Zhao, et al., Nat. Commun., 2021, 12, 2256.
[7] A. Langella, A. Massaro, A. B. Muñoz-García and M. Pavone, Chem. Mater., 2024. [1] N. Surname, N. Surname,

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TEO-PO-008

Activity of Single Atom Catalyst for Nitrogen Reduction: The More Reactive the Better Does Not Always Holds True

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Single Atom Catalysts (SACs) are emerging as a new frontier in heterogeneous catalysis.[1,2] They are made of metal atoms atomically dispersed on a matrix. Computational chemistry allows to study catalytic processes with an atomic detail and to rationalise, and even predict, the properties of systems. A lot of attention has been dedicated to the electrochemical Nitrogen Reduction Reaction (NRR) to ammonia, because of the key role that it could have in energy transition.[3] The activity of SACs is usually rationalized by using the Computational Hydrogen Electrode (CHE), a thermodynamic approach proposed by Nørskov and co-workers, making possible to explain the catalytic activity evaluating Gibbs free energies of key adsorbed intermediates.[4,5] In this presentation we rationalise the activity of Single and Dual Atom Catalysts made of a set of transition metal atoms for NRR. We show the importance of using self-interaction corrected functionals. We also observed that DACs are more active than SACs, an aspect in line with the nature of the real catalyst (nitrogenase) for NRR in ambient condition.[6] Also, the highest thermodynamic barrier decreases from 3d to 5d metals. Interestingly, if one combines the two positive effects, this results into too strongly stable intermediates, showing that *"the more reactive the better"* does not always hold true in single atom catalysis. We, finally, show that the NRR mechanism cannot be limited to the classical. This work highlights *i)* the importance of using self-interaction corrected functionals, *ii)* DACs could be a valid option for NRR, and *iii)* the combined effect of DACs with 5d metals does not necessarily lead to an increment of the activity.

References:

[1] G. Di Liberto, G. Pacchioni, 2023, *Adv. Mater.*, *35, 2307150*
[2] G. Di Liberto, L. A. Cipriano, G. Pacchioni, 2021, *J. Am. Chem. Soc.*, *143, 20431–20441*
[3] X. Y. Cui, C. Tang, Q. Zhang, 2018, *Adv. Energy Mater.*, *8, 1800369*
[4] J. K. Nørskov *et al*, 2002, *J. Catal.*, *209, 275-278*
[5] J. K. Nørskov *et al*, 2005, *J. Electrochem. Soc.*, *152, 23-26*
[6] B. M. Hoffman, D. Lukoyanov, D. R. Dean, L. C. Seefeldt, 2013, *Acc. Chem. Res.*, *46, 587-595*

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TEO-PO-009

Hydrogen Complexes on Single-Atom Alloys: A combined DFT-Kinetic Monte Carlo Study

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Single-atom alloys (SAAs) are emerging in the field of catalysis, offering a new paradigm for enhancing catalytic performance. These materials, composed of isolated metal atoms dispersed on a metal substrate, represent a class of single-site catalysts with exceptional properties[1], exhibiting enhanced catalytic activity by breaking the Brønsted–Evans–Polanyi relationship[2].

SAAs are widely studied for processes involving hydrogen, such as water splitting or hydrogenation reactions. Previous studies have shown that dihydrogen and dihydride complexes can form on SAAs, indicating the potential for non-conventional intermediates in catalytic reactions. These complexes play a crucial role in modelling studies aimed at screening new materials, identifying descriptors, and predicting novel catalysts[3].

The combination of DFT calculations with kinetic modelling makes it possible to capture trends in activity and selectivity. The Kinetic Monte Carlo (KMC) approach is attracting growing interest for the study of catalytic reactions, due to its versatile framework and its ability to provide unique insight, by bridging molecular scale processes (micro) and observable phenomena[4].

In this work we investigate the adsorption of hydrogen on a set of 14 SAAs. We show that in 4 cases: CoRh(111), PdRh(111), CoAu(111), NiAu(111) the formation of the dihydrogen intermediate (H_2*) is observed. Importantly, the H_2 adsorption process necessarily passes through that intermediate and it is barrierless. On the other hand, the breaking of the bond and the formation of H* ad-atoms entail a sizeable reaction barrier.

The static information is used as input for KMC simulations to capture information about overall reaction rate and hydrogen coverage and to provide insight into the role of the H_2* kinetics in H_2 adsorption.

References:

[1] Ryan T. Hannagan, Georgios Giannakakis, Maria Flytzani-Stephanopoulos, and E. Charles H. Sykes. Chemical Reviews 2020 120 (21), 12044-12088

[2] Matthew T. Darby, Michail Stamatakis, Angelos Michaelides, and E. Charles. H. Sykes The Journal of Physical Chemistry Letters 2018 9 (18), 5636-5646

[3] Ilaria Barlocco, Giovanni Di Liberto and Gianfranco Pacchioni. Catal. Sci. Technol., 2023,13, 5301-5312

[4] M. Pineda, M. Stamatakis. J. Chem. Phys. 156, 120902 (2022)

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TEO-PO-010

Theoretical Investigation of Inorganic Particulate Matter: The Case of Water Adsorption on a NaCl Particle Model Studied Using Grand Canonical Monte Carlo Simulations

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Sodium chloride (NaCl) represents the principal component of atmospheric particulates of marine origin.[1] To gain a molecular-level understanding of the adsorption process of water vapor on the NaCl surface, Monte Carlo simulations performed in the Grand Canonical ensemble were carried out, considering the water adsorption at different water pressures on a NaCl(001) surface.[2] The calculated adsorption isotherm shows four different regions, whose coverages correspond to those of the low-, transition-, high-, and pre-solution-coverage regions experimentally observed. Detailed analysis, leveraging unsupervised machine learning for water clusters detection, revealed how the structure of the adsorbed water molecules (islands, layer, and multi-layer) changes depending on water pressure, and how their orientation with respect to the surface varies with the distance from the surface. This detailed information further supports the picture coming from previous experimental IR absorption spectroscopy studies.

References:

[1] I. Sandu, M. Chirazi, M. Canache, I.G. Sandu, M.T. Alexianu, A.V. Sandu, V. Vasilache, J. Environ. Eng. Landsc. Manag. 2010, 9, 881–888.
[2] F. Rizza, A. Rovaletti, G. Carbone, T. Miyake, C. Greco, U. Cosentino, Inorganics 2023, 11, 421.

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TEO-PO-011

CO oxidation mechanism of Ag-substituted Mo/Cu CO-dehydrogenase. Analogies and differences to the native enzyme

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The aerobic oxidation of carbon monoxide to carbon dioxide is catalysed by the Mo/Cu-containing CO-dehydrogenase enzyme in the soil bacterium *Oligotropha carboxidovorans*, enabling the organism to grow on the low-weight gas molecule as a carbon and energy source [1]. It was shown experimentally that silver can be substituted for copper in the active site of Mo/Cu CODH to yield a functional enzyme. In our laboratories, we employed QM/MM calculations to investigate whether the reaction mechanism of the silver-substituted enzyme is similar to that of the native enzyme. Due to remarkable consistence with experimental findings, our theoretical results indicate that the Ag-substituted enzyme can oxidize CO and release CO_2 following the same reaction steps as the native enzyme. Surprisingly, lower activation energies for C–O bond formation have been found in the presence of silver. We also evaluated the effects that differences in the water-active site interaction may exert on the overall energy profile of catalysis. Finally, the formation of a thiocarbonate intermediate along the catalytic pathway was found to be energetically unfavorable for the Ag-substituted enzyme. This finding aligns with the hypothesis proposed for the wild-type form [2], suggesting that a step corresponding to the formation of such species may not be necessary for the enzymatic catalysis of CO oxidation. Further perspectives in terms of investigations on engineered forms of the enzyme active site will be also considered in our presentation.

References:

[1] M. Can, F. Armstrong, S.W. Ragsdale, Chemical reviews 2014, 114, 4149–4174.
[2] A.G. Ritacca, A. Rovaletti, G. Moro, U. Cosentino, U. Ryde, E. Sicilia, C. Greco, ACS Catalysis 2022, 12, 7336–7343.

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TEO-PO-012

Role of Key Intermediates of Oxygen Evolution on IrO_2, RuO_2 and TiO_2 catalysts: A Computational Electrochemistry study

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Water electrolysis is a key reaction for the transition to sustainable fuels and green energy production.[1] The Oxygen Evolution Reaction (OER) still needs to be improved in terms of efficiency and fundamental understanding of its chemistry. In terms of efficiency, RuO_2 is considered a promising candidate. OER is typically assumed to occur through the path OH*, O*, OOH*.

Previous studies demonstrated that on RuO_2 unconventional intermediates can form. For instance, instead of forming OOH*, the oxygen bond changes from hydroperoxide type (OOH) to superoxide ($OO^{-}H^{+}$) one.[2]

In the presentation we systematically investigate the role of key reaction intermediates on three relevant metal oxides for electrocatalytic and photoelectrocatalytic OER, TiO_2, RuO_2, IrO_2.[3-4] This study was conducted by first, investigating the stability by means of ab-initio thermodynamics, and then by looking at the critical role of solvation. Finally, static calculations were complemented by ab-initio molecular dynamic simulations.

Results allow to rationalize both the role of solvation in the stability and reactivity of OER intermediates, as well as the role of the electronic structure of the metal oxide, giving an interesting overview of the intermediates formation and stability.

References:

[1] S. Divanis, A. M. Frandsen, T. Kutlusoy, J. Rossmeisl, Phys. Chem. Chem. Phys., 2021, 23, 19141
[2] G. Di Liberto, G. Pacchioni, Y. Shao-Horn, L. Giordano, J. Phys. Chem. C 2023, 127, 10127−10133
[3] Y. Lee, J. Suntivich, K. J. May, E. E. Perry, Y. Shao-Horn, J.Phys.Chem.Lett.2012, 3, 399−404
[4] H. Eidsvåg, S. Bentouba, P. Vajeeston, S. Yohi, D. Velauthapillai, Molecules 2021, 26, 1687

TEO-PO-013

Using semiclassical vibrational spectroscopy to gain a new perspective of water solvation

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It is now common knowledge that solvation can play an important role in many areas of chemistry, such as reactivity and the study of biomolecular processes. What is less obvious and still remains an open problem for the theoretical community is how to properly model and describe such processes. In this work[1] we take as an example the case of water solvated thymidine. We chose this system due to its peculiar experimentally observed behavior in the vibrational spectrum,[2,3] where in gas phase the signal relative the pyrimidinic rings' C4 = O and the one to the C5 = C6 are well separated while upon water solvation the same two signals are degenerate. To investigate the reason of this concerted shift of signals and gain a new atomistic physical picture of this phenomenon we use the Divide and Conquer Semi-classical Initial Value Representation (DC-SCIVR)[4] which allows us to add Nuclear Quantum Effects (NQEs) to classical molecular dynamics. Furthermore, to retain an high accuracy on such a complex and massive system we combined our semiclassical approach with the cutting edge QM/AMOEBA potential.[5] During this presentation it will be shown how the use of these tools allowed us to build a new physical picture of water solvation which keeps in account for the atomistic details in a dynamical way.

References:

[1] Moscato D. , Mandelli G., Bondanza M., Lipparini F., Conte R., Mennucci B., Ceotto M., JACS ASAP
[2] Ivanov A. Y., Stepanian S., Karachevtsev V., Adamowicz L., Low. Temp. Phys. 2019, 45, 1008-1017
[3] Beyere L., Arboleda P., Monga V., Loppnow G., *Can. J. Chem.* 2004, *82*, 1092–1101
[4] Ceotto M., Di Liberto G., Conte R., *Phys. Rev. Lett.* 2017, *119*, 010401
[5] Lipparini F., Scalmani G., Mennucci B., Cances E., Caricato M., Frisch M. J., *J. Chem. Phys.* 2010, *133*

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TEO-PO-014

Linear Response Equation Revisited: A Simple And Efficient Iterative Algorithm

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Light-matter interaction plays an essential role in many aspects of life and technology, including biologically relevant photochemical processes (e.g., photosynthesis, bioluminescence, vision), light-induced chemical reactions, photovoltaics, photonics, materials engineering. The advent of spectroscopy provided chemists and physicists with a powerful tool to investigate the interaction between matter and electromagnetic radiation. An accurate study of such interaction, however, is also possible with the application of rigorous ab-initio electronic structure methods which are employed to perform computer simulations of molecular systems. These studies are particularly important for the interpretation of complex experimental spectra and a better understanding of electronic properties of matter.

The most common procedure used to calculate molecular properties is based on linear response theory[1], which allows for the direct simulation of spectroscopic properties. The computation of these quantities requires the solution of the so-called "response equations" which are casted in the form of a generalized eigenvalue problem. However, the determination of its solutions can become expensive and, in many cases, could lead to numerical instabilities[2][3].

In this talk, I will present an improved version of the well-established Davidson direct diagonalization approach[4], able to fix those instabilities at a reduced computational cost. This new algorithm is referred to as Swapped Metric-Orthogonal Generalized Davidson (SMO-GD)[5]. In its first formulation it has been applied by us to simulate spectra at the CASSCF level of theory but it can be also applied, without lack of generality, to time-dependent density functional theory (DFT) and Hartree-Fock (HF)[6] approaches.

This algorithm represents a stable and efficient eigensolver that can be, in principle, applied to the solution of response equations both for molecules and solid state systems.

References:

[1] Norman, P., Ruud, K. & Saue, T. John Wiley & Sons, Inc., 2018, Hoboken, NJ, USA
[2] Christiansen, O., Jørgensen, P. & Hättig, C. International Journal of Quantum Chemistry, 1998, 68, 1–52.
[3] Olsen, J. & Jørgensen, P. The Journal of Chemical Physics 1985, 82, 3235–3264.
[4] Davidson, E. R. Journal of Computational Physics 1975, 17, 87–94.
[5] Alessandro, R., Gianni, I., Pes, F., Nottoli, T., and Lipparini, F. Journal of Chemical Theory and Computation. 2023, 19, 24, 9025–9031.
[6] Casida, M.E. J. Mol. Struct. TheoChem. 1995, 155-192.

TEO-PO-015

Electronic excitations in complex and multichromophoric systems with machine learning

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Photophysical processes of biological interest occur in condensed phase, within "complex" systems where chromophore-environment interactions shape optical properties and excited-state dynamics. Faithful quantum chemical (QM) modeling of these processes requires a multiscale QM/classical strategy that accounts for all such interactions [1], as well as a thorough sampling of the configurational ensemble. The computational cost of QM methods however limits the number of calculations, forcing a compromise between statistical accuracy and feasibility. Machine learning (ML) techniques hold great promise in alleviating the computational burden of QM calculations, and have been successfully employed for the prediction of excited-state properties and dynamics [2]. However, much less attention has been paid to environment effects on excited states [3].

Here I will outline potential ML strategies to model excited states within complex systems, showing that the effects of the environment can be incorporated in a physically sound way within ML models. I will focus on light-harvesting pigment-protein complexes, as examples of complex environments where excitations are delocalized over multiple chromophores and also tuned by the interactions with the protein [4]. The obtained ML models [5] not only can faithfully predict the effect of the environment on electronic excitations, but can be used to simulate the excited-state dynamics of large multichromophoric complexes [6]. Finally, physically sound ML models can also assist the interpretation of solvatochromic effects, effectively complementing traditional QM/classical methods [7].

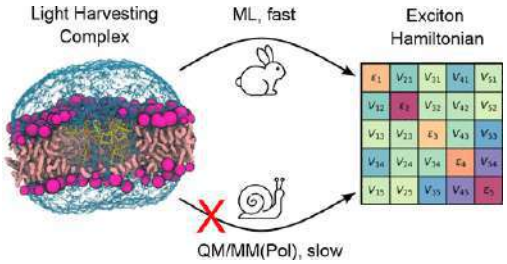

Figure 1: Graphical abstract.

References:

[1] M. Nottoli, et al.,Annu. Rev. Phys. Chem. 2021, 72, 489
[2] J. Westermayr, P. Marquetand. Chem. Rev. 2021, 121, 9873
[3] M. S. Chen et al., J. Phys. Chem. Lett. 2020, 11, 7559
[4] L. Cupellini et al., BBA – Bioenerg. 2020, 1861, 148049.
[5] E. Cignoni et al., J. Chem. Theory Comput. 2023, 19, 965
[6] E. Betti et al., doi:10.26434/chemrxiv-2024-0h765
[7] A. Arcidiacono et al., doi:10.26434/chemrxiv-2024-3zrx2

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Four component relativistic calculations at reduced cost: a Cholesky decomposition implementation

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Including relativistic effects[1] in the computational description is paramount when dealing with molecules containing heavy-metal atoms. Such effects can be divided into scalar relativistic and spin-orbit effects. The former have a large impact on the overall energy, while the latter are responsible for fine effects on the electronic states. In this contribution, we pursue a computationally efficient, but rigorous description of scalar relativistic effects by adopting the four-component spin-free Dirac-Coulomb Hamiltonian[2] in combination with Coupled-Cluster with single and double excitations (CCSD)[3] as an electronic structure method. A four-component treatment introduces a major computational bottleneck, because the 4-component structure of the wave function leads to a sizeably larger number of two-electron integrals that need to be computed and processed when compared with the non-relativistic case. The additional two-electron integrals are not only affecting all computationally intensive step of a quantum chemistry calculation, but are also *per se* expensive to compute. However, they are numerically smaller than the non-relativistic integrals, which makes them an ideal problem for rank reducing techniques. In this contribution, we apply the Cholesky Decomposition (CD)[4] to the spin-free, relativistic two-electron integrals to accelerate the computation. We present an efficient, two-step[5] implementation of the CD, and discuss possible approximations that can be adopted when selecting the Cholesky basis, and in particular, the neglect of pivots stemming from the small component integrals. Using the CD has several advantages: it reduces the cost of computing the integrals themselves, accelerates the SCF and integral transformation computations, which further become trivially parallelizable, and, due to the effective compression of the two-electron integral tensor achieved by the technique, allow for an efficient MO implementation of the CCSD treatment that is not memory limited. This is particularly attractive, as it allows to use the same machinery used for non-relativistic CD-CCSD calculations, making thus it possible to perform the correlation calculation, which is the most expensive overall computational step, at no additional computational cost with respect to the non-relativistic counterpart. Various numerical experiments are presented to show in detail the possibilities and performance of the CD-SFDC-CCSD implementation.

References:

[1] P.Pyykko, *Annual Rev. Phys. Chem.*, 2012, 63, 45 – 64.
[2] K. G. Dyall, *J. Chem. Phys.*, 1994, 100(3), 2118 – 2127.
[3] L. Cheng, J. Gauss, *J. Chem. Phys.*, 2011, 134(24).
[4] T. B. Pedersen, *et al.*, *WIREs Comp. Mol. Sci.*, published online 2023.
[5] T. Zhang, *et al.*, *J. Phys. Chem.*, 2021, 125(19), 4258 - 4265.

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Accurate description of environment effects on Thermally Activated Delayed Fluorescence: role of state-specific polarization response and dispersion interactions

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The accurate simulation of environmental effects in the formation and relaxation of electronic excited states (ESs) is essential for efficient design of new materials with target properties.[1] The consideration of non-equilibrium effects is a crucial aspect but the quantum mechanical (QM) approach must flexibly address the diverse descriptions of the environment's polarization response.[2] While numerous studies have explored singlet ESs,3 less is known about the impact of solvent effects to triplet transitions, that have garnered considerable attention due to their potential applications in optoelectronics[4,5] and their role in the photoprotection mechanisms in plants and bacteria.[6] Here, we delve into the challenges of accurately characterizing the polarization response of the environment to triplet excitations, surpassing the limitations of the standard linear response framework in continuum dielectric models. The latter indeed fails to incorporate solvation effects arising from singlet-to-triplet transitions. Notably, the state-specific polarization (ss-pol) response also plays a crucial role in determining the ESs structure minima, facilitated by analytical gradients through a lagrangian formulation in a TDDFT framework.[7] Since it has been shown by an open quantum systems approach[8] that the delayed solvent response due to the solute charge density reorganization evolving in a time regime naturally include both ss-pol and dispersion interactions, both of them have been included in our effective protocol here presented. Simulations in the study of systems with inverted singlet-triplet gap[9] in solution for thermally activated delayed fluorescence applications will show the pivotal role of an accurate solvent response description.[10]

References:

[1] Nelson, T.R.; White, A. J.; Bjorgaard, J. A.; Sifain, A. E.; Zhang, Y.; Nebgen, B.; Fernandez-Alberti, S.; Mozyrsky, D.; Roitberg, A.E.; Tretiak, S. *Chem. Rev.* 2020, *120*, 2215–2287.
[2] Guido, C.A.; Caprasecca S. *Int. J. Quantum Chem.* 2018 119, e25711.
[3] Guido, C.A.; Jacquemin, D.; Adamo, C.; Mennucci, B. *J.Chem. Theory Comput.* 2015, *11*, 5782-5790.
[4] Bardi, B. et al. Mater. Horiz. 2023, 10, 4172-4182.
[5] Turelli M.; Ciofini, I.; Wang, Q.; Ottochian, A.; Labat, F.; Adamo, A. *Phys. Chem. Chem. Phys.* 2023, 25, 17769-17786.
[6] Gall, A. et al. *Byophys. J.* 2011 2011, 101, 934-942.
[7] Guido, C. A.; Scalmani, G.; Mennucci, B.; Jacquemin, D. *J. Chem. Phys.* 2017, *146*, 204106
[8] Guido, C. A.; Rosa, M.; Cammi, R.; Corni, S. *J. Chem. Phys.* 2020, *152*, 174114.
[9] Omar, Ö. H.; Xie, X.; Troisi, A.; Padula, D. *J. Am. Chem. Soc.* 2023, *145*, 19790.
[10] Salvi, E.; Padula, D.; Guido, C. A. 2024 (*submitted).*

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Implementation of Coupled Cluster analytical gradients based on the Cholesky decomposition of ERIs

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In recent years, rank-reducing techniques have seen a surge of interest by the quantum chemistry community, due to them being able to mitigate the intensive computational cost associated with electronic structure methods, thus extending their applicability to larger molecular systems. In that regard, we exploit the Cholesky decomposition (CD) of the electron repulsion integrals (ERI) tensor[1], reducing the impact of its manipulation on the cost of quantum chemical calculations. CD is not only able to compress the information stored within the ERI tensor, making it possible to manipulate it without recomputing or reading the integrals from disk, but also affords a strict control over the accuracy of their representation, since the approximation error is bound to be lower than the predetermined threshold used for the decomposition.

Here we applied the CD of ERIs and their derivatives to the computation of analytical geometrical gradients at the Coupled Cluster (CC) level of theory[2-4]. We present an efficient and parallelized implementation of CD, using a two-step algorithm[5] that can fully exploit Abelian point-group symmetry[6] and compute not only the Cholesky vectors, but also their derivatives with respect to nuclear displacements, also fully exploiting point-group symmetry. We use the Cholesky vectors and their derivatives to achieve an efficient and parallel implementation of the CC density matrices and for the intermediates in the *Z*-vector equations, along with their contractions with Cholesky decomposed differentiated integrals, yielding optimized molecular structures at the CCSD and CCSD(T) levels. The capabilities of our new implementation are tested on a range of systems, for which we compute the energies and molecular structures.

References:

[1] H. Koch, A. Sánchez de Merás, T. B. Pedersen, J. Chem. Phys. 2003, 118, 9481 – 9484.
[2] U. Bozkaya, C. D. Sherrill, J. Chem. Phys. 2016, 144, 174103.
[3] A. K. Schnack-Petersen, H. Koch, S. Coriani, E. F. Kjønstad, J. Chem. Phys. 2022, 156, 244111.
[4] U. Bozkaya, C. D. Sherrill, J. Chem. Phys. 2017, 147, 044104.
[5] S. D. Folkestad, E. F. Kjønstad, H. Koch, J. Chem. Phys. 2019, 150, 194112.
[6] T. Nottoli, J. Gauss, F. Lipparini, J. Chem. Phys. 2023, 159, 231101.

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Scaling the Quantum Frontier: From PCS3 to FPCS3 in Pursuit of Thermochemical Precision

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Quantum chemistry plays an increasing role in complementing experimental studies since its accuracy and feasibility for large systems are constantly increasing. Several procedures have been developed for the generation of accurate thermochemical data[1]. For small molecules, among the most successful approaches are the Weizmann-*n* series (e.g. W4[2]) and the extrapolated *ab initio* thermochemistry (HEAT) protocol[3], providing results with sub-chemical accuracy but with a very unfavorable scaling with the system size. Alternative protocols have been proposed, which employ explicitly correlated (F12) approaches[1], that can save some computer time thanks to their faster convergence to the complete basis set limit. For larger molecular systems, more approximate composite methods are unavoidable, which aim at reaching chemical accuracy. The most well-known are the last versions of the G*n*[4] and CBS-*x*[5] families employing conventional methods or the W1-F12[2] and SVECV-F12[6] models with F12 approaches. Recently, an accurate computational protocol rooted in the F12 coupled cluster method, referred to as the Pisa composite scheme (PCS), has been developed and tested for structural and energetic data[7]. Two PCS variants with different accuracy and computational requirements are proposed, PCS3 and FPCS3, which can be employed for the study of medium-to-large molecules. Particular attention has been paid to core-valence contribution, extrapolation recipes, and optimization of the cost/performance ratio of the approach. The PCS3 variant can be applied to systems containing about 15 atoms, while the FPCS3 scheme, with the introduction of the frozen natural orbital approximation, permits to obtain accurate electronic energies for systems containing up to about 50 atoms, without the use of local correlation methods. These schemes have been benchmarked and applied to the calculations of atomization energy and heat of formation of systems of increasing size, from benzene (12 atoms) to a molecular motor (47 atoms), and open new frontiers for accurate characterizations and studies of energetic and biological interest.

References:

[1] A. Karton, WIRES Computational Molecular Science 2016, 6, 292-310.
[2] A. Karton, J. M. L. Martin, Journal of Chemical Physics 2012, 136, 124114 1-12.
[3] A. Tajti, P. G. Szalay, A. G. Császár, M. Kállay, J. Gauss, E. F. Valeev, B. A. Flowers, J. Vázquez, J. F. Stanton, Journal of Chemical Physics 2004, 121, 11599-11613.
[4] L. A. Curtiss, P. C. Redfern, K. Raghavachari, WIRES Computational Molecular Science 2011, 1, 810-825.
[5] J. A. Montgomery, J. W. Ochterski, G. Petersson, Journal of Chemical Physics 1994, 101, 5900-5909.
[6] O. N. Ventura, M. Kieninger, A. Katz, M. Vega-Teijido, M. Segovia, K. Irving, International Journal of Quantum Chemistry 2021, 121, e26745 1-19.
[7] V. Barone, L. Crisci, S. Di Grande, Journal of Chemical Theory and Computation 2023, 19, 7273-7286.

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TEO-PO-020

Rapid Screening of Gold Nanoparticle-Small Molecule Affinities: Applications in Sensing and Beyond.

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Gold nanoparticles hold great promise in a myriad of advanced applications across chemistry, material science and biology, owed largely to their advanced optical and electrical properties. These intrinsic qualities have positioned nanoparticles as key players in sensing, catalysis, and drug delivery. However, a pivotal challenge lies in the design and engineering of gold nanoparticle monolayers that feature specific, high-affinity binding sites. It is this ability to tailor selective binding that underpins much of the practical applications of gold nanoparticles' unique properties, representing a significant hurdle in reaching their full potential.

Computer-aided rational design has proved invaluable in the effort to design and tailor nanoparticle monolayers for specific binding [1]. Yet, as with drug design, computer-aided rational design of nanoparticle monolayers requires a detailed understanding of the desired systems to allow researchers to make rational choices. Within drug development, preliminary screening techniques such as docking are routinely employed to swiftly identify and eliminate inferior candidates, thereby concentrating efforts on molecules with the most promise. However, such docking methods are inapplicable to nanoparticle systems due to the highly dynamic and evolving nature of the monolayers [2].

Here, we introduce a rapid screening approach, combining molecular dynamics simulations with machine learning, to explore the interactions between gold nanoparticles and small molecules. Utilising Nanomodeler [3], which allows the automated creation of monolayer-protected gold nanoparticles *in silico*, our approach facilitated the efficient evaluation of thousands of gold nanoparticle ligands for their binding affinity to small molecules, demonstrated through the case study of 3-methoxytyramine, a vital neuroblastoma biomarker.

While our immediate aim is the development of nano-based chemosensors for early neuroblastoma detection, the versatility of our method shows potential for broader applications in catalysis, drug delivery and energy harvesting with gold nanoparticles.

References:

[1] L. Riccardi, L. Gabrielli, X. Sun, F. De Biasi, F. Rastelli, F. Macin, M. De Vivo, Chem, 2017, 3, 92-109.
[2] L. Riccardi, S. Decherchi, W. Rocchia, G. Zanoni, A. Cavalli, F. Mancin, M. De Vivo, The Journal of Phycial Chemistry Letters, 2021,12, 5616-5622.
[3] S. Franco-Ulloa, L. Riccardi, F. Rimembrana, M. Pini, M. De Vivo, Journal of Computational Theory and Computation, 2019, 15, 2022-2032.

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TEO-PO-021

Oxygen-promoted Au(111)-supported polyboroxine formation probed by core-electron spectroscopies: a combined theoretical and experimental study

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On-surface synthesis of organic structures is a convenient bottom-up approach for tailoring both the chemistry and the morphology of surfaces and for the synthesis of complex hybrid interfaces of potential interest in the development of organic based devices[1,2].

The unexpectedly rich surface chemistry of trinaphtylboroxine (TNB) deposited on the Au(111) support has been monitored through X-ray Photoemission and B K-edge NEXAFS. Through computational screening of a set of possible structures, by exploiting the element sensitivity and site specificity of core-electron spectroscopies we were able to uncover the role of adsorbed O atoms in promoting B-C bond cleavage which resulted in the on-surface formation of a stable B-O-B motif. Furthermore, the synthesis of the B-O-B motif allows for tuning the electronic properties at the interface between molecules and gold substrate. This work has been carried out in close collaboration with experimental groups of the CNR-IOM in Trieste.

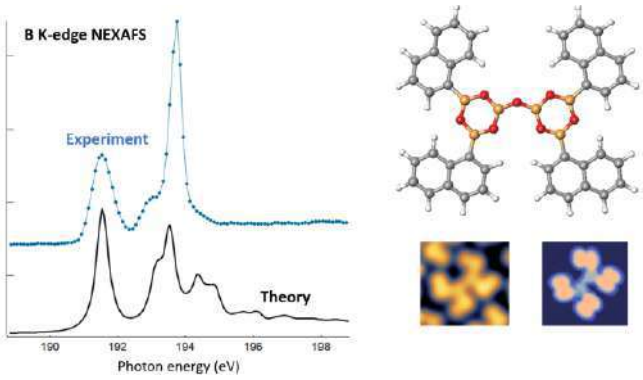

Figure 1: Left panel: experimental and calculated B K-edge NEXAFS spectra of TNB/Au(111). Right panels: top: model of the H-shaped molecule proposed in the present work; bottom: comparison between experimental and simulated STM image of the molecule.

References:

[1] L. Bartels, Nat. Chem. 2010, 2, 87-95.
[2] D. Toffoli, M. Stredansky, Z. Feng, et al. Chem. Sci. 2017, 8, 3789–3798.
[3] D. Toffoli, E.Turco, M. Stredansky, et al. submitted.

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Hybrids QM/MM methods for simulating spectroscopic properties of zwitterionic L-tryptophan in water

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Spectral properties of isolated molecules can be drastically different from those of the same molecules dissolved in aqueous solution[1]. Multiscale Quantum Mechanics (QM)/Classical models are highly effective for simulating solvated molecules by partitioning the system into two components: the solute, which is treated at the QM level, and the solvent, which is modelled classically[2-4]. Among these methods, QM/Molecular Mechanics (MM) approaches have undergone a great expansion in recent decades and have become widely used to study spectroscopic properties of systems in solution[1-3]. The success of this type of theory lies in retaining the atomistic details of the solvent and the ability to describe the hydrogen bonding[1,3].

In this work, we study several spectroscopic properties of Zwitterionic L-Tryptophan in aqueous solution, by using fully polarizable QM/MM and QM/Frozen Density Embedding (FDE)/MM approaches[5-7]. The MM portion is in all cases described employing the Fluctuating Charges (FQ) and Fluctuating Charges and Dipoles (FQFμ) force fields[8,9], and the coupling to classical molecular dynamics allows the sampling of the solute/solvent configurational space[1]. While QM/ FQFμ well describes long-range electrostatic interactions, the use of a three-layer QM/FDE/ FQFμ approach permits an accurate ab initio description of short-range non-electrostatic interactions[6]. The simulated properties are UV-Vis absorption, Nuclear Magnetic Resonance, and Electronic Circular Dichroism, which are all very sensitive to solvent effects. The work aims to demonstrate the improved accuracy of the methodology by increasing the level of sophistication which is employed to model solute/solvent interactions, through comparison with experimental data.

References:

[1] T.Giovannini, F.Egidi, C.Cappelli, *Chem. Soc. Rev.*, 2020, 49(16), 5664-5677
[2] A.Warshel, M.Levitt, *J. Mol. Biol.*, 1976, 103(2), 227–249
[3] H.M.Senn, W.Thiel, *Angew. Chem. Int. Ed.*, 2009, 48(7), 1198-1229.
[4] J.Tomasi, B.Mennucci, R.Cammi, *Chem. Rev.*, 2005, 105(8), 2999-3094.
[5] T.A.Wesolowski, A.Warshel, *J. Phys. Chem.*, 1993, 97(30), 8050-8053.
[6] F.Egidi, S.Angelico, P.Lafiosca, T.Giovannini, C.Cappelli, *J. Phys. Chem*, 2021, 154(16), 164107-164107
[7] P.Lafiosca, F.Rossi, F.Egidi, T.Giovannini, C.Cappelli, *J. Chem. Theory Comput.*, 2023, *20*(1), 266-279.
[8] C.Cappelli, *Int. J. Quantum Chem.*, 2016, 116(21), 1532-1542
[9] T.Giovannini, L.Grazioli, M.Ambrosetti, C.Cappelli, *J. Chem. Theory Comput.*, 2019, 15(10), 5495-5507.

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TEO-PO-024

GPU Acceleration in First Principle Computational Materials Science for Enhanced Efficiency and Scalability

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We present a new version of the CRYSTAL ab initio simulation software designed to use graphics processing units (GPUs) and meet the escalating computational demands of theoretical materials science. CRYSTAL[1] is a solid-state simulation software that allows to perform calculations on materials, making use of the Density Functional Theory (DFT) framework, including hybrid functional approaches.

In present days, the accurate description and prediction of material properties rely heavily on the computational power and efficiency of simulation programs. Traditional CPU-based approaches encounter substantial challenges in terms of hardware demand and execution time. In this regard, a valuable alternative is to use GPUs, which are the most powerful components in computers and HPCs.[2] Our work leverages their high throughput capabilities to significantly accelerate the execution of DFT simulations, particularly for large-scale systems encountered in real-world applications.[3]

Employing publicly available GPU-accelerated libraries for linear algebra operations, we achieve remarkable performance enhancements. In the case of the Metal Organic Framework ZIF-8 (supercell containing 2208 atoms, 22176 atomic orbitals), we reduced single-point energy calculation time by 86% (128 CPU cores vs 1 NVIDIA A100 GPU) while maintaining numerical precision.[4] The incorporation of GPUs into CRYSTAL not only enhances computational efficiency but also expands the scalability, enabling the handling of huge size system that were previously prohibited with the conventional CPU-based approach.

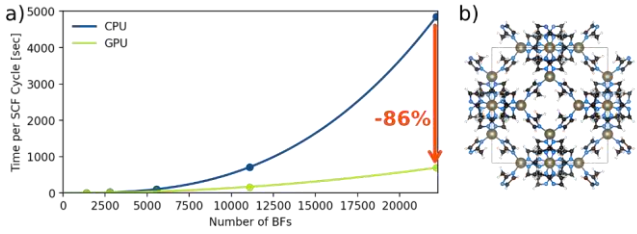

Figure 1 a) Execution time vs system size (series of supercell) of CPU and GPU codes. b) Unit cell of ZIF-8.

References:

[1] A. Erba, J. K. Desmarais, S. Casassa, B. Civalleri, L. Donà, I. J. Bush, B. Searle, L. Maschio, L. Edith-Daga, A. Cossard, J. Chem. Theory Comput. 2023 19, 6891-6932.
[2] C. McClanahan, A Survey Paper 2010, 9, 1-7.
[3] A. Erba, J. Baima, I. J. Bush, R. Orlando, R. Dovesi, J. Chem. Theory Comput. 2017 13, 5019-5027.
[4] G. Ambrogio, L. Donà, C. Ribaldone, S. Casassa, J. K. Desmarais, F. Spiga, B. Civalleri, A. Erba, [in preparation] 2024.

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TEO-PO-025

Anharmonic Assignment of the Water Octamer Spectrum in the OH Stretch Region

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Spectroscopic characterization of water clusters is a powerful tool to gain insight into the hydrogen bonding structure of water. New experimental advances have made it possible to record the vibrational spectrum of clusters of increasingly higher dimensionality,[1] such as the water octamer,[2] which exhibits a behavior characteristic of the solid-liquid phase transition of water.

On the theoretical side, anharmonicity has to be taken into account to correctly assign the vibrational features of water clusters.[3]

In this work, we study the OH-stretch region of the water octamer spectrum using the quasi-classical trajectory (QCT) technique,[4] which is a computationally affordable classical method capable of providing very accurate anharmonic frequencies. Differently from the conclusions of the previous scaled harmonic assignment,[2] which invoked the contribution of 5 conformers and a solvated form of the water heptamer in the spectrum, we find out that the spectroscopic features can be related to the 4 lower energy conformers of the octamer.[5]

References:

[1] B. Zhang, Y.-Y. Zhang, et. al., J. Phys. Chem. Lett. 2020, 11, 851 – 855.
[2] G. Li, Y.-Y. Zhang, et. al., Nat. Commun. 2020, 11, 5449 – 5554.
[3] A. Rognoni, R. Conte, M. Ceotto, Chem. Sci. 2021, 12, 2060 – 2064.
[4] L. Bonnet, J. Rayez, Chem. Phys. Lett 1997, 277, 183 – 190.
[5] D. Barbiero, G. Bertaina, M. Ceotto, R. Conte, J. Phys. Chem. A 2023, 127 (30), 6213 – 6221.

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TEO-PO-026

A look into the electrolyte structure of Molten Carbonate Electrolysis Cells.

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Clean energy is one of the big demands of this century, driven by the need to mitigate human impact on the planet's ecosystems.[1] Weather-dependent renewable sources require advancements in energy storage technologies.[2] Molten carbonate electrolysis cells (MCECs) are a prime example of devices able to convert surplus energy from a renewable source into gaseous energy carriers, like H_2.[3-4] To further improve the efficiency of these devices, we require reaching a deeper understanding of each step involved in the functioning process. Here, we start with a thorough structural investigation of the electrolyte of choice for MCECs, namely the molten $Li_{1.24}K_{0.76}CO_3$ eutectic mixture. We employ explicit polarization molecular dynamics to show that the structure of this molten mixture is characterized by tight lithium-carbonate interactions, giving rise to a structural network in which the K^+ ions are loosely embedded. Using the knowledge of the melt structure at an atomic level, we can rationalize the conductivity trends we see experimentally in molten carbonate mixtures. Finally, from our simulation we provide the first theoretical prediction of the static structure factor, S(q), of the $Li_{1.24}K_{0.76}CO_3$ melt at the typical operating temperature of MCECs ($923\ K$, see Figure 1). This work will be the first step in a larger endeavor to characterize at an atomic level each element of the chemical processes involved in these devices. The polarizable force field developed here will be a steppingstone towards more advanced studies: on the role of the electrolyte first, and the rest of the cell later.

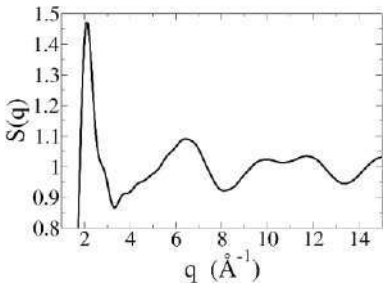

Figure 1: Static structure factor (S(q)) of the $Li_{1.24}K_{0.76}CO_3$ melt, calculated from our simulation.

References:

[1] R. Quadrelli and S. Peterson, *Energy Policy*, 2007, **35**, 5938–5952.
[2] M. Beaudin, H. Zareipour, A. Schellenberglabe, and W. Rosehart, *Energy Sustain. Dev.*, 2010, **14**, 302–314.
[3] L. Hu, I. Rexed, G. Lindbergh, and C. Lagergren, *Int J Hydrog. Energy*, 2014, **39**, 12323–12329.
[4] J. P. Perez-Trujillo, F. Elizalde-Blancas, M. Della Pietra, and S. J. McPhail, *Appl. Energy*, 2018, **226**, 1037–1055.

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TEO-PO-027

Exploring the Time-Scale Complexity of Molecular Dynamical Systems: A Novel Refined Clustering Approach

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Molecular systems display both complexity and dynamism, undergoing continuous changes and interactions that are challenging to fully anticipate or comprehend. Over time, they demonstrate diverse behaviours driven by molecular interactions, feedback processes, and external factors, aligning them closely with the characteristics of complex dynamical systems.

In the quest to unravel the complexities of these dynamical systems, the ability to distinguish and categorize a wide range of signal behaviours poses a significant challenge, one that traditional clustering methods struggle to meet.

This study introduces an advanced methodology designed to enhance the classification of complex dynamical systems, specifically by refining the analysis of segments traditionally deemed non-classifiable. Building upon the foundational principles of "Onion Clustering" [1], and its feature which allow us to catch non-classified signals data, due to their high fluctuations, our approach delves deeper into the data, revealing previously obscured layers and offering a richer understanding of the system's inherent dynamics. Like its predecessor, which efficiently discerned statistically relevant fluctuations from noise through an iterative detect-classify-archive strategy, our methodology extends this paradigm by further classification and optimization of the clustering time window.

These refinements enable a precise yet comprehensive analysis, capable of uncovering subtle dynamical events across different scales. In this paper, we outline the development of our methodology, the analytical framework, and the wider implications of this sophisticated approach for revealing the complex and concealed patterns within complex systems.

References:

[1] M.Becchi, F. Fantolino, and G. M. Pavan, arXiv preprint arXiv:2402.07786 (2024).

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TEO-PO-028

A computational study of the interaction between the sterol transporter Niemann-Pick C1-Like 1 protein and new natural ligands with potential inhibitory activity

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Niemann-Pick C1-Like 1 (NPC1L1) is a transmembrane protein, involved in cholesterol absorption in the intestine, whose activity can be modulated by ezetimibe, a drug that prevents cholesterol transport from the lumen to the membrane. The structure of the complex NPC1L1-ezetimibe was recently resolved[1]: ezetimibe localizes in a tunnel which is the path for cholesterol transport from the N-terminal domain (NTD), where cholesterol is first recognized, to the sterol sensing domain (SSD), where cholesterol leaves the protein and is released in the membrane.

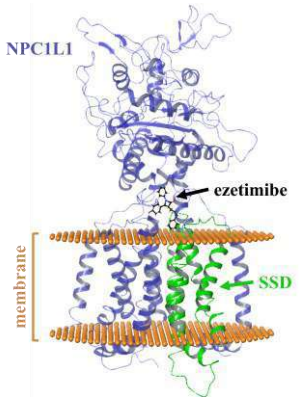

Figure 1: Structure of the NPC1L1-ezetimibe complex.

Molecules such as sterols and polyphenols, contained e.g. in plants, have been shown to act against NPC1L1 activity[2]. However, it is still unknown where they bind NPC1L1, and which is the mechanism by which they manage to prevent cholesterol absorption. In this study, we aim to predict the structures of the complexes the aforementioned molecules could form with NPC1L1. Computational approaches such as protein-ligand docking and all-atoms molecular dynamics simulations, with explicit modelling of the membrane[3], are used. Structural information on the binding of other molecules to NPC1L1 and NPC1 proteins, a structural homologous which is also involved in cholesterol transport, is exploited to drive the modelling procedure.

References:

[1] M. Hu, F. Yang, Y. Huang, X. You, D. Liu et al., *Science Advances* **2021**, 7, eabg3188.
[2] R. Zhang, W. Liu, J. Zeng, J. Meng, H. Jiang et al., *Eur. J. Med. Chem.* **2022**, 230, 114111.
[3] H. Ingólfsson, M. Melo, F. van Eerden, C. Arnarez, C. Lopez et al., *J. Am. Chem. Soc.* **2014**, 136, 14554-14559.

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TEO-PO-029

Enhancement in Raman spectroscopy? Combined theoretical and experimental investigation

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Surface-Enhanced Raman Spectroscopy (SERS) is a powerful analytical technique that has garnered significant attention thanks to its capability to amplify the Raman signals of molecules adsorbed on nanostructured metal surfaces up to the detection of a single molecule[1]. However, one challenge to the interpretation of the data is the difficult reproducibility of the results, complicated by the multitude of effects that contribute to the enhancing factor.[2] This complexity makes it difficult to predict both the level and the effect of enhancement on the analyzed compound. One potential enhancement factor may be purely related to the response of the molecule itself, especially when dealing with chromophores.

In this contribution, to discern this effect, we propose a combined experimental-theoretical study of enhancement processes using the methylene blue molecule as a test case. From an experimental point of view, the compound is examined under various conditions to obtain a comprehensive picture of the enhancement effects. This includes utilizing non-conventional state-of-the-art spectroscopy setups, as well as standard analytical methodologies with bench instrumentation. Concurrently, the proposed computational study relies on density functional theory (DFT) calculation are used to provide an accurate insight into the molecular nature of the Raman enhancement effect[3].

This work represents a step for systematic modeling of SERS spectra under real experimental conditions. Its aim is to establish a theoretical methodology that supports the interpretation of Raman enhancement phenomena.

References:

[1] K. Kneipp, Y. Wang, H. Kneipp, L. T. Perelman, I. Itzkan, R. R. Dasari, M. S. Feld, Phys. Rev. Lett., 1997, 78, 1667–1670.
[2] R. J. Lombardi, R. L. Birke, Accounts of chemical research 2009, 42.6, 734-742.
[3] A. Baiardi, J. Bloino, V. Barone, The Journal of chemical physics 2014, 141.11, 114108.

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TEO-PO-030

Multi-path Primary Charge-Separation in Photosystem II

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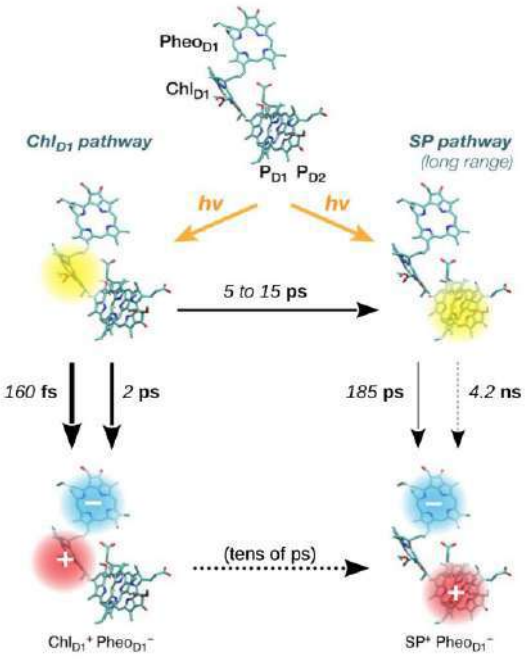
Photosystem-II (PSII) is a multi-subunit protein complex that harvests sunlight to perform oxygenic photosynthesis. Initial light-activated charge separation takes place at a reaction center consisting of four chlorophylls and two pheophytins. Understanding the processes following light excitation based on experimental results remains elusive due to spectral congestion as well as to the ultrafast nature and multi-component behavior of the charge-separation (CS) process. Using advanced computational multiscale approaches, based on all-atom molecular dynamics simulations coupled with the Perturbed Matrix Method[2], we were able to achieve the first direct calculation of the kinetics of the charge separation processes in the reaction center (RC) of PSII[1]. Our results indicate the presence of a multi-path scenario for the primary charge separation that, eventually, leads to the formation of the $SP^{+}Pheo_{D1}^{-}$ pair. We identified two primary radical-pair formation components that considerably differ in their respective time constants. The dominant faster channel starts from Chl_{D1}* and leads to the formation of a $Chl_{D1}^{+}Pheo_{D1}^{-}$ charge-separated pair subsequently evolving to the $SP^{+}Pheo_{D1}^{-}$ couple. In the second and slower path a long-range ET event occurs starting from SP* and leading directly to $SP^{+}Pheo_{D1}^{-}$. We also found an energy transfer pathway between the Chl_{D1}* and the SP* localized excited states, the efficiency of which is tuned by the protein environment. This observation can also explain the experimental heterogeneity measured for $Pheo_{D1}^{-}$ formation ranging from picoseconds to tens of picoseconds. The presence of a preferential channel for CS and shortcuts from different localized excited states in the RC, consistently leading to the same rapidly formed radical pair, is crucial for efficient light harvesting.



References:

[1] Capone, M. and Sirohiwal, A. et al. (2023). Angew. Chem. Int. Ed., 135(16), e202216276.
[2] Zanetti-Polzi, Laura, et al. Phys. Chem. Chem. Phys. 20.37 (2018): 24369-24378.

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TEO-PO-031

Spectroscopic characterization of the interface between tripyrenboroxine and Au(111) surface

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Boroxines represent a class of compounds extensively employed as templates on metal surfaces[1]. Their exceptional mechanical properties and thermal stability have sparked significant interest in utilizing them for the development of new electronic devices. In this study we performed a combined experimental and theoretical study to characterize the interface between tripyreneboroxine (TPyB) and Au (111) surface in term of its electronic properties through NEXAFS core spectroscopy studies. Density Functional Theory (DFT) calculations were performed to describe the geometry of the system (shown in Figure 1) and elucidate the nature of TPyB /surface interaction. A finite cluster was then cut out from the periodic relaxed structure for the calculations of the NEXAFS spectra at both B and O K-edge. The calculations suggest the presence of unoccupied orbitals strongly hybridized with gold atoms, close to the Fermi level. The coupling of these orbitals with the Au substrate demonstrates the importance of the boroxine group to mediate possible charge transfer between molecule and surface. These findings suggest that such systems, typically utilized as templates for the growth of organic films, can also serve as active interlayers, establishing an efficient electronic transport channel that bridges the inorganic substrate and organic overlayer.

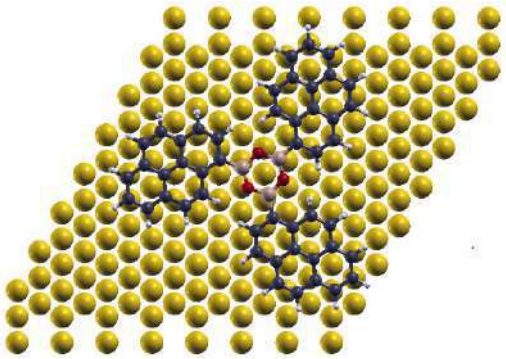

Figure 1: Top view of TPyB-Au system

References:

[1] S. Clair, M. Abel and L. Porte, Chem. Commun., 2014, 50, 9627–9635.
[2] A. L. Korich and P. M. Iovine, *Dalton Transactions*, 2010, 3*9*(6), 1423-1431.

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TEO-PO-032

Theoretical study of charge and energy transfer processes in materials for organic electronics

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Nowadays, a myriad of organic semiconductors (**OSCs**) have been proposed across diverse domains, including electronics, flexible displays, and cost-effective solar cells. [1] Since early investigation on their charge mobility it has been clear that i) local vibrations are strongly coupled to the charge-transfer process ii) the fluctuation in the transfer integrals can significantly affect the transport mechanism, because their magnitude is comparable to the average value of the transfer integrals. [2] Therefore the study of charge mobility in **OSCs** can be tackled by developing quantum dynamical models in a system where electronic and nuclear degrees of freedom exhibit strong coupling. Starting from this point we propose a study of electron dynamics in emerging hole-transport materials (**HTM**) devices. Using specific atomistic models of the materials we compute the relevant parameters that controls the charge transfer (**CT)** process: site energy, electron transfer integrals and electron-vibrational coupling using state-of-the art methodologies. [3,4] These parameters are used as input for a subsequent studyof the electron-nuclear dynamics using a properly defined **Holstein-Peierls** model Hamiltonian. Using this approach we show how these parameters affect the various regime of charge-mobility in organic **HTM**.

References:

[1] G. Geyn'ova, L. Kun-Han, and C. Clémence, Journal of the American Chemical Society, 2018, 140.48, 16370-16386.

[2] H. Oberhofer, R. Karsten, and J. Blumberger, Chemical reviews, 2017, 117.15, 10319-10357.

[3] R. Borrelli, and A. Peluso, Wiley Interdisciplinary Reviews: Computational Molecular Science, 2013, 3.6: 542-559.

[4] M. F X Dorfner, S. Hutsch, R. Borrelli, M. FX, G. and F. Ortmann, Journal of Physics: Materials, 2022, 5.2, 1-13.

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TEO-PO-033

Photophysics and Fluorescence of a Nucleic Acid-Protein Photo-Crosslinking Model through hybrid QM/MM MD and non-adiabatic Surface Hopping simulations

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Isolation of transient nucleoprotein complexes in their biological conformation is a challenging task: a promising technique for this goal is to induce in vivo crosslinking between the nucleic acid and the protein, by UV light (UV-CL). The photo-cyclization of 5-benzyluracil (5BU) to 1,2-indaneuracil has been proposed as a model reaction for studying the mechanism of UV-CL.[1] In this context, we present a combined experimental and theoretical study of the thermal equilibrium, the photophysics and the ultrafast photo-activated dynamics of 5BU in methanol,[2] exploiting the framework of the DFT and TD-DFT.[3] We adopted the ADMP[4] method and an hybrid QM/MM ONIOM partition scheme, enforcing non-periodic boundary conditions.[5] We recorded the UV absorption spectrum in methanol solution and simulated the band shape through TD-DFT calculations performed on the structural ensemble given by the AIMD trajectory, finding a good agreement between experiments and simulation. With respect to previous studies,[6] we uncovered that first two excited states are indeed the ones responsible for the absorption preceding the photoreaction; that their brightness is strongly influenced by the accessible conformations of the 5BU at room temperature and the microsolvation of its oxygen and nitrogen atoms. After excitation, 5BU exhibits an ultrafast non-radiative decay (probed by fluorescence upconversion experiments), which competes with the reactive path and is debated to be due either to a de-excitation to the ground state or a relaxation within the excited state.[6] To give a molecular interpretation of the photo-induced relaxation, we conducted a mixed quantum/classical non-adiabatic molecular dynamics, by adopting the Surface Hopping[7] approach; we finally performed a vibrational analysis through an innovative protocol, based on the wavelet transform of time resolved generalized modes extracted from the trajectories.

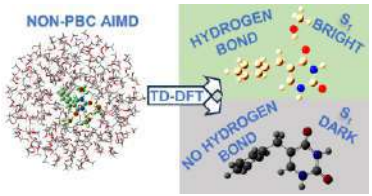

Figure 1: Left: a snapshot from the AIMD of 5BU in methanol. Right: two sampled configurations of 5BU.

References:

[1] L. Zhang *et al.*, Biochem. Biophys. Res. Commun. 322. (2004). 705.; G. Sun *et al.*, Org. Lett. 8. (2006) 681.
[2] G. Iuzzolino *et al.*, Phys. Chem . Chem. Phys, *accepted.*
[3] M. E. Casida *et al.*, J. Chem. Phys. 108. (1998). 4439.; G. Scalmani, M. J. Frisch, J. Chem. Phys. 124. (2006). 094107.
[4] S.S. Iyengar, J. Chem. Phys. 115. (2001). 10291.; H. B. Schlegel, J. Chem. Phys. 117. (2002). 8694.; N. Rega *et al.*, J. Phys. Chem. B, 108. (2004). 4210.
[5] T. Vreven *et al.*, J. Chem. Theory Comput. 2. (2006). 815.; N. Rega *et al.*, Chem. Phys. Lett. 422. (2006). 367.
[6] M. Valadan, *et al.*, Phys. Chem. Chem. Phys. 21. (2019). 26301.
[7] J. C. Tully, R. K. Preston, J. Chem. Phys. 1971, 55, 562-572.

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TEO-PO-034

Novel Theoretical and Computational Approaches for Modelling Photoinduced Proton-Coupled Electron Transfer Reactions in Complex Environment

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Proton-Coupled Electron Transfer (PCET) reactions represent an important class of reactions of fundamental importance in both biological and technological contexts [1,2]. In these reactions, a transfer of electrons and protons between two molecular species occurs, which may involve different sites. A challenging case regards the proton transfer from a solute towards a solvent molecule. A reasonable classification of PCET reactions is based on the degree of electronic, vibrational and vibronic adiabaticity between the transferred electron and proton [3]. Recently, our research group [4] has introduced an innovative procedure to discriminate between different degrees of adiabaticity in mechanisms.

In this contribution, we aim to characterize the mechanism of photoinduced PCET reactions between tyrosine and tryptophan in oligopeptide models [5] in solvent. In this context, theoretical/computational methodologies significantly contribute to the atomistic/molecular-level interpretation of the processes involved. The solvent plays a key role as proton acceptor species, thus requiring an accurate description of the solute/solvent interaction potential and the main configurations assumed by it around reactive sites. We therefore aim to develop a generalized protocol based on hybrid multiscale methods, where the solute is described at the quantum mechanics level, the first two/three solvation shells at the molecular mechanics level, while the bulk properties of the solvent are described using a continuum dielectric model (QM/MM/Continuum) [6]. For the QM/MM clusters thus described, we will assess the possibility of characterizing stationary points of the potential energy surface and finally address the development of a new flexible methodology for ab initio molecular dynamics simulations of solute/solvent systems using non-Periodic Boundary Conditions in non-spherical cavities (e.g., elliptical) for the description of non-spherical solutes such as oligopeptides and linear polymers. The high computational efficiency of this procedure promises to analyze and provide evidence on PCET mechanisms that regulate the reactivity of numerous biological systems.

References:

[1] R. Improta, S.Antonello, F.Formaggio, F.Maran, N.Rega, V.Barone, *J. Phys. Chem. B* 2005, 109, 1023 – 1033.
[2] D.R. Weinberg, et. al., *Chem. Rev.* 2012, 112, 4016 – 4093.
[3] S.Hammer-Schiffer, *J. Am. Chem. Soc.* 2015, 137, 8860 – 8871.
[4] U.Raucci, et. al., *J. Comp. Chem.* 2020, 41, 1835 – 1841.
[5] H.Li, S.Cao, S.Zhang, J.Chen, J.Xu, *Chem. Journ. Chem. Phys.* 2023, 36, 384 – 396.
[6] N.Rega, G. Brancato, V. Barone, *Chem. Phys. Lett.* 2006, 422, 367 – 371.

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TEO-PO-035

Unraveling the photorelaxation of a light-driven molecular rotary motor by means of excited state *ab-initio* dynamics

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Artificial molecular machines represent a hot research topic directly linked to the development of nanoscale devices.[1] Among the molecular machines synthesized, the light-driven molecular rotary motors represent an elegant way to transform the electromagnetic radiation in a unidirectional rotary motion. In this work, we focused on a Feringa-type motor.[2] This molecule is characterized by two parts, the *stator* and the *rotor*, connected by a carbon double-bond axle, and performs a full unidirectional rotation about this latter, in an isomerization cycle characterized by two photochemical and two rate-limiting thermal steps. In order to unveil the photophysics of the system and providing a molecular interpretation of the photorelaxation process, we performed *ab-initio* molecular dynamics simulations[3-7] in both the ground and excited electronic states, within density functional theory and its time-dependent version formalism[8,9] along with a transient vibrational analysis based on the Wavelet transform[10,11] of specific quantities. An accurate, calibration of the potential with a detailed balance of the environment effects, was carefully addressed. Then, relying on the electronic excited state trajectories, we extracted generalized normal modes and collective structural rearrangements to shed light on the main molecular determinants involved in the vibrational dynamics. Within the early stages upon excitation, a clear mechanism emerges, a bi-phasic energy decay from the Franck-Condon region occurs and is modulated by coupled vibrations involving the central carbon-carbon double bond. Our findings contribute to expanding the knowledge of processes that underlie the photorelaxation and provide a detailed interpretation of time-resolved spectroscopic experiments.

References:

[1] M. Baroncini, S. Silvi and A. Credi, *Chemical Reviews* 2019, 120, 200 – 268.
[2] C. R. Hall et al., *J Am Chem Soc* 2017, 139, 7408 - 7414.
[3] J. M. Milliam, V. Bakken, W. Chen, W. L. Hase, and H. B. Schlegel, *J Chem Phys* 1999, 111, 3800 - 3805.
[4] T. Helgaker, E. Uggerud, and H. J. A. Jensen, *Chem Phys Lett* 1990, 173, 145 - 150.
[5] H. B. Schlegel et al., *J Chem Phys* 2001, 114, 9758 - 9763.
[6] S. S. Iyengar et al., *J Chem Phys* 2001, 115, 10291 - 10302.
[7] N. Rega et al., *J Phys Chem B* 2004, 108, 4210 - 4220.
[8] M. E. Casida, C. Jamorski, K. C. Casida, and D. R. Salahub, *J Chem Phys* 1998, 108, 4439 - 4449.
[9] G. Scalmani et al., *J Chem Phys* 2006, 124, 094107.
[10] G. Donati, A. Petrone and N. Rega, *Phys Chem Chem Phys* 2020, 22, 22645 – 22661.
[11] F. Coppola, P. Cimino, A. Petrone and N. Rega, *J Phys Chem A* 2024, 128, 1620 – 1633.

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TEO-PO-036

Insights into the rate limiting step of the natural water oxidation reaction from all-atom molecular dynamics simulations of Photosystem II

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In nature the manganese cluster (Mn_4Ca) located inside the enzyme Photosystem II (PSII) catalyses the water oxidation reaction, which represents a key step of the whole photosynthetic process. The complex reaction takes place along the five steps (S_0-S_4) of the Kok-Joliot cycle. The slowest step in oxygen evolution has been recently identified after the S_3 state by a combined experimental and computational study, highlighting a significant entropic slowdown.[1] Classical molecular dynamics (MD) simulations allow to get insights on the H-bond network sampled by the solvent molecules around the Mn_4Ca cluster on timescales inaccessible to quantum chemical calculations, thus representing a suitable tool for investigating at molecular level on the origin of this entropic slowdown. Here, starting from the experimentally determined structure of PSII in Thermosynechococcus vestitus BP-1,[2] we simulated the wild-type (WT) form of PSII in the oxidized S_3 state, embedded in a lipid bilayer, and the respective D1-N298A variant. Firstly, by following a recent approach,[3] we developed a new classical force field derived by Ab Initio Molecular Dynamics simulations[4] of the manganese cluster in the oxidized S_3 state. Thereafter, by means of classical all-atoms MD simulations, we started working on the origin of the entropic contribution associated with the bottleneck of photosynthetic oxygen evolution. Our MD simulations reveal pronounced fluctuations regarding the H-bonded protein-water network in the surrounding of the Mn_4Ca cluster. Starting from the simulated trajectories, we carried out several analyses to sample the water molecules distribution and take into account their intrinsic mobility in the oxygen evolving complex (OEC) over the simulation time. Our results show an increased mobility of the closest water molecules to the Mn_4Ca and a concomitantly more flexible protein environment upon N298A mutation, thus resulting in a weaker H-bond network in the OEC when compared to the WT form. These results could explain both the experimentally found increased entropic and decreased enthalpic contributions to the activation free energy of the S_3 to S_4 transition in the mutated PSII.

References:

[1] P. Greife, M. Schönborn, M. Capone, *et al.*, *Nature* **2023**, 617, 623-628
[2] A. Bhowmick, R. Hussein, I. Bogacz, *et al.*, *Nature* **2023**, 617, 629–636
[3] G. Cárdenas, P. Marquetand, S. Mai, L. González, *Catalysts* **2021**, 11, 1-16
[4] D. Narzi, M. Capone, D. Bovi, L. Guidoni, *Chem. Eur. J.* **2018**, 24, 10820-10828

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TEO-PO-037

How Machine Learning enhances simulation of energy transfer in Light-harvesting Complex II

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In plant photosynthesis, the harvesting of solar energy is made possible by aggregate of pigments embedded in specialized membrane proteins, called light-harvesting complexes (LHCs)[1]. Specific interactions with the protein and electronic couplings with other chromophores alter the optical properties of individual pigments, and light absorption in the aggregate is followed by a cascade of energy transfer processes. Because of the complex nature of LHCs, the simulation of such excited state dynamics is challenging and requires expensive multiscale methods[2] to estimate all the involved parameters. Structural disorder adds on top, requiring calculations to be repeated over many configurations of the system. Machine learning (ML) can represent a valuable alternative to traditional approaches in the simulation of the energy transfer events. Here, we show that a ML strategy[3] can be applied to estimate excitonic quantities of LHCII of higher plants with accuracy comparable to standard multiscale methods, with the advantage of an extremely higher speed which allows wide sampling of the configurational space of the system when coupled to molecular dynamics. The resulting estimated parameters are robust and allow simulation of the excited state dynamics which closely reproduces the experimental one, as demonstrated by comparison to transient absorption[4,5]. New insights on the most relevant pathways and associated characteristic times are achieved through this integrated model.

References:

[1] R. Croce, H. Van Amerongen, Nat. Chem. Biol. 2014, 10, 492–501.
[2] L. Cupellini, M. Bondanza, M. Nottoli, B. Mennucci, Biochim. Biophys. Acta - Bioenerg. 2020, 1861, 148049.
[3] E. Cignoni, L. Cupellini, B. Mennucci, J. Chem. Theory Comput. 2023, 19, 965–977.
[4] P. Akhtar, T. N. Do, P. J. Nowakowski, A. Huerta-Viga, M. F. Khyasudeen, P. H. Lambrev, H. Tan, J. Phys. Chem. B 2019, 123, 6765–6775.
[5] E. Betti, P. Saraceno, E. Cignoni, L. Cupellini, B. Mennucci, ChemRxiv. 2024.

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TEO-PO-038

Computational investigation on the Hydrogen Evolution Reaction mechanism by Chini complexes

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The transition from fossil fuels to renewable energy sources necessitates the development of efficient energy storage methods to address the spatiotemporal challenges posed by the limited ability to store this energy for use when it is most needed. Chemical bond energy storage, particularly through electrochemical conversion of renewable resources into carbon-neutral fuels, emerges as a promising solution.[1,2] Metal Carbonyl Clusters (MCCs) with their tailored electronic structures present as ideal candidates for electrocatalysis, notably in hydrogen evolution reaction (HER) and carbon dioxide reduction (CDR). The utilisation of MCCs as homogeneous electrocatalysts offers distinct advantages over conventional catalysts, owing to their unique properties.[3] Their high proton affinity in the reduced state facilitates hydride intermediate formation at low potentials, while the flexibility in substitution reactions enables precise tuning of catalytic properties.[4] Here, we present a comprehensive Density Functional Theory (DFT) study focusing on a specific class of platinum carbonyl clusters with general formula $[Pt_{3n}(CO)_{6n}]^{2-}$ ($n \leq 10$), known as Chini clusters (Figure 1).[5] Our computational approach delves into the efficacy of Chini clusters in prompting the reduction of protons and (possibly) CO_2 to produce molecular hydrogen and (hopefully) formate utilising metal hydride intermediates. We assess the accuracy of various levels of theory in describing the structure and infrared spectra of Chini clusters and explore the reaction profile for the hydrogen evolving reaction.

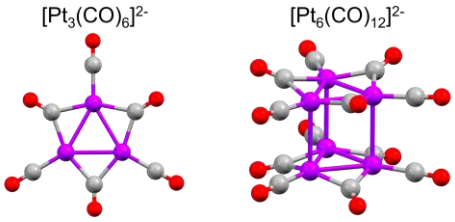

Figure 1: Structures of monomer and dimer Chini clusters.

References:

[1] P. De Luna, C. Hahn, D. Higgins, S. A. Jaffer, T. F. Jaramillo, E. H. Sargent, Science 2019, 364, eaav3506.
[2] R. Francke, B. Schille, M. Roemelt, Chem. Rev. 2018, 118, 4631 – 4701
[3] C. R. Carr, A. Taheri, L. A. Berben, J. Am. Chem. Soc. 2020, 142, 12299 – 12305
[4] B. Berti, C. Femoni, M. C. Iapalucci, S. Ruggieri, S. Zacchini, Eur. J. Inorg. Chem. 2018, 2018, 3285 – 3296
[5] P. Chini, G. Longoni, J. Am. Chem. Soc. 1976, 98, 7225 – 7231

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DID-KN-01

The Interconnectedness of Sustainable Development-oriented Critical Challenges, Chemistry Teaching and Systems Thinking

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School science and chemistry curricula around the world are beginning to incorporate the critical challenges that society faces today into teaching, sometimes presented alongside the potential solutions that chemical science can offer. However, it should be recognized that this shift isn't always occurring within the 'core' curriculum; rather, it's often only suggested in as 'engaging' real-world scenarios related to green chemistry and sustainable development for educators to integrate into their instruction. Even though this integration is a subject of debate in curricula that are already overloaded with content, the objective remains crucial. It is essential for all students to feel equipped and capable of participating in vital societal decisions that will determine their uncertain future in the Anthropocene era.

The international chemistry education community has rallied around holistic approaches such as systems thinking, which leverage sustainable development-oriented contemporary science innovations to generate a self-sense of teacher and student agency towards addressing critical challenges facing society today. The IUPAC project Systems Thinking in Chemistry for Sustainability: Toward 2030 and Beyond (STCS 2030+) and other associated implementation projects promote systems thinking as a vital tool to assist chemistry to make connections with Earth and societal systems. However, teaching and learning resources and available professional learning have not kept up with the rapid increases in innovation taking place in industry. This presentation describes some recent examples of schoolteacher professional learning programs that have taken place in different countries, focussed on supporting educators to embed systems thinking-oriented activities into their classrooms. The presentation will also encompass insights from both students and teachers on the implementation of systems thinking within the chemistry classroom. In addition, it will contemplate the necessary support structures that should be established to enhance professional learning initiatives in the future.

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DID-KN-02

Acids and bases from Arrhenius to Brønsted and Lowry: a story with many protagonists

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During our previous studies aimed at better specifying the independent paths which in 1923 brought J. N. Brønsted and T.M. Lowry to the definition of acids and bases, which goes by their name [1], we have had the opportunity to reflect more carefully on the framework of knowledge in which their research was placed. Starting from the statement of the theory of electrolytic dissociation by Arrhenius in 1887 [2], which led to a first definition of acids and bases as substances that release into water ions H+ e OH- respectively, in the following years several authors added their contribution, by globally examining other important properties of the two classes of substances, such as their ability to change the color of indicators and act as catalysts in many organic reactions. The research by these scientists, among whom we can mention R. Abegg [3], A. Werner [4] and L. Micaelis [5], ended up leading to an expansion and greater articulation compared to the initial definition of Arrhenius. In this sense the two publications by Brønsted [6] and Lowry [7] can be seen as the culmination of a process to which others also contributed significantly.

References

[1] F. Calascibetta, Chimica nella Scuola, 2024 (5), 142.
[2] S. Arrhenius, Zeit. Phys. Chem.,1887, 1, 631.
[3] R. Abegg, The electrolytic dissociation theory (trad. C.L von Ende), John Wiley & Sons, New York, 1907, p.5.
[4] A. Werner, Ber. Dtsch. Chem. Ges., 1907, 40, 4133.
[5] L. Michaelis, Die Wasserstoffionenkonzentration, Verlag von Julius Springer, Berlin, 1922, p. 14.
[6] J. N. Brønsted, Recl. Trav. Chim. Pays-Bas, 1923, 42, 718.
[7] T. M. Lowry , J. Soc. Chem. Ind., 1923, 42, 43.

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DID-OR-001

Inclusion through the disciplines: the case of chemistry

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In recent years, schools have become familiar with acronyms such as DSA, BES, PDP that categorize the casuistry of disadvantage and dispensatory and compensatory modes of intervention. Without detracting from the recognition that certain functional characteristics of individuals exert on learning, there is an excessive cataloging of discomfort forms that proves paralyzing of the educational action of curricular teachers. As Maurizio Muraglia[1] reports, a dangerous drift of medicalization of all discomfort forms is detected, in view of an ideal state of well-being that in reality does not exist. In fact there is instead a continuum between so-called "normality" and the most severe forms of distress[2]. The impression is that the concept of inclusion, which should characterize daily schooling because it is understood as a way of promoting learning by taking into account the peculiarities of each student, is being fragmented into bureaucratic classifications which are followed by pedagogical interventions entrusted to non-experts in the discipline. In schools, the intervention of neuropsychiatrists and social workers tends to exert a deresponsibility action on teachers. Faced with diagnoses that spare no one, teachers retreat from their mandate to teach those who need it most. Collaboration between support teachers and curricular teachers is often non-existent or occasional.

This contribution reports on an effective collaboration between support and curricular teacher in a third grade class of an art High School, which led to good results in terms of "possible" learning, with respect the degree of discomfort of the three students considered. The topic of the study was Lavoisier's fundamental 1772 discovery[3] in which he understood that air is involved in the combustion of phosphorus and sulfur. Storytelling[4] played an essential role in learning for all students in the class and particularly for the most fragile subjects.

References:

[1] M.Muraglia , Insegnare 2023, https://www.insegnareonline.com/rivista/scuola-cittadinanza/torsione-concetto-inclusione

[2] L.Bigozzi, 2008, Apprendimento e riabilitazione a scuola. Aspetti psicologici. Roma, Carocci, 2008.

[3] C. Fiorentini, E. Aquilini, D. Colombi, A. Testoni, Leggere il mondo oltre le apparenze: per una didattica dei concetti fondamentali della chimica, Armando Editore, Roma, 2007.

[4] J.Bruner, La cultura dell'educazione, Feltrinelli, Milano 1997, p.135.

DID-OR-002

Ten Fashionable Years – Keeping Dyeing Chemistry from Dying

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Almost ten years have passed since the first cycle of "reformed" Italian High School was completed. The laws of 2010-2012 strongly rearranged every curricula[1], and had a very harsh effect on the *Istituti Tecnici*. The two former courses of *Perito Chimico Tintore* (Dyeing Chemistry Engineer) and *Perito Tessitore* (Weaving Engineer) merged into a brand new interdisciplinary path, that a bad marketing strategy baptized *Tecnico di Sistema Moda* (Fashion System Technician), or S.M. It has two subsection (for textile and for leather industry); our *Setificio*, unique in Italy, also has a section for Fabric Designers, inherited from an older tradition, that faces disrupting innovations in printing.

Oddily, those of S.M. are the only schooling paths in Italy that have Applied Chemistry among the characterizing subjects for the final exam, other than the "true" chemical course (*Chimica e Materiali*). But the latter is mostly focused on general items, so, despite their name, *Sistema moda* graduates are in practice the only specialists surfing the waves of innovation that dyers and printers, finishers and weavers, QC and certification labs are struggling to keep up with. And textiles are everywhere, fashion is only the tip of the iceberg. It is relevant that the majority of S.M. students continue their studies, and not only in STEAM; a good number then comes back in the textile field with widened experiences.

The world of textile covers almost all the branches of chemistry and is less than halfway through a radical transformation, due to changes in materials, procedures and approaches, driven by sustainability instances[2]. Italy is leading in most of these fields, but there is a dramatic lack of people with a sound technical background, so we need to motivate young people also with more adequate teaching procedures. After a decade, it is worth reflecting on what we did in the meanwhile. There seems to be a new push toward more substantial changes in secondary and tertiary education, developing integrated and advanced curricula, so it could be useful to collect and share any effective idea.

In this oral communication, that also looks at some already published works[3] and others still in progress, we will propose several suggestions on how to introduce, in more effective ways, the chemistry and technologies of dyes, formulations, pigments and ligands, finishing agents, new and/or recyclable fibers, digital colour science, water and energy saving etc, supporting a lab-centered teaching along the five years (or soon 4+2?). Learning approaches often lean on real-life references, from historical documentation to the ZDHC and REACH databases and new production quality protocols, in close interaction with academic and industrial environments. We also reflect on the pros and cons arising from these experiences.

References:

[1] S. Palazzi, CnS – La Chimica nella Scuola, XXXIV-3, 2012, 284-289
[2] see the always growing corpus of EU norms on http://environment.ec.europa.eu/strategy/textiles-strategy.en
[3] S. Palazzi, La Chimica e l'Industria online, IV-4, 2022, 54-57

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The Chemistry of Macromolecules in the stories of Primo Levi

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Primo Levi was a macromolecular chemist. Director of SIVA (1953-1973), a paint and similar industry, he dealt for a long time and with passion with all the problems connected with the synthesis, production and use of products based on thermoplastic vinyl polymers or phenolic thermosetting polymers. His work as a chemist represented an inexhaustible source of literary inspiration which not only sheds light on the complexity of the human soul, but is a source of scientific reflection, useful from an educational point of view for the new generations.

In *La chiave a stella* (Einaudi, 1978) the worker Faussone, a sort of *alter ego* of the Author, deals with things that are only apparently elementary: he assembles pylons and mechanical structures. To Levi's perceptive eye, this hard and intelligent work becomes a metaphor for the work of the macromolecular chemist who on an infinitely smaller scale with invisible forceps, and with even greater difficulty, neatly assembles the monomers into macromolecules with a structure no less elaborate than the immense oil derricks.

In *Il sistema periodico* (Einaudi, 1975) the macromolecular ideas are numerous and intriguing. Like the worker Lanza who engages in an all-out night fight with the red-hot autoclave of phenolic resin that is under pressure and on the verge of exploding. Small, great daily heroisms that Levi recounts with involvement, glimpses of industrial life unknown to those who have not experienced that world from within. Lanza, after having tamed the crazy baekelizer with strokes of the key and inventiveness, finally smugly pours the resin produced, shining like a mirror, and as if nothing had happened, passes the deliveries to the day shift worker saying that everything is fine.

And then the artisanal lipstick that drools on the lips, and the paints that have undergone an unwanted sol-gel transition, the thermosetting enamel that mysteriously detaches from steel cans, the unusual preparation of boiled linseed oil ... All cases that seem like thrillers, solved with brilliant chemical acumen, in which the Author is always aimed at understanding the microcosm of man and nature.

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DID-OR-004

Design and testing of a teaching sequence on the notions of permanent and instantaneous dipole

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Educational research shows that the notions of permanent and instantaneous dipole referred to the atomic-molecular realm are difficult to understand and a source of alternative conceptions[1-3]. Difficulties include: the identification of dipolar systems with charged species; the misinterpretation of symbols $\boldsymbol{\delta}+/\boldsymbol{\delta}-$; the lack of correlation between electron mobility (thought in the frame of a shell atomic model) and the onset of intermolecular interactions; the inability to perceive the systemic nature of these interactions.

A teaching sequence focused on dipolar interactions and their interpretation at the nucleus-electron level was designed with the aim to tackle the above-mentioned teaching problems. The didactic transposition addressed the following conceptual issues: (1) description of the molecular dipole as a consequence of electron motion within an overall electrically neutral chemical species; (2) development of the issue of intermolecular interactions starting from the concept of instantaneous dipole, which is present in all atomic-molecular systems (3) conceptualization of dispersion forces as a result of a systemic process in a particle ensemble, rather than the sum of intrinsic properties of individual molecules; (4) treatment of the concepts of instantaneous and permanent dipole within a unified, non dualistic theoretical framework that emphasizes the temporal variable.

The teaching action is based on the use of several didactic tools: individual worksheets aimed at introducing new concepts through problem-situations, formulation of interpretive hypotheses, identification etc.; collective discussions in the classroom, moderated by the teacher; slides for recap and synthesis of the newly learned concepts. This teaching sequence was tested on three classes of a technical secondary school (ITIS “Q. Sella” in Biella, Italy) over a period of 7 weeks. The individual answers provided by students and their contributions to collective discussions were analysed, in order to monitor the learning process and identify strengths and weaknesses of the teaching sequence. Such analysis shows that this sequence was effective in overcoming several obstacles, e.g. the difficulty to distinguish between phenomena and their interpretive models, or to identify causal relationships. The results of a test administered before and after the experimentation, showed that a significant percentage of students achieved the learning objectives. Overall, the sequence was effective in promoting the understanding of the notions of permanent and instantaneous dipole within a coherent and unitary theoretical frame.

References:

[1] L.C. Williams, S.M. Underwood, M.W. Klymkowsky, M.M. Cooper, *J. Chem. Educ*., 2015, 92, 1979-1987.
[2] M.M. Cooper, L.C. Williams, S.M. Underwood, *J. Chem. Educ*., 2015, 92, 1288−1298.
[3] A.C.G. Miranda, M.S.N. Pazinato, *Problems of Education in the 21st Century*, 2023, 81, 176-187.

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DID-OR-005

Three-Dimensional Structures in Late Nineteenth and Early Twentieth Century Chemistry Textbooks

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Graphical representations of three-dimensional structures play a pivotal role in the field of chemistry education. Their correct interpretation is indeed essential for a full understanding of basic concepts that are central for both organic and inorganic chemistry. Students should have a deep knowledge of the correct meaning of the symbolic representations that appear in school and university manuals in order to avoid misunderstandings and a meaningless learning of the discipline.

The aim of the present work is to analyse two important historical examples: the three-dimensional representations of tetrahedral carbon, proposed by van't Hoff and Le Bel 150 years ago to describe the stereoisomerism of organic compounds, and the geometry of metal complexes introduced by Werner in 1893.[1-3] This work investigates in detail the way in which these three-dimensional representations were received and presented in school and university textbooks, published in Italy and abroad in the late nineteenth and early twentieth centuries, before the introduction of techniques of structural investigation such as X-ray crystallography.

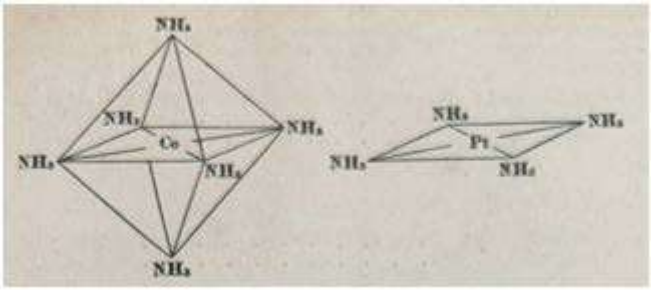

Figure 1: Representation of coordination geometries of metal complexes.[4]

References:
[1] J. H. van't Hoff, *Arch. Néerl. Sci. Exact. Nat.* 1874, 9, 445 – 454.
[2] J. A. Le Bel, *Bull. Soc. Chimique (Paris)* 1874, 22, 337–347.
[3] A. Werner, *Z. Anorg. Chem.* 1893, 3, 267 – 330.
[4] F. Sestini, A. Funaro, *Corso di Chimica ad uso delle scuole secondarie - decima edizione* 1912, Livorno, Raffaello Giusti Editore.

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DID-OR-006

Computing in Class for Chemistry Teaching and Learning

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In the last two decades, computers have gained increasing importance in almost of all aspects of our life, including education. At different levels, STEM disciplines can benefit of computer support, ranging from presentations and lectures, data analysis, code development, self-evaluation and examination, but also modeling, simulations and visualization and, more recently, artificial intelligence tools. Our interest is focused on the use of computer modeling, i.e., calculations and simulations, in chemistry teaching and learning. Several cases are presented and discussed, including activities developed and organized in the secondary school classes in the framework of Piano nazionale Lauree Scientifiche Chimica [1] and PNRR Orienta [2].

A recent project, including tasks of organic chemistry designed for bachelor students and proposed to the third-year students of the Chemistry degree in Padova, is also reported. This project uses the idea of creating cognitive conflicts to engage students in working with computational data to derive claims about structure-property relationships. The qualitative analysis provides insights into the role of computational chemistry for understanding fundamental chemical concepts.

References:

[1] pls.scienze.unipd.it/chimica (last access: March 31st 2024)

[2] pnrrorienta.unipd.it (last access: March 31st 2024)

DID-OR-007

How Science on Stage contributes to improving STEM education

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Science on Stage Italy1 (SonS It), to which the Italian Chemistry Society cooperates through its Didactic Division, is part of Science on Stage Europe2 (SonS Eu) an international network of 35 nations for the dissemination of best practices in Science, Technology, Engineering, and Mathematics or STEM education. STEM permeates and moulds a great part of our lives and STEM skills are crucial to take a critically active part in society and make informed decisions with responsibility and autonomy. Chemistry, physics, biology, astronomy, mathematics, technology, and earth sciences, to quote some of the STEM components the students face through the curricula, contribute to the education of future citizens. The Italian Ministry of Education and Merit, in 2023, released guidelines for STEM education3 stressing its importance at every school level.

The aims of SonS are the promotion of quality STEM education and the enhancement of students' interest in STEM by promoting teachers' professional development. One motto of Science on Stage states: "*Teachers make the difference*". SonS offers professional development based on the exchanges of best practices "*from teachers to teachers*". Every year the activities of SonS reach approximately 100,000 teachers in different countries members of the network offering them the possibility of meetings, professional enrichment, and exchange of effective and useful teaching practices. SonS offers teacher training and releases teaching materials. Its best-known activity is probably the biennial European Science on Stage Festival. The 13th edition will take place from 12-15 August 2024 in Turku, Finland, attended by 450 teachers of primary and secondary schools from all over Europe. During the Festival, the participants who won a national selection will present the most creative STEM ideas at stands, in workshops or highlight sessions, and on stage. The eleven Italian projects that will be present in Turku, have been selected at the Italian SonS Festival, which took place in September 2023 at Città della Scienza in Naples.

This communication reports on a short history of SonS, its activities and the outcomes of the last European SonS Festival, in which Italian delegates will present several innovative Chemistry-based projects.

References:

[1] Science on Stage Italy Homepage: https://www.science-on-stage.it/it/ (online 20/03/2024)
[2] Science on Stage Europe Homepage: https://www.science-on-stage.eu/ (online 20/03/2024)
[3] Linee guida per le discipline STEM (legge 197 del 29 dicembre 2022)

DID-OR-008

The "Giochi della Chimica" competition: analysis of students results and participation

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Since 1984, Società Chimica Italiana (SCI), to promote the dissemination of basic chemical culture and support and enhance the overall growth path of girls and boys, has organized the "Giochi della Chimica", competitions aimed at Second Degree Secondary Schools [1]. Starting from 2024, the "Giochi della Chimica" has been organized into two competitions: the "**Individual Competition**" and the "**Team Competition**" with a total of more than 35,000 participating students and 800 schools from all over Italy.

The individual competition is divided into 3 categories. *Class A* involves the participation of students of the first two years of Second Level Secondary Schools; *class C* is dedicated to students of the following three years of Technical Institutes on Technological sector (Chemistry, Materials and Biotechnology); *class B* is reserved for all the other students of the last three years of Second Level Secondary Schools. For each class, the competition includes three phases: i) ***Institute Phase***, consisting of a unique national competition held in all participating Secondary Schools; ii) ***Regional Finals***, performed in Universities of each region; iii) ***National Final***, reserved to the best 100 students at regional and national level. In the 2024 edition, for the first time the team competition has been also organized, where Second Degree Secondary Schools can participate with teams made up of 4 students.

Questions and problems for both competitions are elaborated by a Questions Working Group, involving delegates of SCI Divisions, based on a dedicated Syllabus. Such Syllabus has been prepared by the National Organizing Committee of "Giochi della Chimica", with the collaboration of the Chemistry Teaching Division of SCI, starting from the National Guidelines for the lyceum and technician and professional high school and the Guidelines for teaching civic education.[2, 3]

The most talented students who participated in the National Final of the Individual Competition are selected by National Organizing Committee for participating in the Italian delegation of International Chemistry Olympiad (IChO). The training of these students is conducted by experts of different fields of chemical sciences and includes theoretical preparation and laboratory practice according to the topics of the "Preparatory Problems "published on the IChO website [4].

The present communication will present and analyze the results obtained, starting from the gender and age distribution of the participants, then moving on to the type of questions proposed in the competition sessions and their respective answers.

References:

[1] https://www.soc.chim.it/giochi_della_chimica/home
[2] https://www.soc.chim.it/sites/default/files/Syllabus-Competizione%20individuale_2023-24.pdf
[3] https://www.soc.chim.it/sites/default/files/Syllabus-Competizione%20a%20squadre_2023-24.pdf
[4] https://www.icho2024.sa/en/Pages/default.aspx

DID-OR-009

I Giochi di Avogadro: Analysis of an Experience in Promoting Chemical Culture in First Degree Secondary Schools in Italy

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Since 1984, the Società Chimica Italiana (SCI), to promote the dissemination of basic chemical culture and support and enhance the overall growth path of girls and boys, has organized "I Giochi della Chimica", competitions aimed at Second Degree Secondary Schools. The achievements of the latest editions have initiated, within the SCI, a reflection on the importance of the medium of the Giochi to involve new actors (be they students or their teachers), also with the aim of conveying a more modern and captivating vision of the discipline, often experienced only in its most mnemonic aspects and little connected with everyday life. Therefore, for the academic year 2023-2024, with the patronage of Ministero dell'Istruzione e del Merito (the Ministry of Education and Merit), SCI has decided to also address the first cycle of education and the national competition called "I Giochi di Avogadro" was proposed and organized.[1] Participation was open to all students attending the second and third classes of First Degree Secondary School. The first edition involved 14 regions for a total of over 1700 students. There were two computer-based competition phases. The first one, at the school level, which included 20 multiple-choice questions to be completed in 45 minutes, and the national final, in which the top 4 students from each school participated, with 30 multiple-choice questions to be completed in 60 minutes. The questions for both competitions were developed based on a framework elaborated in light of the National Guidelines for the curriculum of the first cycle of education (D.M. 254/2012 of the Ministry of Education, University, and Research), the Guidelines for teaching civic education (Attachments A and B to D.M. n. 35/2020 of the Ministry of Education), reflections carried out within the National Organizing Committee of Giochi di Avogadro, and shared experiences in the journal "La Chimica nella Scuola" (Chemistry in School). The communication will present and analyze the results obtained, starting from the gender and age distribution of the participants, then moving on to the type of questions proposed in the two competition sessions and their respective answers.

References:

[1] Homepage of Giochi di Avogadro: https://www.soc.chim.it/it/giochi_della_chimica/giochi_di_avogadro/home.

DID-OR-010

Serious games on chemistry and sustainability for schools and the citizens

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Sustainability education may be challenging due to the complexity of the matter that relies on multidisciplinary and interdependent knowledge.[1] Serious game could be a successful methodology to educate a broad audience on sustainability issues. As a continuation of our work on chemistry dissemination[2], here, we present three educational and ludic activities, based on serious games, designed for schools and the citizens, with the aim of increasing interest towards Chemistry and Sustainability.

Figure 1: The serious games: a) "Verso la sostenibilità…e oltre", b) "Celle a combustibile a ossidi solidi: il puzzle"; c) "Libri in Tavola"

In the board game called "*Verso la sostenibilità…e oltre*", participants are engaged by answering question cards featuring multiple choices to learn some key concepts about chemistry and sustainability while playing. The 3Dpuzzle called "*Celle a combustibile a ossidi solidi: il puzzle*" is crafted from scraps and waste-derived components. Participants have some time to study the puzzle image and the technical information required to correctly assemble the device as fast as possible. Through this activity participants can learn what a solid oxide fuel cell is, its basic components, and their primary roles within the cell. In the interdisciplinary challenge called "*Libri in Tavola*" participants need to place each book title into the right position on the EuChemS periodic table of critical elements[3]. Depending on the audience, three different difficulty levels are proposed. Following each participant's response, an experiment, a technical information, or a curiosity is shared and explained in association to the chemical element.

References:

[1] S. Parry, E. Metzger, Sustainable Earth Reviews 2023, 6, 2
[2] F. Deganello, M. L. Testa, A. Zanelli, R. Lucentini, A. Ienco, M. Calamante, C. Vineis, A. Varesano, A. Torreggiani, Chimica nella Scuola, 2024, 1, 40-50
[3] https://www.euchems.eu/euchems-periodic-table/

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DID-OR-011

The National Chemistry Project of the Piano Lauree Scientifiche

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The Piano Lauree Scientifiche (PLS) is a plan of the Ministry of University and Research aimed at promoting enrollments in scientific degree courses, reducing university dropouts, improving the careers of university students, and the professional growth of the School's teachers Upper secondary [1].

All 32 Italian universities where there is a course of study in class L-27 Chemical Sciences and Technologies participate in the PLS National Chemistry Project [2].

In the imminent prospect of the decrease in high school students who will enter the university path due to the demographic decline, both the theme of orientation and that of reducing dropouts and improving the careers of our students are of great importance.

This contribution will present the work carried out in the first year of the project on the topic of the transition of students from secondary schools to university, illustrating the intervention strategies developed in the field of orientation and the reduction of dropouts and improvement of careers.

References:

[1] MUR, Linee Guida PLS e POT 2021-2023, https://www.mur.gov.it/sites/default/files/2023-04/Linee%20guida%20PLS%20e%20POT_6.4.2023.pdf

[2] U. Cosentino, Chimica nella Scuola, 2024, accepted.

DID-OR-012

Laboratory activities of the PLS Chemistry: an opportunity for teachers and students.

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For many years now, PLS has offered teachers and students in the three-year period of secondary school the opportunity to practically try their hand at various chemistry topics. The aim that has accompanied these activities since its inception is both to bring out scientific vocations in students (in our case particularly in the chemical field) and to contribute to the training of science teachers with new teaching proposals.

The common thread in the PLS Chemistry activities of the current academic year was "The colors of chemistry" and was divided into three laboratory activities which involved different disciplines present on site. In this communication will be discussed the educational ideas offered as part of the project and the students’response.

DID-OR-013

Should I enroll or not? A profile of freshmen in Chemistry and Industrial Chemistry undergraduate courses in Italy and analysis of the impact of the activities of the "Piano Lauree Scientifiche" on university study course enrollments.

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The decline in enrolments in chemistry-related degree courses observed internationally is a matter of great concern, as it could lead to a loss of expertise and competitiveness in an extremely important field for both research and productive system[1]. For many years, several EU countries have been implementing orientation actions for high schools' students aiming at guiding them towards a more conscious choice of university studies, with particular emphasis on STEM areas. In this framework, the Italian "Piano Lauree Scientifiche"[2] - Chemistry Area (PLS-Chem), for two decades now, has played a leading role, implementing numerous activities aimed at high school students to introduce them to Chemistry oriented degree courses, with particular reference to those in Chemistry and Industrial Chemistry.

In this context, during 2023, a questionnaire aimed at investigating the reasons underlying the choice of their university study course has been administered to 1163 freshmen (44.3% female students) enrolled in Degree Courses in Chemistry or Industrial Chemistry of 21 Italian Universities. The questionnaire employed various psychometric scales to examine the motivations for the university choice, the attitude towards the discipline, the awareness of a generic "scientific" disciplinary identity, or of a specifically chemical" one. To estimate the impact of the activities of the PLS-Chem on the choice of the university study course, the questionnaire also asked which extracurricular activities the student had participated in and how much the activities had influenced their subsequent choice.

The results show that the motivations that most led the interviewed freshmen to enrol in the degree course in Chemistry or Industrial Chemistry are "*interest and passion for the subjects covered by the course*" (mean = 3.80/5), "*desire to understand the world around me*" (3.79/5), and "*propensity towards the subjects covered by the course*" (3.71/5), thus indicating a strong attitude toward the discipline. On average, freshmen demonstrate a significantly higher attitude towards chemistry than perceived self-efficacy (4.22 vs. 3.50, $p < .001$) and a significantly higher "scientific" disciplinary identity than "chemical" identity (3.81 vs. 3.67, $p < .001$). The impact of PLS-Chem activities was particularly significant: although only 26% of freshmen who responded to the questionnaire participated in PLS-Chem labs, for 73% of these, such participation was "very important" in the degree choice. Students who participated in PLS activities seem to have a higher chemical identity (3.80 vs. 3.62 of non-participants, $p < .001$), suggesting that PLS-Chem activities develop in students a greater self-perception as "future chemists". This contribution will present in detail the profiles of freshmen and discuss the correlations with the participation in the activities of PLS-Chem.

References:

[1] Archer, L. et al. J Res Sci Teach. 2023;60:978–1013; [2] https://www.pianolaureescientifiche.it

DIVISIONE DI DIDATTICA CHIMICA

COMUNICAZIONI POSTER

DID-PO-001

From the periodic system to the recognition of carbohydrates

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"The Periodic System" by Primo Levi, which represents a key to understanding the periodic system, table of elements. Our guys reviewed the text in an original way, through a podcast. Contents of the podcast: We are chemists, we must not surrender to incomprehensible matter. This is why we are here, to make mistakes and correct ourselves, to take hits and return them. The profession of chemist teaches us that by making mistakes we learn and improve. Making a mistake in an improvised electrolysis experience, Levi guides us through a reflection on the importance of hydrogen, the same one that burns in the sun and stars. Nature is immense and complex, but it is not impervious to intelligence. Chemistry is not an abstract subject, because it sets our reasoning in motion, both in the laboratory and in everyday life. Primo Levi talks about his first falling in love, his teenage life and his relationship with his work colleagues. Experimenting helps us analyze and predict the effects of our actions. Just as carbon, such a simple element, can be transformed into valuable and precious substances, in adverse situations we have the ability to adapt and find beauty in our environment. Chemistry serves to awaken consciences in the dark and sad context of World War II and the Holocaust. Doctor Müller was head of the chemical laboratory at Auschwitz, where Levi also worked. Müller was considered the redeemer of Nazism, he was described as a monster, but Levi knew the human side of him. At the end of the war Müller called Levi, saying he wanted to meet him; he accepted but 8 days later he received the announcement of his death. "I didn't feel capable of representing the dead of Auschwitz, nor did it seem sensible to me to see Müller as the representative of the executioners." The soft and delicate zinc, so succumbing to acids, behaves very differently when it is very pure: then it stubbornly resists attack. Two philosophical consequences can be drawn from this: the praise of purity that protects from evil; the praise of impurity that generates changes, that is, gives life. Impurities are therefore necessary, dissent and diversity are needed, but fascism does not want them, it prohibits them and for this reason you are not a fascist; he wants everyone to be the same and you are not the same. We must not conform to fashion or bad habits, we must not be alienated by prejudices, but be ourselves even when it means not being taken seriously. Impurities make us feel free. Here's what Levi says when talking about his friendship with Sandro: the diversity of our origins made us rich in goods to exchange, like two merchants who meet coming from remote and unknown areas. Our activity is part of another of an experimental nature, starting from the Chapter relating to Carbon:1 "Now our atom is inserted: it is part of a structure... a ring structure, an almost regular hexagon, which however is subject to complicated exchanges and equilibria with the water in which it is dissolved; because it is now dissolved in water, or rather, in the sap of life....It has become part of a glucose molecule... which prepares it for first contact with the world.Recognition Carbohydrates2

Laboratory activity activity 1.Compilation of the table relating to the general information of some commonly used carbohydrates, assisted by 'tasting' and solubility tests; activity 2. Bread making with different types of yeasts and flours and construction of the leavening curve; activity 3. Separation of gluten and starch from a dough of water and wheat flour; activity 4. Colorimetric test for the evaluation of the presence of starch in foods; activity 5. Colorimetric test for the evaluation of the presence of proteins in foods.

References:

[1] Primo Levi "il sistema periodico"
[2] La Chimica nelle scuola, Maria Maddalena CARNASCIALI*, Laura RICCO, Alessandra MINGUZZI Dipartimento di Chimica e Chimica Industriale, Genova

DID-PO-002

Using Interrupted Case Studies to Enhance Argumentation Skills

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Fruits mainly comprise living tissues and are characterized by a high level of water availability, which makes them highly perishable. Edible film and coating applications show promising results in increasing the shelf-life, as well as preserving their quality. This study reports on the implementation of three interrupted case studies[1], and the use of edible film and coatings in fruit conservation. The case studies, entitled 'The delicious crimson grapes', 'Mr. Jairo´s pears' and 'Guavas, edible films and minerals', were undertaken by undergraduate chemistry students. Implementing the case study as a teaching strategy focused on students utilizing data provided in case studies to formulate a written scientific argument in defense of the best solution for the cases. This work utilizes the Leitão's framework[2] to investigate the students' written arguments regarding solutions for the case studies. Leitão[2] outlined a unit of analysis, which is meant to capture how dealing with opposition affects the speakers' position. The unit of analysis includes three basic elements: argument (justified claim), counterargument and reply. According to Leitão[2], there are three types of replies: dismissing the counterargument (speakers find themselves able to dismiss a piece of information a counterargument conveys), local agreement (speakers normally start by stating their agreement with the content of a counterargument and then they keep defending their previous position by adding to it some new support), integrative (integrating both positions and rejecting the initial view). The reply is made up of points of view and justifications. The research questions investigated in this study was "What are the types of replies in the student's written texts when faced with counterarguments presented by the case studies characters about the best edible films to use in each problem situation? The results show that the majority of the counterarguments was dismissed. To do this the students took a position regarding counterarguments, being forced to revise them carefully. Almost all the students effectively used evidence to formulate their replies. Indeed, students cited data by linking specific inscriptions (e.g., graph representing changes in weight of grapes over time, tables presenting information on various properties of fruit after edible coatings/films, etc.) to their argumentative texts. In conclusion, using an interrupted case study method facilitates written argumentative texts based on using evidence. FAPESP (Grant 2023/01936-1); CNPq (Grants 304974/2020-0 and 420662/2023-5).

References:

[1] M. S. Lima, S. L. Queiroz, Journal of Chemical Education 2024, 101(2), 467 – 473.
[2] S. Leitão, Human Development 2000, 43(6), 332 – 360.

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ELE-MD-01

Paving the way to a sustainable stationary energy storage system: The development of aqueous zinc-ion batteries

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In the last few years, aqueous Zn-ion batteries have attracted a great attention as energy storage devices for stationary applications, thanks to their high safety and environmental friendliness, together with low toxicity and costs[1]. Their working principle (see Figure 1) is based on shuttling of zinc ions in solution from the negative to the positive electrode (discharge) and vice versa (charge). Although promising, still several challenges, which limit their cycle life and therefore their commercialisation, remain unsolved.

On the negative electrode side, the major problems are related to: (I) the hydrogen evolution reaction occurring in parallel to the Zn deposition reaction[1,2], and (II) the formation of isolating layered double hydroxides, which block the surface of the zinc[3].

On the positive electrode side, Prussian blue analogues (PBA) show extremely promising performances thanks to their excellent rate capability, which is strongly required in the case of stationary applications, and high operating potential, leading to competitive energy densities of the final battery[1]. However, they suffer from a relatively short cycle life, mostly related to unwanted changes in their structure upon cycling[2].

Here, an overview of some recent strategies adopted to optimise the cycle life of both metallic zinc negative electrodes and PBA positive electrodes will be shown, emphasizing how, by understanding the fundamental mechanism leading to degradation, it was possible to specifically operate on them in order to enhance the cycle life of the battery from 20 to 1000 cycles.

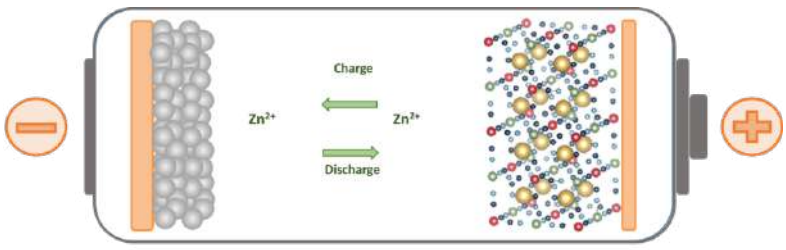

Figure 1: Working principle of an aqueous zinc-ion battery.

References:

[1] G. Zampardi, F. La Mantia, Nature Commun. 2022, 13, 687
[2] G. Zampardi, F. La Mantia, Curr. Opin. Electrochem. 2020, 21, 84-92
[3] M. Tribbia, J. Glenneberg, F. La Mantia, G. Zampardi, ChemElectroChem 11, 2024, e202300394

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ELE-KN-01

Addressing key challenges in the development "beyond Li-ion" chemistries

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Renewable energy production is characterized by intermittent power output and requires large-scale applications to improve energy storage capability (currently, less than 1% of the electrical energy production can be stored). Developing low-cost and environmentally friendly electrochemical storage systems characterized by high performance is of fundamental importance for a sustainable energy economy. The currently most mature battery technology is the lithium-ion battery, which is considered one of the most appealing candidates for power sources for electric vehicle applications. However, the large-scale application of lithium-ion batteries is currently under discussion due to the limited lithium and certain transition metals such as Co and Ni resources. Several other metallic anodic materials such as sodium, potassium, calcium, magnesium and aluminium [1-3], characterized by a higher abundance of lithium, have been considered suitable candidates for electrochemical storage devices in replacing lithium systems. Notably, significant efforts are being devoted to understanding and addressing key challenges in developing these so-called "beyond Li-ion" chemistries, and substantial insights into their storage and failure mechanisms have been obtained over the past few years thanks to advanced characterization and computation/modelling techniques. An overview of our activity in "beyond Li-ion" batteries field and an evaluation of the capability of this technology will be presented. [4–9]

References:

[1] G. A. Elia, K. Marquardt, K. Hoeppner, S. Fantini, R. Lin, E. Knipping, W. Peters, J.-F. Drillet, S. Passerini, R. Hahn, *Adv. Mater.* **2016**, *28*, 7564.

[2] G. A. Elia, K. V Kravchyk, M. V Kovalenko, J. Chacón, A. Holland, R. G. A. Wills, *J. Power Sources* **2021**, *481*, 228870.

[3] G. G. Eshetu, G. A. Elia, M. Armand, M. Forsyth, S. Komaba, T. Rojo, S. Passerini, *Adv. Energy Mater.* **2020**, *10*, DOI 10.1002/aenm.202000093.

[4] G. A. Elia, I. Hasa, G. Greco, T. Diemant, K. Marquardt, K. Hoeppner, R. J. Behm, A. Hoell, S. Passerini, R. Hahn, *J. Mater. Chem. A* **2017**, *5*, 9682.

[5] G. A. Elia, G. Greco, P. H. Kamm, F. García-Moreno, S. Raoux, R. Hahn, *Adv. Funct. Mater.* **2020**, *30*, 2003913.

[6] X. Liu, G. A. Elia, S. Passerini, *J. Power Sources Adv.* **2020**, *2*, 100008.

[7] X. Liu, H. Euchner, M. Zarrabeitia, X. Gao, G. A. Elia, A. Groß, S. Passerini, *ACS Energy Lett.* **2020**, DOI 10.1021/acsenergylett.0c01767.

[8] X. Liu, G. A. Elia, B. Qin, H. Zhang, P. Ruschhaupt, S. Fang, A. Varzi, S. Passerini, *ACS Energy Lett.* **2019**, DOI 10.1021/acsenergylett.9b01675.

[9] S. Porporato, M. Bartoli, A. Piovano, N. Pianta, A. Tagliaferro, G. A. Elia, R. Ruffo, C. Gerbaldi, *Batteries* **2022**, *8*, 183.

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ELE-OR-001

Blue-Emitting Carbon Quantum Dots: Insight into the Effect of the Synthesis Parameters of the Hydrothermal Approach

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Since their serendipitous discovery in 2004, carbon quantum dots (CDs) gained increasing interest from the scientific community because of their outstanding optical properties, which make them suitable for a plethora of applications, going from sensing to bioimaging, optoelectronics, photovoltaics, etc., as an alternative to the classic chalcogenide-based quantum dots. Their production is simple, low-cost, sustainable, and could employ precursors recycled from biomass and biowaste. Furthermore, through the modulation of the synthesis parameters, it is possible to produce CDs with desired properties, and a recent work by Patel et al.[1] gives an interesting example of the possibility of modulation of the properties of CDs for theranostic applications through the proper setting of the reaction parameters. Starting from those considerations, here we aim to give an insight into the effect of the synthesis parameters on the optical, chemical, and structural properties of blue-emitting CDs. We selected the hydrothermal approach owing to its feasibility for future large-scale industrial applications, and we employed eco-friendly precursors that could be obtained from biowaste, like citric acid (CA) and glucose (Glu) as carbon sources, and urea as both nitrogen source and base (Figure 1). Through spectroscopic, electrochemical, and structural investigations, we studied and discussed the effects of the reaction parameters considering the formation of graphitic nitrogen *N*-oxides[2] and their role.

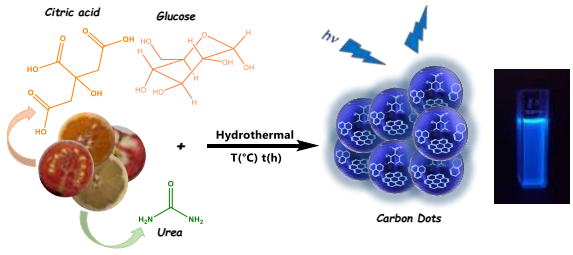

Figure 1: CDs synthesis scheme.

References:
[1] M. Patel, et al. Colloids and Surfaces A 2024, 684, 133097.
[2] B. Vercelli, et al. Electrochimica Acta 2021, 387, 138557.

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ELE-OR-002

Intact photosynthetic bacteria-based photoanodes for energy and contaminant monitoring

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The use of intact, metabolically active, photosynthetic bacteria for the development of sustainable photoelectrodes allows converting solar energy into electrical energy without requiring long purification processes of the biocatalysts.[1] To this end, the photoinduced electrons generated following the charge separation event must be transferred from the photosynthetic apparatus located inside the bacterial membrane to the electrode surface. Our group recently developed a sustainable approach to obtain a redox-adhesive polydopamine matrix that simultaneously facilitates the photoinduced extracellular electron transfer, with a 5-fold enhanced photocurrent production, while maintaining the bacteria in close contact with electrode surfaces. [2] Additionally, we recently developed free-standing biobased electrodes that allowed enhancing bacterial colonization and a further 18-fold increase in current generation from the biobased electrodes.

Herein, the possibility to employ these biohybrid photoelectrodes for the on-line, early monitoring of different contaminants is presented. The high versatility of the photosynthetic organism utilized (i.e., the purple bacterium *Rhodobacter capsulatus*) allowed studying the influence of both organic and inorganic contaminants on the obtained photocurrent. Electrochemical and spectroscopic investigations revealed a complex interaction between bacterial cells and the contaminants, paving the way for the use of these biohybrid systems as self-powered biosensors.

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References:

[1] L. D. M. Torquato, M. Grattieri, Current Opinion in Electrochemistry 2022, 34, 101018.
[2] G. Buscemi, D. Vona, P. Stufano, R. Labarile, P. Cosma, A. Agostiano, M. Trotta, G.M. Farinola, M. Grattieri, ACS Applied Materials & Interfaces 2022, 14, 26631-26641.

ELE-OR-003

Development of battery components based on biomass-derived materials

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As the market for energy storage system expands, safety and production sustainability of lithium ion batteries (LIBs) have become new concerns in addition to battery performance. Many battery components are synthesized from critical raw materials (CRMs) that are at risk of depletion, and alternative materials based on highly abundant and readily available elements need to be developed. Lignocellulose, composed of cellulose, hemicellulose, and lignin, is one of the most abundant and environment-friendly feedstocks. Their use is expected to be an effective way to reduce the energy consumption and negative environmental impact during the production of batteries.

In the present study, battery components have been developed based on commercially available Kraft lignin, sodium carboxymethyl cellulose (CMC), the lignin extracted from poplar wood, and cellulose extracted from pistachio shells. Two types of lignin were utilized to synthesize hard carbon (HC) through hydrothermal treatment at 250 °C with the presence of citric acid and/or pyrolysis at 600 °C. The synthesized materials were examined as the anode material for LIBs and found to exhibit a specific capacity around 200 mAh/g at C/10.

In the case of cellulose, it was investigated as a binder for $LiNi_{0.5}Mn_{1.5}O_4$ (LNMO). CMC is frequently utilized as a binder in aqueous electrode fabrication processes. In our study, cellulose extracted from biomass has been mixed with CMC in different ratios. A highest capacity of 125 mAh/g at 1C was obtained when the binder composition was cellulose:CMC=2:8 w/w, which was higher than the specific capacity of LNMO having solely CMC as the binder. By increasing the concentration of cellulose, the capacity value decreased, which was probably due to inhomogeneity of electrodes caused by poor solubility of cellulose in water.

Development of cellulose-based separator was also attempted. However, due to amphiphilic property of cellulose, the membrane being able to absorb traditional electrolytes was not obtained. To solve this issue, two different types of membranes were prepared: one is composite membranes based on poly(ethylene oxide) and CMC, and the other is CMC-membrane with an enhanced porosity prepared by lyophilization. Both membranes were soaked in 1M $LiPF_6$ in ethylene carbonate and dimethyl carbonate 1:1 v/v mixture and examined in Li|LNMO cells. The porous CMC-membrane allowed the cell showing a discharge capacity above 100 mAh/g at C/20. Combining all these results, it is possible to design LIBs based on highly abundant and easily accessible materials, enabling more sustainable production of LIBs.

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ELE-OR-004

Thiol-ene Polymerization towards easily up-scalable Gel Polymer Electrolyte

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The continuous increase in energy consumption worldwide has catalysed the attention of research players on the production of safer and more efficient energy storage systems. A possible strategy to reduce the leaking of liquid electrolyte is the employment of solid or semi-solid polymer electrolytes. Gel polymer electrolytes (GPEs) present the best compromise between mechanical and electrochemical properties, as well as an improvement of the cell safety[1]. The UV mediated radical polymerization is a common GPE fabrication strategy due to its low reaction time and economic advantages. However, the polymerization can only occur in the presence of an initiator, and is hindered by oxygen, thus impeding the industrial scale up of the GPEs production. In this work, an UV mediated thiol-ene photopolymerization, employing polyethylene glycol diacrylate (PEGDA) and two different thiols (trimethylolpropane tris(3-mercaptopropionate) - T3 and pentaerythritol tetrakis(3-mercaptopropionate) - T4) as oligomer and crosslinkers, respectively, was carried out in a liquid electrolyte solution (1 M LiTFSI in EC/DEC) to obtain a self-standing GPE (noted as PT3 and PT4). The thiol-ene polymerization mechanism enables an easily up-scalable, fast, cheap and environmentally friendly GPE production, eliminating the need for a photoinitiator and an inert atmosphere[2]. A comparative study between the properties of membranes cured in an inert Ar atmosphere (AR), as well as GPEs produced in a dry atmosphere (DR), was performed. All the produced GPEs present an excellent room temperature ionic conductivity above 1 mS cm^{-2}, as well as a wide electrochemical stability window up to 4.5 V. The full cells were tested to evaluate the rate capability of the GPEs comparing between membranes produced as self-standing and subsequently sandwiched between anode and cathode (referred to ex-situ), and GPEs directly cured on the cathode surface (referred to as in-situ). The assembled cells display stable cycling, reaching a specific capacity up to 140 mAh g^{-1}, when tested at a current density of C/10 for 300 cycles.

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References:

[1] Xiaoqi, Y. et al., "A Review of the Relationship between Gel Polymer Electrolytes and Solid Electrolyte Interfaces in Lithium Metal Batteries," Nanomaterials, 2023, 13, 1789.

[2] Hoyle, C.E. et al., "Thiol-ene Click Chemistry," Angew. Chem. Int. Ed. 2010, 49, 1540 – 1573.

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ELE-OR-005

Characterization of hybrid DMSO-aqueous electrolytes for non-flammable lithium-ion batteries

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The most commonly used electrolytes in lithium-ion batteries (LIBs) present serious problems of flammability and environmental impact, due to the organic solvents that are employed. In order to overcome this problem, one of the most promising current research lines about LIBs electrolytes is focused on the replacement of these solvents with water-based electrolytes[1]. Unfortunately, water present a narrow electrochemical stability window (ESW) of only 1.23 V, which limits the maximum potential that can be reached by a full cell and the choice of the possible electrodes that can be employed. In the last years, two different strategies were adopted with aim of expand di ESW of water: (I) the use of high amount of salts, up to a superconcentrated solution and (II) the addition of some non-flammable solvents. The addition of salts causes molecules to get caught in the solvation shells of ions, hindering their reactions[2], while the solvent can make it more difficult for the water molecules the access to the electrodes, where the decomposition reaction occurs, giving H_2 and O_2. Moreover, the right choice of these two component can promote some reaction of the electrolyte, from which the Solid Electrolyte Interphase (SEI) layer is generated. This layer is able to protect the electrolyte from degradation reaction and increase in this way the durability of the full device.

The non-flammable co-solvent chosen for this work is dimethyl sulfoxide (DMSO), that is highly miscible with water, quite cheap and low toxic[3]. Instead, the ideal salts that can promote the SEI layer generation are those containing F atoms, because they decomposes giving LiF, that is on of the components of the layer.

The main focuses of this work are the physicochemical and electrochemical characterizations of aqueous electrolytes made of superconcentrated solution of fluorinated salts, dissolved in a mixture of water and DMSO in a 1:1 molar ratio. In order to complete the electrochemical studies, a full-cell device was built, by using $LiMn_2O_4$ as the positive electrode and $LiTi_2(PO_4)_3$ as the negative electrode.

References:

1. Khalid S, Pianta N, Mustarelli P, Ruffo R. Use of Water-In-Salt Concentrated Liquid Electrolytes in Electrochemical Energy Storage: State of the Art and Perspectives. *Batteries*. 2023;9(1). doi:10.3390/batteries9010047
2. Gao H, Tang K, Xiao J, et al. Recent advances in “water in salt” electrolytes for aqueous rechargeable monovalent-ion (Li+, Na+, K+) batteries. *Journal of Energy Chemistry*. 2022;69:84-99. doi:10.1016/J.JECHEM.2021.12.025
3. Dimethyl Sulfoxide Safety Data Sheet. *Fluorochem*. Published online 2023.

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ELE-OR-006

From recycled PVB to innovative separators and binders for Li- and Na-ion Batteries

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Li- (LIBs) and Na-ion batteries (NIBs) play a crucial role as energy storage devices for electric vehicles and smart grids. It's widely recognized that all the components contribute to the overall performances, not only the active materials, but also conductive carbons, current collectors, electrolyte separators and binders, so that the optimization of each component is likely to result into huge economic and environmental benefits [1].

In this context, we explored the possibility of repurposing in batteries the recycled polyvinyl butyral (PVB) from post-consume laminated glasses (from automotive and construction) that cannot be reused in glasses because of degraded optical properties. Indeed, nowadays most of the PVB collected after disposal is incinerated or landfilled, causing tons of losses every year [2].

Two strategies were pursued: either using recycled PVB as binder in the electrodes composition or transforming it into a membrane to be used as electrolyte separator.

In the case of PVB as binder, we investigated the electrochemical and structural properties of polymer blends of PVB with standard binders, as polyacrylic acid (PAA) and poly(vinylidene fluoride) (PVDF), producing hard carbon (HC) anodes for both LIBs and NIBs.

On the other side, the membrane preparation required the conversion of PVB into a cross-linked polyurethane by reaction with a diisocyanate, controlling the morphology of the produced membranes by changing the conditions of the coagulation bath used for their casting [3]. Many parameters must be considered for the preparation of an optimal separator, including electronic insulation, low ionic resistance, mechanical stability, chemical resistance to degradation, wettability and uniform thickness.

Preliminary results are highly encouraging and pave the way to the development of more sustainable separators and binders from waste products for safe, low-cost energy storage devices.

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References

[1] Arora, P. et al., Chem. Rev., 2004, 104, 4419–4462
[2] F. Duffner et al., Renewable Sustainable Energy Rev., 2020, 127, 10987
[3] Lian, F. et al., J Memb. Sci., 2014, 456, 42–48

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ELE-OR-007

Designed Solutions to Face the Bigger K-ion Challenge in Potassium Organic Batteries

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Our world is grappling with an energy transition vital for planet survival. For this reason, Li-ion batteries (LIBs) have reached unprecedent attention from the research community and the global market. Nonetheless, lithium scarcity prevents LIBs from covering the entire demand of storage at global scale. As a result, potassium-ion batteries (PIBs) are strongly emerging as a viable technology for stationary storage and large-scale production for its features: abundancy, low costs, the closest redox potential to Li, the smallest Stokes radius, and compatibility with aluminium current collector at every voltage. Nonetheless, desolvated K-ions show the biggest radius, arising some challenges: once intercalated in rigid inorganic electrode material structures, K-ion may cause their distortion, resulting in drastic capacity decay, like in commercial graphite and Prussian blue. And yet, the latter two are still the best option as anode and cathode materials for PIBs.

From this starting point, our group has focused on possible solutions to address these issues in both anode and cathode, keeping always into account the imperative of lower impact PIBs production since they are meant for the large-scale. Indeed, here we report a highly porous carbon material, prepared from lignin and potassium carbonate, with X-Ray diffraction evidences of no stacking of graphene layers, and thus no limited interlayer volume. Its disordered structure allows the K-ions to insert in the carbonaceous anode without causing any damage to the structure, but instead, upon cycling, they may cause its rearrangement to a structure perfectly suitable for K-ion hosting. This behaviour is electrochemically translated in an increase of capacity for the first cycles and null decay of capacity, the values of which are comparable to commercial carbon blacks[1].

On the cathode site, in potassium battery field very few satisfying options have been published to now, due to the challenging bigger K-ions. Organic electrodes are not-critical raw materials-based, cheap, environmentally friendly, tunable, and - above all – their intrinsic mechanical flexibility can lead to the reversible and damage-free accommodation of large sized K-ions, resulting in stable PIB performance. Their biggest drawback is the high solubility in organic solvents. In consideration of this, stable aminoxyl radicals like TEMPO have been investigated to exploit its tunability both as monomeric unit and polymeric materials, in pristine for and also functionalized in order to reduce its solubility in organic electrolytes. In our work, we also considered the effect of the amount of free radicals on the electrochemical properties, as well as the possibility to integrate the redox activity of an n-type material in a TEMPO-like-based electrode on an aluminium current collector.

References:

[1] S. Trano, et al., Energy Mater. 2024, 4, 400008.

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ELE-OR-008

Anion exchange membrane based on N,N- dimethyl piperidinium cation for water electrolyzer application

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Water electrolyzers based on Anion Exchange Membranes (AEMs) are the new frontier for green hydrogen production. This enable the use of platinum group metal-free catalysts and reduce the capital cost of hydrogen. Despite intensive research over the last decade the commercial use of AEMs is hindered by the poor alkaline stability of polymer electrolyte, lower conductivity compared to the Proton Exchange Membranes (PEMs) and non-trivial synthesis procedure. The poor alkaline stability is due to several degradation mechanisms. The main one is Hoffman elimination, which occurs in the presence of beta hydrogens with respect to conductive quaternary ammonium groups and leads to a decrease in ionic conductivity[1].

Recently, Olsson et al. discovered a new class of AEMs known as Poly(aryl piperidinium) (PAP)[2]. These combine a heteroatom-free aromatic backbone with the piperidinium group. The N,N-Dimethyl Piperidinium shows a longer half-life than any other quaternary ammonium grups. Stability in alkaline einvironment is due to the stiff six-members chair conformation that disfavour the Hoffman elimination process[3].

A simple approach for the production of AEMs is the functionalization of commercial polymers (e.g. PE, PP, PS ecc.). by radiative grafting[4] and chemical modification[5]. To the the best of our knowledge the effect of the average polymer molecular weight on functional properties of AEMs has been poorly investigated[6].

Inspired by the recent work of Olsson et al. on chemical grafting of polystyrene by superacid hydroxyalkylation[7] we investigated the effect of PS molecular weight variation on electrochemical and functional properties.

References:

[1] J.R. Varcoe, P. Atanassov, D.R Dekel, A.M. Herring, M. A. Hickner, P.A. Khol, A.R. Kucernak, W.E. Mustain, K. Nijmeiker, K. Scott, T. Xu, L. Zhuang, Energy Environ. Sci. 2014, 7, 3135 – 3191.
[2] J.S. Olsson, T.H. Pham, P. Jannasch, Adv. Funct. Mater 2017, 28, 1702758.
[3] M.G. Marino, K.D. Kreuer, ChemSusChem 2014, 8, 513 – 523.
[4] L. Wang, X. Peng, W.E. Mustain, J.R. Varcoe, Energy Environ. Sci. 2019, 12, 1575 – 1579.
[5] A. Roggi, G. Agonigi, C. Resta, A. Filpi, E. Martinelli, E. Guazzelli, Macromol. Rapid Commun. 2024.
[6] Q. Ling, T. Wang, T. Jiang, Y. Ding, H. Wei, J. Membr. Sci. 2024, 694, 122407.
[7] J.S. Olsson, T.H. Pham, P. Jannasch, Macromolecules 2020, 53, 4722 – 4732.

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ELE-OR-009

Functionalized Templatation: Precision Engineering of Fe-N-Cs Active Structure for Oxygen Reduction Reaction

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A strategy to atomically disperse the Fe-N-Cs active sites in the micro-mesoporous environment facilitating the mass transportation for oxygen reduction reaction (ORR) is presented. Herein, in-house prepared silica nanoparticles (ca. 70 nm) were functionalized with atomic Fe via amino ligands namely 3-aminopropyltriethoxysilane (APTES) and N-(2-Aminoethyl)-3-aminopropyltrimethoxysilane (EDTMS). The derived materials i.e SAFe (silica functionalized with Fe via APTES) and SEFe (silica functionalized with Fe via EDTMS) were then used as porosity templates, as well as an iron precursor with a potential to restrict the coalesce of Fe into metallic nanoparticles. Subsequently, SEFe and SAFe were impregnated with methylimidazole (carbon and nitrogen source). The achieved sludge after drying was then pyrolyzed for 1 h at 900 °C to develop the basic Fe-N-Cs structures (SEFe_M_P1 and SAFe_M_P1) followed by etching with HF solution to remove silica and produce porous structures (SEFe_M_P1A and SAFe_M_P1A). Lastly, samples were again pyrolyzed under a reducing atmosphere to confirm atomically dispersed active sites in the defect-rich graphitic frameworks (SEFe_M_P1AP2 and SAFe_M_P1AP2). Analyzing the ORR activities under acidic and alkaline conditions, it was witnessed that activity evidently enhanced as the synthesis steps proceeded. High surface area, atomically dispersed active moieties in the defective architecture along with the absence of undesired metallic nanoparticles gave rise to excellent ORR electrocatalysis of the final Fe-N-Cs samples. Therefore, SEFe_M_P1AP2 and SAFe_M_P1AP2 outpaced the other samples in terms of performance by realizing the uppermost onset potentials of 950 mV vs RHE and 965 mV vs RHE, respectively in 1 M KOH while 772 vs RHE and 808 mV vs RHE, respectively in 0.5 M H_2SO_4 while following an obvious 4 electron ORR route. Eventually, the alkaline exchange membrane fuel cells (AEMFC) were configured using them as cathode electrocatalysts and noted open circuit voltage (OCV) of 0.825 V for SAFe_M_P1AP2 and 0.845 for SEFe_M_P1AP2. Whereas the peak power densities came out to be 219 mW cm^{-2} (at 500 mA cm^{-2}) and 103 mW cm^{-2} (at 230 mA cm^{-2}) for the above-mentioned Fe-N-Cs, respectively. These findings emphasize the significant potential of employing an engineering approach to Fe-N-Cs synthesis to bolster progress in green energy production via fuel cells.

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ELE-OR-010

Near-infrared sensors for the determination of the state of charge in all-copper redox flow batteries

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Redox flow batteries (RFBs) are affected by the crossover of the active species, leading to electrolyte unbalancing and self-discharge. For this purpose, is fundamental to monitor the state of charge (SoC) during the RFB operation to recognize the need for rebalancing or restoring the electrolyte and prevent system failure[1]. UV/Vis/NIR spectroscopy is a suitable technique for real-time SoC monitoring. The development of sensors that could be integrated into the electrolyte reservoir, capable of detecting the oxidation state of species in solution is facilitated by the independence of absorption spectroscopy from temperature and electrochemical processes of the system[2,3].

In an all-copper RFB, the electrochemical conversion of Cu(I) to Cu(II) occurs in the positive half-cell and can be efficiently monitored by UV/Vis/NIR spectroscopy. The Cu(II) absorption spectrum is characterized by two prominent bands of different electronic natures. A ligand-to-metal charge transfer transition in the UV part of the spectrum is present, which strongly depends on the copper solvation shell and gives information about the Cu(II) chloro-complexes speciation. Meanwhile, a broad transition present in the NIR region can be assigned to Cu(II). In this transition, the chloride coordination can be ignored, and the magnitude of the absorption mostly depends on the Cu (II) concentration.[4]

According to the Lambert-Beer equation, NIR bands allow studying highly concentrated systems (up to 2M) by tuning b thickness thanks to the low molar extinction coefficient of Cu(II) in this region. In this work, the SoC monitoring system for both negative and positive half-cells with the NIR spectrophotometric monitoring of Cu(II) will be presented and discussed.

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References:

[1] C. Stolze, M. D. Hager, U. S. Schubert, Journal of Power Sources 2019, 423, 60-67
[2] S. Kyung-Hee, J. Chang-Soo, S. Jae-Young, P. Se-Kook, K. Dong-Ha, Y. Sun-Hwa, Journal of Energy Storage 2020, 27, 101066
[3] G. Kwon, S. Lee, J. Hwang, H.-S. Shim, B. Lee, M. H. Lee, Y. Ko, S.-K. Jung, K. Ku, J. Hong, K. Kang, Joule 2018, 2(9), 1771-1782.
[4] G.Lacarbonara, N. Albanelli, D. Fazzi, C. Arbizzani, Electrochemical Acta 2023, 458, 142514.

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ELE-OR-011

EC-STM study of self-assembled Cr-octaethylporphyrin monolayer on Au(111) electrode in acid electrolyte and effect of O_2 coordination.

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Electrochemical Scanning Tunnelling Microscopy (EC-STM) has proven to be a powerful technique to study the electrocatalytic behaviour of molecular model catalysts for the "in situ" monitoring of single-atom sites and of the electrocatalytic process dynamic.[1] In fact, provided that the deposited molecules self-assemble on the ideal crystal substrate at the electrode-electrolyte junction, an EC-STM analysis can bring fundamental information regarding the electrochemical double layer.

Metal-substituted macrocycles have recently attracted a lot of attention due to their numerous applications spanning from electrocatalysis, molecular microelectronics, photoemission, and sensing. It is known that metal-substituted octaethylporphyrins deposited on Au(111) and highly oriented pyrolytic graphite (HOPG) substrates can be studied with EC-STM in aqueous electrolyte to characterize their self-assembling into ordered domains; plus, the interaction between the metal center and molecular oxygen dissolved in solution was proven to cause a change in the STM image profile measurable as a ΔZ in the molecular height, due to the coordination with the metal center of the porphyrin.[2,3] From volcano plot analysis of different transition metal octaethylporphyrins OEPs, chromium-based ones are placed in the strong-binding side of the plot, indicating that oxygen should poison the active site by forming a strong coordination bond with the metal center.[4] Chromium tetrapyridyl-porphyrin was observed on Ag(111) substrate with STM in Ultra High Vacuum conditions.[5] However, to our knowledge no chromium porphyrin was studied with EC-STM at the electrode-electrolyte junction.

Here, CrOEP was successfully synthesized from free-base H_2OEP and deposited on Au(111) and HOPG single crystal substrates to characterize the self-assembled molecular monolayers with EC-STM in 0.1 M $HClO_4$ electrolyte. The electrochemical response of the so formed Au(111)-monolayer interphase was evaluated by combining voltammetric and EC-STM measurements in Ar and O_2 atmosphere.

References:

[1] A. Facchin, C. Durante, Advanced Sustainable Systems 2022, 6, 1-24.
[2] A. Facchin, T. Kosmala, A. Gennaro, C. Durante, ChemElectroChem 2020, 7, 1431–1437.
[3] A. Facchin, M. Zerbetto, A. Gennaro, A. Vittadini, D. Forrer, C. Durante, ChemElectroChem 2021, 8, 2825–2835.
[4]J. H. Zagal, M. T. M. Koper, Angewandte Chemie - International Edition 2016, 55, 14510-14521.
[5] K. Schouteden, T. Ivanova, Z. Li, V. Iancu, E. Janssens, C. Van Haesendonck, Journal of Physical Chemistry Letters 2015, 6, 1048-1052.

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ELE-OR-012

PHOTO-ELECTROCHEMICAL DETECTION OF EMERGING POLLUTANTS WITH TITANIA BASED ELECTRODES

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Titanium dioxide is a widely used semiconductor known for its bio-compatibility and high photoactivity, which can be exploited for the preparation of photo-renewable surfaces.[1] The preparation of hybrid electrodes, combining TiO_2 with catalytic metal structures,[2] can further improve the properties of the devices, widening their range of application in the analytical chemistry field. Different procedures can be exploited for the synthesis of the materials: in this work, metal structures (gold and silver) were prepared both chemically and electrochemically, immobilized on conductive glass slides and then covered with a titanium dioxide layer via dip-coating in a TiO_2 sol.[3]

Electrochemical (EC) and Photo-electrochemical (PEC) characterization of such devices, performed mainly via cyclic voltammetry and electrochemical impedance spectroscopy, helped gain a better understanding of the complex relations between the TiO_2 sol aging time and the morphology of the layer, the interaction between the semiconductor and the metal structures and the stability of the electrodes.

Detection of the analytes (e.g. ciprofloxacin, cetirizine, bisphenol-A) was performed both via pulsed electroanalytical techniques (such as differential pulse voltammetry) and photo-electrochemical techniques, achieving in both cases good detection limits and selectivity. The combination of EC and PEC measurements allowed the realization of bimodal sensors able to achieve self-validation. Furthermore, the stability and photo-renewability of the electrode prove the device could be applied for in-situ monitoring of emerging contaminants in the environment.

References:

[1] G. Soliveri, Analyst, 2015, 140, 5, 1486-1494.
[2] G. Di Liberto, J. Phys. Chem. Lett., 2017, 8, 21, 5372–5377.
[3] D. Fumagalli, ChemElectroChem, 2023, 10, 8.

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ELE-OR-013

Pulsed Current Electroplating: Innovations for Sustainable Industrial Enhancement

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In contemporary galvanic industries, direct current electroplating stands as the prevailing technique. Nevertheless, the emergence of novel methods such as unipolar and bipolar pulse plating, enabled by modern electronics, introduces promising possibilities. Despite challenges in theoretical modelization and technological aspects, pulsed current finds practical application due to its capacity to influence electro-crystallization mechanisms, directly impacting the mechanical and physical properties of deposits[1]. By simply adjusting pulse amplitude and duration, control and enhancement of various deposit properties, including composition, thickness, grain size, porosity, and homogeneity, become achievable.

This work aims to thoroughly investigate the correlation between deposition parameters and deposit properties, integrating theoretical analysis with experimental evaluations. The focus lies on a process aiming to achieve products with comparable, if not superior, characteristics to current standards but with reduced metal thicknesses, crucial for fostering a more sustainable industry. In pulse electroplating, the electrodeposition of nanostructures hinges on two fundamental processes: nucleation rate and the growth of existing grains. Favorable factors induce a high nucleation rate (current density) and inhibit grain growth (through specific molecules)[2].

Notably, pulsed currents have demonstrated the capability to yield shinier and brighter films compared to steady currents, thereby enhancing deposition efficiency. Additionally, pulsed currents show promise in augmenting deposit characteristics. Conversely, bipolar currents exhibit remarkable homogeneity across the deposition area and demonstrate reduced susceptibility to edge effects. This research illuminates the potential of pulsed current deposition techniques in electroplating applications, paving the way for advancements in industrial processes[3]. By comprehending the effects of deposition parameters on deposit properties, we can stimulate innovation and optimization in electroplating practices, ultimately leading to improved product quality and performance across various industrial domains.

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References:

[1] N. V. Mandich, Met. Finish. 1999, 97, 382.
[2] L. P. Bicelli et all, Int J Electrochem Sci. 2008, 3, 356–408.
[3] E. Mariani, W. Giurlani, M. Bonechi, V. Dell'Aquila, M. Innocenti, Scientific Reports 2022, 12, 18175.

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ELE-OR-014

Accelerated Metronidazole Breakdown with Nickel Hexacyanoferrate Nanocubes: A Sun-Powered Solution for Wastewater Treatment

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Environmental pollution poses a multifaceted challenge, endangering the well-being of ecosystems worldwide.[1] The scientific community is paying an increasing effort to address this pressing issue, particularly concerning water pollution for which new engineered materials have been designed, synthesized, and tested to enhance wastewater treatment processes.[2]

In this study, we describe an interesting application of Ni-hexacyanoferrate (Ni-HCF) nanocubes, synthesized through a co-precipitation method, aimed at removing metronidazole (MDZ) as the standard pollutant by means of a photocatalytic process. The photocatalytic activity of Ni-HCF toward MDZ was assessed in aqueous solutions under simulated solar irradiation, leading to a degradation as high as 94.3% of the target pollutant within a 6-hour timeframe.[3] We attribute this remarkable performance of Ni-HCF nanocubes to a higher ability in separating the charge carriers and to a lower resistance toward charge transfer, as confirmed by the electrochemistry.

Further investigation into the catalyst's stability and recyclability revealed exceptional performance, even after undergoing three cycles of reuse. This characteristic is crucial for potential applications in water remediation. Additionally, scavenger tests revealed that the active radicals involved in the photodegradation mechanism might predominantly be OH radicals.[3] These achievements highlight the possibility to combine the performance of an earth-abundant catalysts with a renewable energy source for environmental remediation, thus meeting the requirements for a sustainable development.

References:

[1] H. Ren, C. Li, Z. Han, T. Li, X. Jin, R. Zhou, J. Chem. Technol. Biotechnol. 95 (2020) 3202–3212.
[2] N. Spigariol, L. Liccardo, E. Lushaj, E. Rodríguez-Castellón, I. Barroso Martin, F. Polo, A. Vomiero, E. Cattaruzza, E. Moretti, Catal. Today, 419 (2023) 114134.
[3] E. Lushaj, M. Bordin, K. Akbar, L. Liccardo, I. Barroso Martin, E. Rodríguez-Castellón, A. Vomiero, E. Moretti, F. Polo. Small Methods (2024) 2301541.

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ELE-OR-015

Electrochemical reduction applied to wastewater treatment of halogenated compounds

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In order to address environmental concern and contamination issues, numerous strategies have been developed to remove water pollutants, although it is still necessary to enhance their effectiveness against toxic and biorefractory organic molecules. Electrochemical reduction offers considerable advantages over conventional degradation methods. When applied to the wastewater treatment of harmful halogenated compounds, it can offer a double benefit, allowing the elimination of the pollutant and the recovery of the valuable halogen species. In this scenario, the electrochemical reductive dehalogenation of 3,5-dihalogenated derivatives of salicylic acid, chosen as model molecule, is examined in this study as a green technique that, through the cleavage of C-X bonds, makes the transformation products more biodegradable and less bioaccumulative.[1,2] Cyclic voltammetry (CV) was used to study the electrochemical behaviour of the halogenated compounds in aqueous system, comparing different cathode materials.

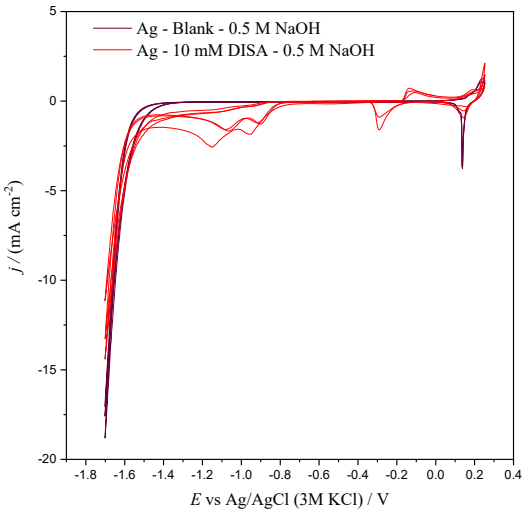

Figure 1: CV of 10 mM 3,5-diiodosalicylic acid (DISA) on Ag electrode in 0.5 M NaOH aqueous solution.

After identifying silver as the most promising cathode,[3] electrolysis was performed, both in batch and flow conditions. The results showed that reductive electrochemical dehalogenation is an efficient process, providing more insights into the mechanism of halogenated compounds degradation in reductive processes.

References:

[1] L. Sorti, F.Vitulano, C. Carbone, F. Uggeri, A. Minguzzi , A. Vertova, Curr. Opin. Electrochem. 2023, 37, 101169
[2] R. Xu, Y. Xie, J. Tian, L. Chen, J. Clean. Prod. 2021, 283, 124645
[3] S. Rondinini, P.R. Mussini, P. Muttini, G. Sello, Electrochim. Acta 2001, 46, 3245 – 3258

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ELE-OR-016

The Interplay between Zn(II) Porphyrins and SnO_2 in Boosting the Sensing of Gaseous Acetone

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Plethora of gas sensing systems for environmental monitoring, food spoilage and non-invasive medical diagnostics have been developed so far[1,2]. Recently, carbonaceous-based sensors have attracted huge attention thanks to their unique properties giving rise to various nanocomposite materials. However, they still suffer from several problems concerning for instance the low sensitivity, which could be overcome by their coupling with metal oxides (MOS), and the scarce selectivity, especially in relatively high humidity environments as the human breath[1,2]. Besides, porphyrin-based macrocycles can play a dual role in gas sensing thanks to both their high chemical versatility and good electrical conductivity, especially when combined to MOS[3].

The present work is aimed at evaluating and comparing the sensing at mild temperatures (120 °C) of SnO_2 coupled with different porphyrins toward the sensing of acetone molecules, *i.e.* the breath biomarker of diabetes type 1. Specifically, zinc tetraphenylporphyrin (ZnTPP) and its perfluorinated derivatives were chosen[3]. Interestingly, the ZnTPP does not seem to give any significant response upon exposure to the analyte, whereas perfluorinated derivatives showed a boosted signal with respect to pristine SnO_2. In addition, the effect SnO_2/porphyrins weight ratio was explored (4:1, 32:1, 64:1). In all cases, 32:1 gave optimal performances also resulting in a detection limit of 200 ppb. Hence, aiming at unveiling the sensing mechanism, DFT calculations were performed. From preliminary results, we may infer that the sensing behavior of theses nanocomposites is mainly based on a balance between the number of accessible MOS states in the conduction band and the electron transfer from the porphyrin's HOMO to the CB of SnO_2. When SnO_2 is coupled to a system that has a high tendency to donate electrons (ZnTPP) a saturation of the accessible states occurs, so there is no room for electrons coming from the interaction with acetone molecules, resulting in the signal quenching. Conversely, when SnO_2 is coupled to perfluorinated porphyrins, that are less prone to donate electrons due to the fluorine presence, a lower number of carriers is injected, and acetone is more liable to interact with the MOS surface. Therefore, we believe that these findings can provide useful guidelines to achieve a boosted light-free gaseous sensing.

References:

[1] A. Tricoli, N. Nasiri, S. De, Adv. Funct. Mater. 2017, 27, 1605271.
[2] E. Pargoletti, U. H. Hossain, I. Di Bernardo, et al., ACS App. Mat. Interf. 2020, 12, 39549–39560.
[3] E. Pargoletti, F. Tessore, G. Di Carlo, et al., Chem. Proc. 2021, 5, 60 – 64.

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ELE-OR-018

Design rule hidden from the eye in S/N-bridged ancillary ligands for copper(I) complexes applied to light-emitting electrochemical cells

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Light-emitting electrochemical cells (LECs) are of high interest for soft-lighting applications and disposable (opto)electronics. Here, the transition towards sustainable and/or "green" LECs is becoming urgent.[1] In this context, recently, fully Cu(I)-based white LECs have been achieved *via* host:guest approach, reaching on par performances of the Ir(III) based counterpart.[2,3] However, the poor performance of the low-energy guests is still a current bottleneck.[4] In this context, this work explored conventional strategies (*i.e.,* π-extension and change of heteroatom-bridge in N^N ligand) that resulted in a series of complexes, in which the PLQY enhances from <1% to 21% in thin-films. Conversely, the success in enhancing the photophysical features is not reflected in efficient LECs that feature a very poor performance with the brightest candidate. Thus, the conventional chemical design rules fail to provide good performing devices.

To fill the gap of knowledge between an optimal photoluminescence-driven ligand design and poor device performance, this work capitalizes the use of a multivariate analysis using a dataset based on all the prior-art $[Cu(N^N)(P^P)]^+$-based thin-film lighting (>90 papers). Success and versatility of our multivariate model were confirmed with close prediction/experiment match across the series of novel complexes. What is more, comparison with the reference complexes allow us to unveil a new design rule: the need to consider the ligand polarization features (*i.e.,* clogP and tPSA) that rule the dielectric constant and ion conductivities in thin-films as confirmed by electrochemical impedance spectroscopy. In detail, the model suggests that high clogP are beneficial for both, PLQY and device efficiency, while the device efficiency is mainly enhanced with ligands featuring low tPSA value. This nicely match the experimental device data and the complex design, rationalizing that only the π-extension strategy can lead to devices with one order enhanced performances (*i.e.,* 0.35 cd/A@117 cd/m^2) despite the PLQY of the thin-films was less promising (*ca.* 10 %).[5]

All-in-all, this work provides fresh insights for the design of Cu-iTMCs fueling research on sustainable ion-based lighting sources.

References:

[1] E. Fresta, R. D. Costa, Journal of Materials Chemistry C 2017, 5, 5643–5675.
[2] L. M. Cavinato, R. D. Costa, *et al.,* Advanced Materials 2022, 34, 2109228.
[3] C. E. Housecroft, E. C. Constable, Journal of Materials Chemistry C 2022, 10, 4456–4482.
[4] L. M. Cavinato, R. D. Costa, *et al.,* Advanced Optical Materials 2022, 10, 2101999.
[5] L. M. Cavinato, R. D. Costa, *et al.,* Advanced Functional Materials 2023, 2304668.

ELE-OR-018

Hybrid fluorescent protein-polymer derivatives for stable deep-red lighting devices

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Recent progress in the field of bio-hybrid light-emitting diodes (Bio-HLEDs) have shown mCherry fluorescent protein as the main candidate for highly stable deep-red devices. We recently revealed that the deactivation mechanism of mCherry embedded in polymer matrices is highly dependent on oxygen permeability and residual water content upon preparation.[1] Here, we report a mCherry functionalization with hydrophilic polymer chains as a strategy to reduce the chromophore deactivation pathways by *i*) acting as a protective shell and *ii*) potentially reducing the H-transfer driven chromophore protonation resulting in emission quenching. First, we ruled out the effect of the chain length on the stability of the FP inside reference coatings upon mild continuous irradiation conditions (55 mW cm^{-2}). Secondly, we refined the overall device performance through the stabilization of the best performing hybrid mCherry-polymer adduct in previously reported PVA-based matrix, preparing first class deep-red Bio-HLEDs (*x/y* CIE color coordinates of 0.6/0.3) stable >200 h upon harsh driving conditions (600 mA, 150 mW cm^{-2}). This overcomes the prior art for mCherry-based Bio-HLEDs (50/~15 h at 55/150 mW cm^{-2}).[1, 2] Thus, this work not only *i)* identifies a novel strategy to protect low-energy emitting proteins from the detrimental effect of the environment in solid state upon irradiation stress, but also *ii)* settles record performances in the field of deep-red Bio-HLEDs.

References:

[1] Ferrara, S., Mejias, S. H., Liutkus, M., Renno, G., Stella, F., Kociolek, I., Fuenzalida-Werner, J. P., Barolo, C., Coto, P. B., Cortajarena, A. L., Costa, R. D., Adv. Funct. Mater. **2020**, 32, 111381.

[2] Hasler, M., Patrian, M., Banda-Vázquez, J. A., Ferrara, S., Stiel, A. C., Fuenzalida-Werner, J., Costa, R. D., *Adv. Funct. Mater.* **2023**, 2301820.

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ELE-PO-001

Exploring the flatland of bi-dimensional materials for energy and (opto)electronics

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Layered materials have many potentials for use in applications requiring (semi)conducting behavior, coupled to anisotropy or preferential orientations. In our group, we try to incorporate them into energy devices of different types, ranging from solar and photoelectrochemical cells up to energy-storage and piezoresistive systems.

In general, we choose to resort to highly scalable methods for their production and their processing, mostly solution-based, through the preparation of inks that can undergo further chemical processes or be deposited *via* spin/spray/dip-coating.

In this talk, we will give a collective view of some of the recent projects we are carrying on: we will discuss some uses of 2D transition metal dichalcogenides in electrochemical capacitors and we will show some recent results in the production and testing of layered heterojunctions based on two different semiconductors for use in photoelectrochemical hydrogen evolution.

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ELE-PO-002

Smart Design, Cleaner Future: Optimization of the *MicroFlowCell* in Cathodic Reactions

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The water splitting reaction and the carbon dioxide conversion into energy dense molecules could cooperate to meet the supply of industrial energy demand using clean and renewable strategies. The electrochemical reduction of the molecules such as CO_2 and H_2O into building blocks or fuels, such as H_2, CO and HCOOH, is a possible solution to meet future energy needs and decrease the carbon footprint. To do that, the most important aspects are the design of the device and the smart synthesis of the catalyst.[1,2,3]

The most important factor for the successful implementation of the reaction lies in the meticulous design and optimal functionality of the reaction device.[3]

In this study, we focus on the development and optimization of a novel flow device known as *MicroFlowCell*. The MicroFlowCell is designed for precise control and manipulation of fluid dynamics, presenting promising applications in industrial fields. The device is coupled with a Gas Diffusion Electrode system, which allows to have higher currents and to maximize the substrate-electrode interactions. The investigation includes a thorough examination the key parameters such as the effects of liquid and gas flow rates, solution pH, electrolyte concentration and gas diffusion layer design on the MicroFlowCell's functionality.[4] Experimental methodologies are employed to systematically explore the interplay between these parameters and the device efficiency.

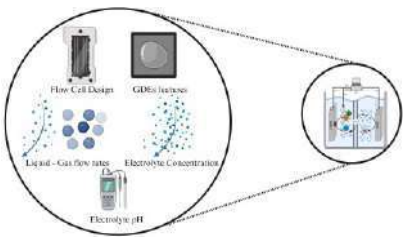

Figure 1: Key parameters associated with MicroFlowCell functioning: FlowCell design, Gas Diffusion Electrodes features, fluids flow rates, solution pH and electrolyte concentration.

The significance of this study lies in the potential advancements in using the reactor to test new electrocatalyst designs within a well-functioning system.

References:

[1] G. Valenti, M. Prato, ACS Appl. Energy Mater. 2020, 3, 9, 8509–8518.
[2] M. Melchionna, P. Fornasiero, ACS Appl. Energy Mater. 2022, 5, 11, 13356–13366.
[3] G. Marcandalli, M. Koper, Acc. Chem. Res. 2022, 55, 14, 1900–1911.
[4] K. Liu, T. Burdyny, ACS Energy Lett. 2019, 4, 3, 639–643.

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ELE-PO-003

Metal Organic Frameworks (MOFs) as catalysts for CO_2 conversion

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The overreliance of fossil fuels has determined a rapid rise in atmospheric CO_2 concentrations and disrupted the natural balance of the carbon cycle. The protection of the ecological environment by developing advanced technologies and methods to close the carbon loop is a key to this solution. Among them, the electrochemical conversion of carbon dioxide to value-added products could be an interesting way for the carbon capture. Aside from the advantage of working at room temperature and ambient pressure, the carbon dioxide reduction reaction presents problems related due to the thermodynamic stability of the CO_2 molecule. Significant efforts are due to the limited solubility of CO_2 in water under the working conditions. Furthermore, the CO_2 reduction reaction (CO_2RR) mechanism involves (multi) proton coupled electron transfer (PCET) pathway generating many different reaction intermediates resulting in a large variety of products which means to poor selectivity (Figure 1) [1].

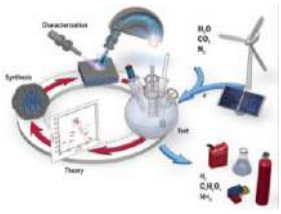

Figure 1: Electrochemical conversion coupled with renewable energy sources [2].

Metal Organic Frameworks (MOFs) used as catalysts show promising results due to their structure and organization in the space. They are composed by metal ions coordinated by organic ligands forming a highly porous and crystalline coordination polymers with facilitated exposure to active sites and structural order [1]. Herein, a copper-based coordination polymer (Cu^{2+}-CP) using (E)-4-aminocinnamic acid (4-ACH) as organic ligand was synthetised and deposited onto the Gas Diffusion Layer (GDL) used as working electrode of a MicroFlowCell with a three electrodes configuration. This design could be a strategic way to achieve high current densities and overcome both mass transport limitation and CO_2 solubility.

References:

[1] Chuan Xia, Qui Jiang, Nano-Micro Lett. (2023) 15, 113.

[2] Z. W. She, F. Jaramillo, Science, (2017), 355, 146.

ELE-PO-004

Electrocatalytic materials and devices for the water splitting

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Electrolytic water splitting is one of the most promising ways to harness intermittent renewable power sources, store the provided energy as a clean-burning and sustainable fuel and mitigate greenhouse gas emissions. However, in the water splitting reaction, the hydrogen evolution reaction (HER) rate is often limited by that of the oxygen evolution (OER) due to the more sluggish kinetics and the large overpotential of the latter, which lowers the overall energy conversion efficiency. In this context, nanostructured catalysts have emerged as a promising avenue to address these limitations.

This research project, in collaboration with Dr. Ferdinand Hof from the Material Science Laboratories in Bordeaux, is focused on the study and characterization of nanostructured electrocatalysts for the OER, based on non-precious metals such as Ni, Co or Cu, at different pH values, aiming to elucidate the pH-dependent catalytic behaviour [1,2]. Electrochemical techniques such as CV, LSV and EIS have been used for catalyst activation, oxygen production and ohmic drop corrections.

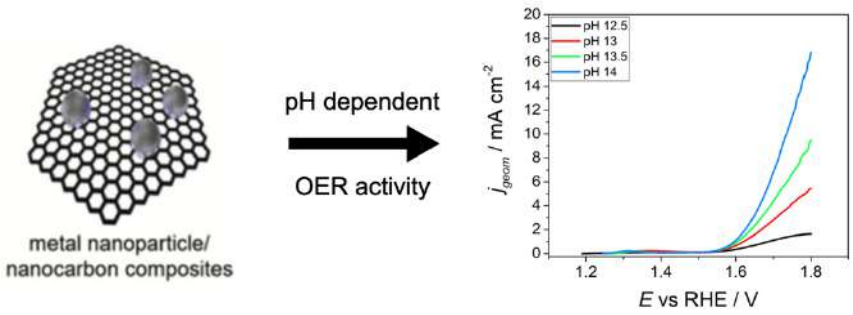

Figure 1: *Representation of nanostructured catalysts and the observed pH-dependent OER activity.*

Overall, this research has the potential to enhance the understanding of the underlying pH dependent OER mechanism, paving the way for the design of more efficient and sustainable electrochemical devices for hydrogen production.

References:

[1] Liu, M.; Hof, F.; Moro, M.; Valenti, G.; Paolucci, F.; Pénicaud, A. Carbon Supported Noble Metal Nanoparticles as Efficient Catalysts for Electrochemical Water Splitting. Nanoscale, 2020, 12, 20165– 20170
[2] Giordano, L.; Han, B.; Risch, M.; Hong, W. T.; Rao, R. R.; Stoerzinger, K. A.; Shao-Horn, Y. pH Dependence of OER Activity of Oxides: Current and Future Perspectives. Catalysis Today, 2016, 262, 2–10.

ELE-PO-005

Sustainable and non-toxic hydrogel-based Dye-Sensitized Solar Cell: Performance evaluation under indoor illumination

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Indoor photovoltaics have gathered growing interest amongst researchers, as a mean to exploit the indoor lighting we use in our daily life to power small devices. Dye-sensitized solar cells (DSSCs) represent good candidates for such applications[1]. However, when it comes to indoor applications, there is an increased demand for non-toxic and non-flammable solvents for electrolytes. The implementation of water-based electrolytes is a promising way to address these issues, whilst also ensuring the eco-friendliness and sustainability of these devices[2]. In this work, aqueous gel electrolytes incorporating a iodide/triiodide redox couple were made with a bio-sourced polymer, xanthan gum[3]. DSSCs were assembled using screen-printed TiO_2 semiconducting layers treated with $TiCl_4$ and sensitized with an organic dye, D149. As counter electrode, Pt sputtered FTO was used. The performance of the cells was investigated under indoor light intensities between 500 and 2000 lux.

References:

[1]: Jilakian, M., & Ghaddar, T. H. (2022). Eco-Friendly Aqueous Dye-Sensitized Solar Cell with a Copper (I/II) Electrolyte System: Efficient Performance under Ambient Light Conditions. ACS Applied Energy Materials, 5(1), 257-265.
[2]: Bella, F., Gerbaldi, C., Barolo, C., & Grätzel, M. (2015). Aqueous dye-sensitized solar cells. Chemical Society Reviews, 44(11), 3431-3473.
[3]: Galliano, S., Bella, F., Bonomo, M., Viscardi, G., Gerbaldi, C., Boschloo, G., & Barolo, C. (2020). Hydrogel electrolytes based on xanthan gum: green route towards stable dye-sensitized solar cells. Nanomaterials, 10(8), 1585.

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ELE-PO-006

In-Situ Surface Activation of Polycrystalline $LaNiO_3$ Electrocatalyst for the OER

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Hydrogen, a key energy carrier for a sustainable future, faces challenges in efficient production via water electrolysis due to the sluggish kinetics of the Oxygen Evolution Reaction (OER). To overcome this, catalytic materials are essential to reduce the high overpotential. Operating in alkaline conditions, non-noble metal electrocatalysts such as nickel oxide, have shown promise for the hydrogen production at lower cost.[1]

In this work, we investigate $LaNiO_3$ for the OER in alkaline water, selected for its cost effectiveness and scalability.[2] $LaNiO_3$, synthetized by the co-precipitation method, shows good OER activity and electrochemical stability. The powder was characterized from a structural, morphological, and electrochemical point of view and also *operando* X-Ray Absorption Spectroscopy (XAS) for a better understanding of the reaction mechanisms.[3] Moreover, to enhance our understanding of the surface behavior of the perovskite during the OER, High Resolution Electron Transmission Microscopy (HR-TEM) was used. The investigation was done on the *as prepared* perovskite (**Figure 1A**), on the same material after having worked under OER conditions (**Figure 1B**) and on the material kept in KOH 1 M overnight (**Figure 1C**). These three-step allow us to confirm that the there is an increasing disorder on $LaNiO_3$ surface, and that it is caused by the electrochemical treatment. In summary, combining XAS, HR-TEM and electrochemical evidence, the study unveils a disordered layer on the $LaNiO_3$ electrocatalyst surface. Under cathodic conditions, a Ni(II) layer forms and oxidizes under anodic potentials, creating Ni(III) sites potentially serving as active sites for the OER. The disorder enhances active sites for improved OER performance.

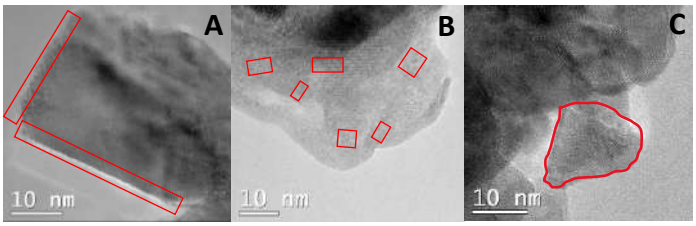

Figure 1: **A)** HR-TEM images of $LaNiO_3$ *as prepared* **B)** after worked under OER **C)** after treatment in KOH 1M

References

[1] Colli et al. *Materials* **2019**, 12, 8
[2] Suen et al. *Chem. Soc. Rev.* **2017**, 21, 365
[3] Dos Santos et al. *ChemElectroChem* **2019**, 6, 22

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ELE-PO-007

Effect of Innovative Carbon Additives in Positive Active Mass of AGM Lead Acid Battery on Dynamic Charge Acceptance

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Battery-based energy storage systems with high power / energy densities and excellent cycle efficiency are expected to play a key role in our everyday life. Even though Lead-Acid Batteries (LABs) are the oldest electrochemical energy storage technology, they still attract a lot of interest thanks to their properties: stability, reliability, recyclability and low cost of raw materials. Precisely for these reasons, LAB technology will retain its strong position at least until 2030 and it remains very competitive, but ongoing investments are needed in order to improve production and performances.

A well-known problem of LABs is the limited charge efficiency and cyclability, due to an important degradation of electrodes during the discharging-charging process. It was observed that small addition (0.5 – 2 $\%_{wtPbO}$) of carbons in the Positive Active Mass (PAM) of LABs improves the battery performances and specifically the weight, mechanical strength, and conductivity, which is beneficial for uniform current distribution during the charge-discharge process.[1] A series of carbon-based materials were selected and they were screened on the bases of physicochemical and electrochemical properties such as surface area, porosity, graphitization degree, conductivity, contact angle (wettability), and the overpotential versus the hydrogen evolution reaction.[2] The best candidates were mixed and tested at different loadings in the positive active mass to prepare positive plates from scratch.

A 1+/2- test cell was developed for the electrical, electrochemical, and chemical characterization of the novel electrodes in AGM configuration. The prepared cells were tested under standard charge-discharge protocol and then tested with a homemade procedure for waterloss using coupled electrochemical polarization and gas analysis, adapted for the AGM configuration, in accumulation mode instead of flux mode.[3] The incorporation of carbonaceous materials is evaluated as impact in the charge/discharge performances, in oxygen recombination and plate corrosion of LAB cell under test, when compared to commercial plates. The effect of increased carbon loading was also considered.

References:

[1] S. Mandal et al, J. Power Sources 2021, 485, 229336.
[2] B. Marinho et al, Powder Technol. 2021, 221, 35.
[3] M. Parnigotto et al, ChemElectroChem. 2022, 9, 20220088.

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ELE-PO-008

Crosslinked ionogels containing active fillers for lithium-metal batteries

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Lithium-ion batteries (LIBs), despite being a rather recent invention, gained a dominant role in the field of energy storage due to their high energy density, long cycle life and low self-discharge. LIBs experienced a dramatic improvement since the first studies in this field in the past century. However, the current technology still requires further improvement to meet the market needs. Concerning next-generation anodes, lithium metal is the most promising candidate, owing a specific capacity (3860 mAh g^{-1}), which is about ten times higher than the presently used graphite (372 mAh g^{-1}), and a very low redox potential (-3.04 V *vs.* SHE). Nonetheless, lithium metal electrodes are suffering a high reactivity with commonly used electrolytes and dendritic lithium deposition, causing severe safety issues[1]. Polymer electrolytes can be a suitable replacement for liquid electrolytes due to their ability to limit dendrite growth and the improved stability against lithium metal anode[2]. An increased electrochemical performance, high thermal stability and extended electrochemical stability window have been observed when introducing ionic liquids (ILs), i.e., room temperature organic molten salt, into the polymer matrix. These ionogels (IGs) are a promising class of polymer-based electrolytes for next-generation lithium-metal batteries. Unfortunately, fast Li^+ kinetics are still a challenge due to the high viscosity and low transference number of ILs[3]. A possible solution is given by a hybrid approach as the insertion of active and passive filler can further boost the electrochemical performances of IGs.

Herein, we present composite IGs prepared via a one-pot preparation protocol by mixing the polymer precursors butyl methacrylate (BMA) and poly(ethylene glycol) diacrylate (PEGDA) with the IL PYR14FSI and, in addition, LLZTO nanoparticles. The inorganic filler is fully integrated in the polymer matrix by using an organosilane functionalization which allows for the formation of covalent bonds during the polymerization step. Three functionalized LLZTO nanoparticles were investigated, differing by the silane content, resulting in a maximum ionic conductivity of $6 \cdot 10^{-4}\ S\ cm^{-1}$ at 20 °C and an anodic electrochemical stability up to 5.3 V (*vs.* Li^+/Li). Li|IG|LFP cells delivered a stable cycling with a specific capacity of 120 mAh g^{-1} at room temperature for hundreds of cycles owing to a high compatibility of the IG composite with lithium-metal anode.

References:

[1] S. Kim, G. Park, S.J. Lee, S. Seo, K. Ryu, C.H. Kim, J.W. Choi, Adv. Mater. 2023, 35, 2206625.
[2] Z. Song, F. Chen, M. Martinez-Ibañez, W. Feng, M. Forsyth, Z. Zhou, M. Armand, H. Zhang, Nat. Commun. 2023, 14, 4884.
[3] G. Antonio Elia, U. Ulissi, S. Jeong, S. Passerini, J. Hassoun, Energy Environ. Sci. 2016, 9, 3210–3220.

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ELE-PO-009

Palladium electrodeposition: a systematic study of α-PdHx and β-PdHx formation conditions

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The electrodeposition of palladium for decorative applications has become widespread in the last decades as a substitution for nickel and it is now used both as a final coating and as an intermediate layer to improve corrosion resistance, increase the adhesion of subsequent precious deposits, and act as a diffusion barrier layer. However, palladium and palladium alloy deposits easily undergo micro-cracking due to the evolution of large quantities of hydrogen during the metal reduction and its consequent co-deposition. Indeed, palladium is able to dissolve hydrogen forming two bulk hydride phases known as α-PdHx (x ~0.02) and β-PdHx (~0.67). Microfractures result from hydrogen desorption associated with the lattice contraction that occurs in the transition from the β-PdHx to the thermodynamically stable α-PdHx phase. On the other hand, high-hydrogen palladium hydrides are of great interest for different industrial sectors, especially in the energy field for hydrogen storage[1]. Identifying the working conditions necessary to ensure the selective formation of the two phases would therefore be of crucial importance for both the electroplating industry and the energy field. We focused on the two parameters that we think have the greatest influence in incorporating and retaining hydrogen during electrodeposition, testing five different current densities (from 0.25 to 4 A/dm^2) and three thicknesses (0.25, 0.5 and 1 μm). The experiments were carried out in a pure Pd galvanic bath (Fe < 1%) at a temperature of 50 °C and pH ranging 7 and 7.3. Brass plates were used as substrates, and subsequent analyses of the samples were performed using the X-ray diffractometry (XRD) technique that allows the two phases to be easily identified thanks to the diagnostic peaks associated with α-PdHx and β-PdHx at 40.1° and 38.34°, respectively[2]. Measurements were performed using a powder diffractometer equipped with a Euler cell and scanning from 35° to 45°. To roughly estimate the kinetics of the desorption process, the XRD analysis were performed 10 minutes, 1.5, 3, and 24 hours after the end of the deposition process. Finally, we identified a heat treatment that can be used by the electroplating industry to facilitate the desorption of hydrogen and quickly obtain the α-phase. The authors acknowledge MUR and EU-FSE for financial support of the PhD fellowship PON Research and Innovation 2014-2020 (D.M. 1061/2021) XXXVII Cycle in Chemical Sciences.

References:

[1] K.S. Nivedhitha, T. Beena, N.R. Banapurmath, M.A. Umarfarooq, V. Ramasamy, M.E.M. Soudagar, U. Agbulut, 2024, 61, 1259 – 1273.
[2] J. D. Benck, A. Jackson, D. Young, D. Rettenwander, Y.-M. Chiang, 2019, 31, 4234 – 4235.

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ELE-PO-010

Electrochemical synthesis of "MIB"-inspired gadolinium-based contrast agents

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Gadolinium-based contrast agents (GBCAs), which are gadolinium complexes, are used worldwide in magnetic resonance imaging (MRI) to enhance the contrast of images and have a clearer visualization of the disease [1]. In the present research, the advantages of electrochemistry are exploited for the synthesis of a new possible GBCA. The project was inspired by the research on metal-ion batteries (MIBs), for which Prussian blue analogues (PBAs) are among the most promising cathodes, thanks to their simple synthesis, non-toxicity, stability, and their high capacity for the electrochemical-driven insertion of several metal ions [2]. For their biocompatibility, they have been considered also in the medical field [3]. The aim of this study is to electrochemically intercalate Gd^{3+} ions into nanometric spherical Zinc-hexacyanoferrate (s-ZnHCF), which was synthesized with a high-temperature coprecipitation method found in literature [4]. After its characterization by XRD and TEM (Fig. 1), it was deposited on FTO (Fluorine-doped Tin Oxide) and used as working electrode in cyclovoltammetries. Successive chronoamperometries in a solution of gadolinium ions allowed to create gadolinium-rich particles.

Since electrochemistry allows a fine control of experimental parameters, with further studies the amount of intercalating gadolinium could be controlled, and so its ability to enhance the MRI signal. Furthermore, the presence of Gd^{3+} in the superficial layer of nanoparticles would improve its interaction with H_2O, which is essential for the functioning mechanism of contrast media.

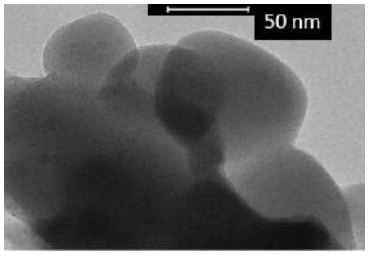

Figure 1: TEM image of synthetized s-ZnHCF

References

[1] Li et al. *J. Am. Chem. Soc.* 2019, 141, 17025
[2] Zampardi et al. *Curr. Op. Electrochem.* 2020, 21, 84
[3] Qin et al. *Adv. Healthc. Mater.* 2018, 7, 1800304
[4] Zhang et al. *Nano Lett.* 2019, 19, 4035

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ELE-PO-011

Solvent-free extrusion process of PEO-polycarbonate blends as electrolytes for Li-ion batteries

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Solid polymer electrolytes (SPEs), composed of a lithium salt dissolved in a polar polymer matrix, are promising candidates for replacing liquid electrolytes in lithium-ion batteries (LIBs)[1]. SPE suffer from low ion mobility at room temperature, which restricts their practical use. Polyethylene oxide (PEO) can reach, in formulation with lithium salts, high conductivity values at elevated temperatures, and its low glass transition temperature (T_g) makes it a good candidate for SPE. PEO presents some drawbacks, like the strong dipolar interaction and complexation of Li^+ that prevent the migration of lithium ions and segmental mobility in crystalline phase[2-4]. Polycarbonates (PC) show moderate interaction between carbonate groups and Li^+ that ensure ions and segmental mobility and wide electrochemical stability window, but they have high T_g values, which makes these materials semicrystalline and restricts ion transport[5]. We selected three PCs, characterized by an increasing chain length, to blend with PEO in different proportions. Through a design of experiment (DoE), we compared the chemical, mechanical and electrochemical properties of polymer electrolytes composed of PEO blended with PCs at fixed LiTFSI salt concentration. The study helps identifying the best PC and the ideal ratio at which the ionic conductivity, the electrochemical stability window and the elastic modulus are optimal. All formulations were prepared by exploiting a mini-extrusor, which enabled us to avoid the use of organic solvents, minimizing polymer degradation phenomena by using an inert atmosphere. Finally, UV-cured PEO and PCs matrixes are investigated to enhance the mechanical and electronic properties of the final electrolytes.

Acknowledgements

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References

[1] Kim, T et al. J. Mater. Chem. A 17 (2019) 2942-2964
[2] Kimura, K et al. Electrochem. Commun. 66 (2016) 46–48
[3] Mindemark, J. et al. Prog. Polym. Sci. 81 (2018) 114–143
[4] He, W. et al. Electrochimica Acta 225 (2017) 151–159
[5] Morioka, T et al. Polymer 84 (2016) 21–26

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ELE-PO-012

Exploiting novel silica etching methods to produce state of the art single atom electrocatalyst for oxygen reduction reaction

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Fuel cells are devices that convert chemical energy into electric energy with higher efficiency compared to thermal engine. Thus, fuel cells are generating attention for their use in transportation and power generation. Among the other, the proton exchange membrane (PEM) fuel cell (FC) results to be the ideal candidate for the commercial application because they can operate at low temperatures (50-100°C) and low pressure (0.3 MPa), and moreover are generally lightweight and small-sized.[1] Unfortunately, PEMFC rely heavily on the utilization of platinum on both anode and cathode. The oxygen reduction reaction (ORR) occurring on the cathode of the fuel cell is the bottleneck of the device therefore greatest effort is devoted to this reaction. Very recently, with the development of anion exchange membrane (AEM), AEM fuel cells have grown exponentially. AEMFC can substitute efficiently Pt supported over carbon on the cathode side with platinum group metal-free (PGM-free) electrocatalysts. These electrocatalysts are also called single atom electrocatalysts and have a structure of a first raw transition metal (TM) coordinated with nitrogen and integrated in a carbon backbone.

State of the art and commercially available ECs use Fe-based electrocatalysts of the type Fe-N_x-C. These electrocatalysts are produced using sacrificial support method (SSM) by the mixing an organic matrix containing nitrogen atoms, silica as a hard templating agent and a Fe salt. This mixture is then subject to pyrolysis with controlled temperature and atmosphere. Silica is then removed through the use of HF.[2] The templating removal etched out not only the silica but remove also undesired oxides and nanoparticles, producing an highly porous carbon containing the active side desired. Due to its lipophilicity, use of HF represents a serious hazard for health and thus safer etching procedure are needed. In this work, an Fe-N_x-C electrocatalysts have been developed exploiting in situ production of HF for the silica etching step, avoiding the direct use of HF. Two salts (NaF and NH_4HF_2) have been used as HF precursor and the safer etching method was optimized. The samples were characterized in terms of composition, morphology and electrocatalytic activity and compared with the HF etched EC.

Interestingly, in alkaline environment (0.1 M KOH), the best performing electrocatalyst was the one etched with NH_4HF_2 possessing an onset potential (E_{on}) of 0.97 V vs RHE and a half-wave potential ($E_{1/2}$) of 0.88 V vs RHE. The electrocatalyst etched with HF had a E_{on} of 0.95V vs RHE and a $E_{1/2}$ of 0.87 V vs RHE.

References:

[1] M. Shao, Q. Chang, J.P. Dodelet, R. Chenitz, *Chem. Rev.* **2016**, *116* (6), 3594–3657.
[2] K. Artyushkova, S. Rojas-Carbonell, C. Santoro, E. Weiler, A. Serov, R.R. Gokhale, P. Atanassov, *ACS Appl. Energy Mater.* **2019**, 2, 5406-5418.

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ELE-PO-013

Critical Aspects in Lithium-Mediated Nitrogen Reduction Reaction for Electroproduced Ammonia

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Ammonia is a fundamental building-block for fertilizers as well as for many other commodities, and its production *via* the Haber-Bosch (HB) process is responsible of around 1.4% of the global greenhouse gas emissions due to the severe conditions (200 atm) of these few huge, centralized plants. Finding a renewable-driven and delocalized electrochemical process for NH_3 production, complementary to HB, could be a key solution for our society that is facing climate change crisis and that is demographically growing[1].

In view of process electrification, the Li-mediated pathway represents the most promising solution in the N_2 reduction reaction challenging field. Exploiting the unique reducing power of this alkali metal, this strategy achieves the highest Faradic efficiency (FE) and NH_3 production rate[2]. Different strategies, both continuous and step-by-step systems, are under evaluation in current literature.

In the first, Li^+ ions from the aprotic electrolyte are electrodeposited on the cathode, where N_2 is reduced and protonated into NH_3 directly in the same environment. On the plated Li, a solid electrolyte interphase (SEI) unavoidably forms due to electrolyte degradation on the interface, and the different diffusion rate of Li^+, N_2, and H^+ trough the SEI layer determines the selectivity towards NH_3 formation[3]. In the latter, the formation of Li_3N is the key intermediate step. The exploitation of a Li-N_2 galvanic cell, inspired by lithium-air batteries, could maximize Li_3N formation[4]. Even in this case, nevertheless, practical aspects are delaying the rising of this innovative research filed, and a critical eye on interferents and impurities should be adopted for a correct NH_3 quantification. Our laboratory is currently addressing these challenges within the SuN_2rise project, and an overview of electrochemical and engineering-related crucial aspects will be presented in this contribution.

References:

[1] G. Soloveichik, Nature Catalysis 2019, 2, 377–380.
[2] X. Fu, J. B. Pedersen, Y. Zhou, M. Saccoccio, S. Li, R. Sažinas, K. Li, S. Z. Andersen, A. Xu, N. H. Deissler, J. B. V. Mygind, C. Wei, J. Kibsgaard, P. C. K. Vesborg, J. K. Nørskov, I. Chorkendorff, Science 2023, 379, 707–712.
[3] K. Li, S. G. Shapel, D. Hochfilzer, J. B. Pedersen, K. Krempl, S. Z. Andersen, R. Sažinas, M. Saccoccio, S. Li, D. Chakraborty, J. Kibsgaard, P. C. K. Vesborg, J. K. Nørskov, I. Chorkendorff, ACS Energy Letters 2021, 7, 36–41.
[6] Z. Zhang, S. S. Wu, C. Yang, L. Y. Zheng, D. L. Xu, R. H. Zha, L. Tang, K. Z. Cao, X.-G. Wang, Z. Zhou, Angewandte Chemie International Edition 2019, 58, 17782–17787.

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ELE-PO-014

Electrochemical CO_2 reduction inspired by the theory of emergence of life

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Since the discovery of the first Oceanic Hydrothermal Vent field in the 1970s, these geological formations have been proposed as possible cradles for the emergence of life on our planet. In the Archean era, Alkaline Hydrothermal Vents were generated by the reaction between alkali, metal, and hydrogen-rich fluid, originating from the oceanic crust, with a slightly acidic and CO_2-rich ocean. Within this environment, a mineral barrier precipitated, composed of iron oxide and hydroxide, green rust, iron sulphide, along with Ni, Zn, Co, and Mn ions. The surface of this material, jointly with the structure of the vent itself, can efficiently promote the coupling of CO_2 reduction reaction (to simple organic molecules) with hydrogen oxidation. [1]

On the other hand, material scientists and chemists worldwide are frenetically searching for an effective material capable of performing CO_2RR at affordable prices. Could the minerals that performed carbon dioxide reduction 4.4 billion years ago be utilized in today's industry to address the environmental challenges of the new millennium? Here is the idea of "emergence of life inspired material" for CO_2 conversion.

Recently, a new approach to the study of Hydrothermal Vents has emerged from electrochemistry. [2][3]

New electrodes based on mineral materials have been tested to determine their effective catalytic ability for CO_2 reduction and product distribution. In our research, Mackinawite (Fe-S) and Violarite (Fe-Ni-S) were tested by performing electrolysis in a CO_2 environment, revealing the production of formic acid, methanol, and carbon monoxide at -1.1 V vs SHE (HCOOH and MeOH had never been identified before on such materials [4]).

The geological system is modelled as a fuel cell where a continuous supply of carbon dioxide and hydrogen is provided. The electrode material is composed of the vent's minerals, with the anode and cathode short-circuited in a configuration that recall a corrosion process. The system, capable of coupling CO_2RR and HOR (or other oxidation process), is ultimately powered by the pH difference between the two compartments (simulated inner vent fluids and oceanic waters). An electrochemical analogue of the vent has been created in an H-type cell to study the current and electrical potential trends during operation. The results are then compared using an Evans-type diagram.

References:

[1] Branscomb, E., & Russell, M. J. (2018). Frankenstein or a Submarine Alkaline Vent: Who Is Responsible for Abiogenesis? Part 1: What is life–that it might create itself? BioEssays, 40(7).
[2] Nitschke, W., Schoepp-Cothenet, B., Duval, S., Zuchan, K., Farr, O., Baymann, F., Panico, F., Minguzzi, A., Branscomb, E., Russell, M. J., Electrochem. Sci. Adv. 2023
[3] Vasiliadou R, Lane N. at al. Possible mechanisms of CO2 reduction by H2 via prebiotic vectorial electrochemistry. Interface Focus. 2019
[4] Hudson R, et al. CO2 reduction driven by a pH gradient. Proc Natl Acad Sci U S A. 2020

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ELE-PO-015

Exploring Novel Solutions for Enhanced Performances in Fluoride-Ion Batteries

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A new era of electrochemical energy storage devices is required to meet the increasing demand for energy storage capacity at lower costs. Furthermore, because the number of batteries produced is constantly increasing, developing more sustainable chemistry without consuming limited resources is an actual research challenge.[1] In recent years there has been growing interest in batteries based on fluoride-ion shuttle. This interest stems from the potential to utilize a cost-effective, high-capacity conversion cathode, taking advantage of multi-electron transfer processes, and use a metal anode without the risks caused by dendrite formation, resulting in enhanced safety and performance.

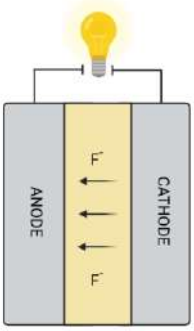

Figure 1: Fluoride-ion batteries working principle

Today, finding a suitable electrolyte is one of the most significant challenges for developing a fluoride-ion battery capable of competing with modern lithium-ion batteries[2,3]. This work attempts to use a novel solution in the electrolyte technology, to ensure ionic conductivity and high chemical and electrochemical stability, enabling cyclability between metal-metal fluoride electrodes at room temperature[4].

References:

[1] Xiao, A. W.; Galatolo, G.; Pasta, M. *Joule* **2021**, *5* (11), 2823–2844.
[2] Davis, V. K.; Bates, C. M.; Omichi, K.; Savoie, B. M.; Momčilović, N.; Xu, Q.; Wolf, W. J.; Webb, M. A.; Billings, K. J.; Chou, N. H.; Alayoglu, S.; McKenney, R. K.; Darolles, I. M.; Nair, N. G.; Hightower, A.; Rosenberg, D.; Ahmed, M.; Brooks, C. J.; Miller, T. F.; Grubbs, R. H.; Jones, S. C. *Science* **2018**, *362* (6419), 1144–1148.
[3] Davis, V. K.; Munoz, S.; Kim, J.; Bates, C. M.; Momčilović, N.; Billings, K. J.; Miller, T. F.; Grubbs, R. H.; Jones, S. C. *Mater. Chem. Front.* **2019**, *3* (12), 2721–2727.
[4] Galatolo, G.; Alshangiti, O.; Di Mino, C.; Matthews, G.; Xiao, A. W.; Rees, G. J.; Schart, M.; Chart, Y. A.; Olbrich, L. F.; Pasta, M. *ACS Energy Lett.* **2024**, *9* (1), 85–92.

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ELE-PO-016

Feasibility and challenges of the electrochemical ammonia production from nitrogen and nitrate in a flow cell reactor

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The Haber-Bosh process is the most optimized and only known way to produce the quantities of NH_3 needed to satisfy the overall world demand. Despite that, the urge to reduce as much as possible greenhouse gases emission paved the way for the discovery of alternative and cleaner paths towards the production of such a fundamental molecule indispensable to sustain agriculture in this period of demographic growth. The research has focused on the possibility of producing NH_3 from direct N_2 electrochemical reduction (NRR) in aqueous electrolytes under ambient conditions, the limitations of which are the low selectivity at high current densities and low yield, due to the high dissociation energy of N_2 triple bond and the unavoidable hydrogen evolution reaction (HER).[1] On the other hand, NO_3^- can be easily converted into NH_3 thanks to the lower activation energy and it is one of the most abundant contaminants of underground waters. Thus, the use of NO_3^- to produce NH_3 under ambient conditions can also address the water pollution issue.[2] The research on such topics is still in the first stages and very few literature reports reliable and consistent results.

Our work is divided into different lines: i) the NO_3^- electrochemical reduction using commercial MoS_2 in a gas-diffusion electrode flow cell of 10 cm^2, ii) NRR tests using different catalysts in different conditions, iii) the study of different sources of contamination, among all that coming from Nafion membrane. Regarding the first line, the design of experiments and surface response methodology (DoE/RSM) revealed the possibility of having stable operations for over 100 h with low NO_3^- concentration (500 mg L^{-1}), with FE and productivity rate for NH_3 stable at values around 60% and 19.6 µg h^{-1} cm^{-2}, respectively. Unfortunately, even with the hardest effort, we were not able to obtain reliable and good results for NRR in all the explored conditions. False positives have been demonstrated to be related to the presence of contaminants, especially the one coming from the Nafion membrane, which can absorb NH_3 in a magnitude dependent on the electrolyte composition and on the cell conditions.

References:

1 H. Iriawan, S. Z. Andersen, X. Zhang, B. M. Comer, J. Barrio, P. Chen, A. J. Medford, I. E. L. Stephens, I. Chorkendorff and Y. Shao-Horn, *Nat. Rev. Methods Prim. 2021 11*, 2021, **1**, 1–26.
2 G. F. Chen, Y. Yuan, H. Jiang, S. Y. Ren, L. X. Ding, L. Ma, T. Wu, J. Lu and H. Wang, *Nat. Energy 2020 58*, 2020, **5**, 605–613.

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ELE-PO-017

Advancements in Atomically Precise Catalysts for Oxygen Reduction Reaction: Insights into Electrochemical Activity and Structural Dynamics of a Pd(II) Complex Catalyst Supported on Multi-Walled Carbon Nanotubes

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The design of efficient catalysts for the Oxygen Reduction Reaction (ORR) continues to be a crucial point in the development of clean energy technologies, particularly in fuel cells. Here we present our latest findings on an innovative atomic precision catalyst, called MWCNT-LPd. This catalyst consists of a Pd(II) tetraazacycloalkane complex anchored to multi-walled carbon nanotubes (MWCNTs) obatained through a supramolecular approach[1]. Our investigation explores the structural and electrochemical characteristics of MWCNT-LPd, to elucidate its catalytic mechanism and performance. Through comprehensive analyses, including quantum-mechanical calculations, electrochemical and spectroscopic techniques, we examine the role of coordination geometry in catalytic activity, shedding light on the need for unoccupied coordination sites for efficient ORR. A tetraazacycloalkane ligand was intentionally chosen to occupy all four coordination sites of the conventional square planar coordination geometry of Pd(II). This choice was made to investigate a fundamental question: whether the metal ion requires unoccupied coordination sites to effectively catalyse the oxygen reduction reaction (ORR) or whether, as suggested by quantum mechanical calculations, catalytic activity may result from O_2 interactions occurring at the fifth coordination position[2]. Remarkably, our results show that the tetracoordination of Pd(II) within the complex does not compromise its catalytic activity, achieving ORR performance comparable to that of Pt commercial bulk electrodes and introducing new notions of the structure-function relationship in ORR catalysis. In this way, the results obtained open new possibilities for the design of inexpensive and highly efficient catalysts that are crucial for the advancement of sustainable energy technologies. Authors thank Project 2022NW4P2T CUP B53D23013890006 "From metal nanoparticles to molecular complexes in electrocatalysis for green hydrogen evolution and simultaneous fine chemicals production (FUTURO)" PRIN2022 Progetti di Ricerca di Rilevante Interesse Nazionale funded by the Italian Ministry of University and Research and NextGenerationEU.

References:

[1] V. Monini, M. Bonechi, C. Bazzicalupi, A. Bianchi, P. Gentilesca, W. Giurlani, M. Innocenti, A. Meoli, G.M. Romano, M. Savastano, Dalton Trans. 2024, 53, 2487-2500.
[2] M. Bonechi, W. Giurlani, M. Vizza, M. Savastano, A. Stefani, A. Bianchi, C. Fontanesi, M. Innocenti, Catalysts 2021, 11, 764.

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ELE-PO-018

NiO Nanoparticles as Electrocatalyst for Nitrates Reduction

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The introduction of the Haber-Bosch (HB) process in the early twentieth century enabled the large-scale production of NH_3, swiftly becoming one of the most crucial chemical products worldwide due to its extensive application in agriculture as a fertilizer. Moreover, NH_3 has recently garnered significant interest as a potential renewable energy storage system, given its capacity to serve as a source of hydrogen.[1]

However, the Haber-Bosch process, reliant on atmospheric nitrogen and fossil fuel, requires H_2 for NH_3 production, as well as high process temperature and pressure, contributing to approximately 1.6% of the annual global CO_2 emissions.[2] A promising alternative lies in the electrochemical nitrogen reduction reaction (E-NRR) to synthesize NH_3 under ambient conditions.[3] However, to date, this process has a limited yield production and a low selectivity due to the high stability of the N_2 molecule and the presence of parasitic reactions, primarily leading to water (solvent) conversion into hydrogen.[4]

A more recent focus has emerged towards the reduction of NO_3^-, as it can be more easily converted into NH_3 with a significant Faradaic efficiency (FE) and high yield. Moreover, owing to the prevalent use of nitrogen-based fertilizers, this process possesses a significant real-case application towards wastewater treatment were high NO_3^- levels have often been detected.[3]

This study presents the utilization of a nanostructured NiO electrocatalyst, prepared by precipitation in aqueous medium and calcinated at 600 °C, for the reduction of NO_3^- into NH_3, achieving an average FE of 36% and a production rate ranging from 28 to 107 μg h cm^{-2}, depending on the initial NO_3^- concentration. The experiments were conducted in a H-type cell, utilizing three different concentrations of KNO_3 (NO_3^- source), i.e. 0.1, 0.05, and 0.008 M. A second investigated experimental parameter was the concentrations of the supporting electrolyte (i.e., K_2SO_4), that was used at 0.4, 0.45, and 0.492 M. The tests were conducted under an applied potential (E) of –1.4 V vs. Ag/AgCl for a duration of 2 h.

In this contribution, we will show the main outcomes derived from this newly explored electrocatalysts, highlighting the main structure-performance correlations.

References:

[1] H. Shen, C. Choi, J. Masa, X. Li, J. Qiu, Y. Jung and Z. Sun, *Chem*, 2021, 7, 1708–1754.
[2] P. Zhang, W. Xiong and M. Zhou, *Nano Materials Science*, 2020, **2**, 353–359.
[3] Q. Liu, Q. Liu, L. Xie, Y. Ji, T. Li, B. Zhang, N. Li, B. Tang, Y. Liu, S. Gao, Y. Luo, L. Yu, Q. Kong and X. Sun, *ACS Appl Mater Interfaces*, 2022, **14**, 17312–17318.
[4] B. Yang, W. Ding, H. Zhang and S. Zhang, *Energy Environ Sci*, 2021, 14, 672–687.

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ELE-OR-019

Development of an eco-friendly by-layer gel-polymer electrolyte for rechargeable Zinc-Air batteries

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The Green Deal sets ambitious goals for EU climate neutrality by 2050, enabled by a increase of renewable energy share, pursued by the 'FIT for 55% package, and based on more affordable, secure, and clean energy systems. Achieving these targets requires the development of sustainable, interconnected, sector-coupled, and flexible Electrochemical Energy Storage (EES) systems. Metal-air batteries present several advantages, including using aqueous electrolytes with inorganic salts, cheap and abundant active materials (e.g., zinc), high gravimetric energy density, and long-term stability. The main goal of the HORIZON EUROPE project "HIPERZAB" is to develop an Electrically Rechargeable Zn-Air Battery (ERZAB) ideal for mid-term storage to be coupled with renewable power sources and electrolysers. HIPERZAB will achieve an actual paradigm shift with respect to the battery performance, lifetime, safety, sustainability, and costs of liquid electrolyte-based Zn-Air Batteries through the investigation of three innovative components: a 3D porous Zn/biopolymer composite anode, an eco-friendly bilayer gel biopolymer electrolyte[1], and a CRM-free structured cathode. The ultimate goal of the project is to integrate these components in a single device, proposing a radically new gel-electrode-assembly (GEA) battery design with a channelled current collector. HIPERZAB will further focus on understanding the mechanisms behind the unique integration of these innovative components by developing advanced operando techniques and atomistic as well as multiscale modelling for the discharge/charge processes and to control/monitor the durability/performance of the materials. More specifically, our research group is working on the development of the acidic side of an aqueous Gel Polymer Electrolyte (GPE) that, coupled with the basic one[2], will increase the battery operating potential from 1.65 V in alkaline-based electrolytes to 2.55 V and, hence, the overall device energy density from ≈ 1353 to 2091 Wh/kg. The electrolyte preparation is based on the use of natural bio-polymers[3], such as cellulose derivatives and low-cost, sustainable chemicals, with also the exploration of the use of redox mediators to modulate the kinetic of OER and ORR processes. Particular attention is also paid to the regulation of Zn ion conduction/transport across the interfaces by adjusting the amount of water and the polymer crosslinking density coupled with mechanistic understanding. The idea is to design a membrane-less battery in which ion mixing is avoided thanks to the proper selection of pH-sensitive polymers for both the acidic and basic environments, separately[4].

References:

[1] Nair, J. R. et al. *J.Power Sources*, **2016**, *306*, 258–267.

[2] García-Gaitán, E. et al. *Chemical Engineering Journal,* **2023,** *472*, 144870

[3] Sun, P et al. *Electrochimica acta,* **2022,** 429, 140985.

[4] Bischoff, C. F. et al. *J. Electrochemical Society,* **2020,** 167, 2.

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ELE-OR-020

Sodium and calcium alginate for innovative green separators

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Bio-based separators represent an important opportunity for next-generation sustainable batteries, and, in the next years, it will become fundamental to investigate more in details these systems to guarantee the best performance of energy storage devices.

The separator is a critical component of batteries since it prevents electrical short circuits, being a physical barrier between the anode and the cathode, but it also serves for ion transportation. Traditional polyolefin-based separators are widely used in lithium-ion technologies thanks to their price and chemical stability[1]. However, this stability determines a high resistance to biodegradation[2]. Consequently, the use of these technologies increases the plastic pollution that is a formidable threat to the sustainable development of human society. To overcome this problem, the use of a bio-based separator is needed.

The aim of this work is the realization of a bio-based separator by means of a green process. After a deep evaluation of several natural polymers, calcium alginate (CA) has been chosen to realize a composite separator for green energy storage. CA is obtained from sodium alginate (SA), a cell wall component of brown algae. In presence of divalent cations (especially calcium), the low viscosity solution is turned immediately into a gel. CA was selected thanks to its thermal and chemical stability that make it a promising candidate for the realization of a new generation separator[3].

Acknowledgements
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References

[1] A. Terella, E. Paolasini, F. De Giorgio , D. Fabiani, M. Rahmanipour, M. L. Focarete, L. Malavolta, C. Arbizzani. J. Power Sources 2020, 449, 227556
[2] S. S. Zhang. J. Power Sources 2006, 164, 351
[3] W. Schlemmer, J. Selinger, M. A. Hobisch. Carbohydrate Polymers 2021, 14, 93

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ELE-PO-021

Aquivion®-based nanocomposite proton exchange membranes containing perfluoroalkylic decorated cerium oxide nanoparticles as radical scavengers.

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The most promising alternative to the current fossil-fuel cantered system is a hydrogen-based circular economy This requires the conversion of hydrogen into electricity in proton exchange membrane fuel cell (PEMFC) using perfluorosulfonated polymer (e.g. Nafion® and Aquivion®).

The main limit of these devices is their relatively low lifetime due to the degradation of the polymeric chains[1] caused by radical species (•OH •OOH) generated at the cathode. The best strategy to improve the device's lifetime is the introduction of radical's scavenging species in the (MEA)[2]. State of the art radical scavengers include cerium oxide nanoparticles, either embedded in the membrane[3], or in the catalyst layer[4].

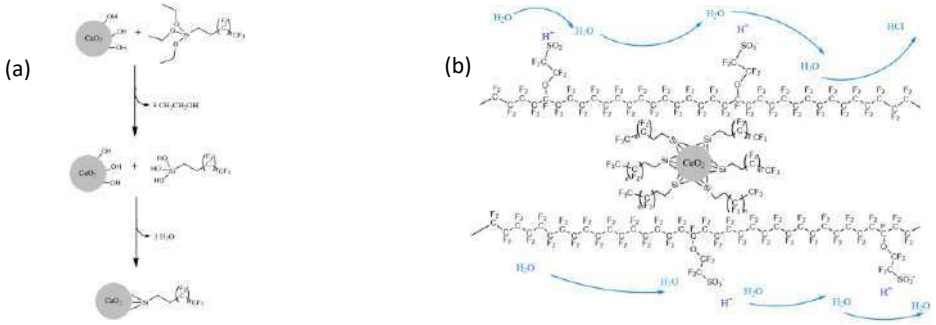

Figure 1: schematic representation of: (a) the grafting procedure and (b)the resulting nanocomposite membrane

To improve the compatibility between the inorganic filler and the organic polymeric matrix we fabricated CeO_2 NPs decorated with 4 different fluorinated silanes through a surface grafting process of the nanoparticles that are then dispersed in the polymeric film (figure1). The success in the fabrication of nanocomposite membranes was proved trough IR spectroscopy, XRD analysis and microscopic imaging. Thereafter the samples were thoroughly physicochemically characterized showing improved thermal, and mechanical properties with comparable electrochemical behavior.

References:

[1] P. Ren, P. Pei, Y. Li, Z. Wu, D. Chen, S. Huang, Prog. Energy Combust. Sci. 2020, 80, 100859
[2] A. Alia, A. Delrue, M. Zatoń, F. Duquet, F. Spanu, M- Taillades-Jacquin, S. Cavaliere, D. Jones, J. Rozière, *Membranes* 2020, 10, 208.
[3] V. D. C. Tinh, D. Kim, J. Membr. SCI 2020, 613, 118517
[4] C. D'Urso, C. Oldani, V. Baglio, L. Merlo, A.S. Aricò, J. Power Sources 2014, 272, 753

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ELE-PO-022

Electrochemical Iodination as a Green Alternative for the Synthesis of X-ray Contrast Media

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Iodinated contrast media (ICM) exploit the radiopacity of the iodine they contain to enhance tissues contrast in X-ray-based analyses. Their usage has widely increased in the last 20 years,[1] but SARS-CoV-2 related lockdowns caused a troubling shortage of ICM in 2022.[2] The solutions adopted to deal with the problem were mainly implementing the conservation strategies and reduce the dosages, but also novel and more efficient synthetic routes must be considered as a possible solution to prevent the problem in the future. This also provides an opportunity to rethink the process to be more consistent with the green chemistry principles.

In this work, the successful electrochemical tri-iodination of N,N'-bis(2,3-dihydroxypropyl)-5-hydroxy-1,3-benzenedicarboxamide, an important intermediate for the synthesis of iomeprol, is reported. This reaction is currently carried out using corrosive and difficult-to-handle reagents (e.g. ICl), the production of which also implies an increase in time and costs.[3] In particular, the possibility of using less hazardous reagents, such as iodides or molecular iodine, that are electrochemically oxidized to the iodinating I_2/I^+ species was explored.[4]

The goal was to have a one-step in situ iodination process, in which the generation of the iodinating agent and iodination itself occurred in the same reaction environment. The final optimized synthesis involves a first stage of chemical iodination with I_2 and a second stage of electrochemical recycling of the iodides formed.[5] For the electrochemical part, working in pH control (pH 10-12) and potentiostatic conditions (+ 0.65 V vs SCE) is the best solution to both avoid the formation of oxidation by-products and enhance the current efficiency. The setup involves a divided cell equipped with a cation exchange membrane and leads to an almost complete iodination of the substrate using stoichiometric iodine and a faradic efficiency of almost 100%. The electrodes selected are inexpensive and robust carbonaceous anode and stainless steel cathode, meeting the industrial requirements. Industrial-scale implementation of this electrochemical iodination could therefore help in the direction of green synthesis and environmental protection in the pharmaceutical field.

References:

[1] H. M. Dekker, G. J. Stroomberg, M. Prokop, Insights Imaging 2022, 13, 30
[2] D. R. Koeppel, I. B. Boehm, Eur. J. Radiol. 2023, 164, 110853.
[3] P. L. Anelli, M. Brocchetta, L. Lattuada, F. Uggeri, Pure Appl. Chem 2012, 84, 485 – 491
[4] L. Sorti, F. Vitulano, E. Cappellini, F. Uggeri, C. F. Morelli, G. Sello, A. Minguzzi, A. Vertova, Molecules 2023, 28, 5555
[5] L. Lattuada, C. Cavallotti, G. B. Giovenzana, F. Uggeri, A. Minguzzi, A. Vertova, L. Sorti, C. Morelli, 2023, WO2023046815A1

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ELE-PO-023

Sodium Chloride/Glycerol.based Deep Eutectic Solvents as ubiquitarius electrolyte in electrochemical energy storage devices

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Nowadays, the integration of renewable energy sources (e.g. photovoltaic) with efficient electrochemical energy storage systems (EESS), such as batteries and supercapacitors, is dramatically important to store the possible excess of energy produced and supply additional power in case of insufficient electricity supply [1]. Yet, EESS are usually based on not sustainable electrolytes, which should be progressively phased out [2].

Here, the exploitation of Deep Eutectic Solvents (DES) based on NaCl as Hydrogen Bond Accpetor (HBA) and glycerol as hydrogen bond donor (HBD) as sustainable [3] and effective alternative to conventional electrolyte is proposed [4]. Indeed, the establishment of the supramolecular hydrogen bond network typical of DES seems to dramatically impact the electrochemical stability of the electrolyte: the 1:10 HBA:HBD molar ratio shows an extremely wide electrochemical stability window (up to 3 V) and faradic efficiency close to 100% when implemented as electrolyte in supercapacitors. Additionally, this system was also fruitfully tested in thermoelectric devices.

Reling on these very promising results, we developed a multi-technique approach also taking advantages of measurement campaigns at large-scale facilities) to thoroughly characterize our electrolytes and to get meaningful insights toward the design of a second generation of Deep Eutectic Electrolytes. As a result, we decided to further widen the chemistry of our solvent by the (i) engineering of the HBD and/or (ii) the replacement of the sodium salt with the zinc counterparts. The former was reached by selective etherification of one or two hydroxyl moieties of the glycerol with alkyl chain (e.g. methyl, ethyl, trifluoromethyl…)[5].

This study could be seen as a thoughtful effort in the design, characterization and implementation of innovative and sustainable electrolytes in line with the 7th sustainable development goal of the United Nations.

[1] Notton et al. Renewable and Sustainable Energy Reviews, 2018, 87, 96
[2] Ferrari et al. Advanced Energy Materials, 2021, 11, 2100785
[3] S. Nejrotti et al. ACS Omega, 2022, 7, 47449–47461
[4] E.L. Smith et al. Chemical Reviews, 2014, 114, 11060–11082.
[5] Leal-Duaso, A. et al. ACS Sustainable Chemistry and Engineering, 2019, 7, 13004–13014

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ELE-PO-024

Nanocomposite Oxides from High Entropy MAX-phases $Ti_3Al_xSi_ySn_zC_2$ as Negative Electrode for Lithium-Ion Batteries

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In recent years, batteries have significantly influenced societal advancements, with the lithium-ion battery (LIB) standing out for its impressive electrochemical capabilities. However, the commonly negative electrode, graphite, has encountered challenges related to aging and safety, particularly under high current densities.[1]

An alternative worth exploring for the negative electrode in LIBs is the utilization of Li-alloy systems such as Li-Sn and Li-Si (theoretical reversible capacity of Sn and Si are, respectively, 783 mAh g^{-1} and 4212 mAh g^{-1}). However, the significant volume changes during cycling pose obstacles to their practical use.[2]

To mitigate this challenge, one potential strategy is the adoption of corresponding conversion oxides like SnO_2 and SiO_2, which, through a conversion mechanism with lithium ions, potentially create smaller metal particles embedded within the Li_2O framework. Despite the promise of this approach, managing volume fluctuations remains a critical concern.[3]

Within this framework, a less explored route involves employing solid solutions of conversion oxides with intercalation oxides, such as TiO_2, capable of providing a robust framework. Regarding this, we have introduced an innovative approach to produce nanostructured solid solutions of oxides by thermally treating MAX-phase systems and we have shown that controlled oxidation of these Sn-containing phases ($Ti_3Al_{1-x}Sn_xC_2$ with x= 0.4 or 0.7) at 600°C in air yields a composite material capable of very good electrochemical performance as a negative electrode in lithium-ion batteries.[4] Moreover, in this context, we have also studied how the final temperature of the oxidation step can modify the final product and how these related differences can affect its electrochemical properties.

With an analogous approach, here it's proposed a novel parallel study starting from Si-based MAX-phases, both $Ti_3Al_{1-x}Si_xC_2$ and $Ti_3Al_xSi_ySn_zC_2$ (with x+y+z=1). First, their physical-chemical properties were investigated; then their electrochemical performances were evaluated as possible negative electrodes for LIBs.

References:

[1] C.Y. Wang, T. Liu, X.G. Yang, S. Ge, N.V. Stanley, E.S. Rountree, Y. Leng, B.D. Mccarthy, Nature 2022, 611, 485.
[2] M. Peng, K. Shin, L. Jiang, Y. Jin, K. Zeng, X. Zhou, Y. Tang, Angewandte Chemie International Edition 2022, 61 (33), e202206770.
[3] T. Autthawong, C. Yodbunork, N. Ratsameetammajak, O. Namsar, Y. Chimupala, T. Sarakonsri, ACS Applied Energy Materials 2022, 5 (11), 13829-13842.
[4] I. Ostroman, C. Ferrara, S. Marchionna, A. Gentile, N. Vallana, D. Sheptyakov, R. Lorenzi, R. Ruffo, Small Methods 2023, 2300503.

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ELE-PO-025

Tailoring the self-assembly properties of $Au_{25}(SR)_{18}$ atomically precise clusters in the solid state

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The manipulation of Atomically Precise Clusters (APCs) stands as a key objective in the quest to deliver responsive nanomaterials for catalysis, sensing, and optoelectronic applications.[1-4] A pivotal breakthrough in this pursuit involves the precise adjustment of ligand within $Au_{25}(SR)_{18}^0$, enabling the modification of cluster assembly properties in the solid state.[5-7] Through deliberate variation of the ligand length (SC_4H_9, $SC_{10}H_{21}$, $SC_{18}H_{33}$), we achieved a precise control over cluster interactions, inducing consequential alterations in their aggregation properties of $Au_{25}(SR)_{18}^0$. Notably, we found, employing scanning electron microscopy (SEM) and atomic force microscopy (AFM), that $Au_{25}(SC_{18}H_{33})_{18}^0$ exhibited anisotropic self-assembly in the solid state, thus forming ultralong fibers having a length of hundreds of micrometers and an average diameter of 850 nm. Moreover, XRD and Selected Area Electron Diffraction (SAED) analysis suggested that the $Au_{25}(SC_{18}H_{33})_{18}^0$ fibers displayed crystallographic order and a high degree of symmetry in the three dimensions. This study not only provides insights into the fundamental principles governing cluster self-assembly in the solid state but also offers a pathway to engineer tailored materials with customized properties. By gaining the ability to fine-tune APCs' self-assembly through ligand manipulation, a new era of nanomaterials design emerges, promising enhanced performance and versatility in diverse applications.

References:

[1] X. Kang, M. Zhu, *Coordination Chemistry Reviews*, **2019**, 394, 1-38.
[2] V. Tiwari, T. Karmakar, *J. Phys. Chem. Lett.*, **2023**, 14, 6686-6694.
[3] T. Chen, H. Lin, Y. Cao, Q. Yao, J. Xie, *Adv. Mater.*, **2022**, *34*, 2103918.
[4] X. Yuan, M. Zhu, *Inorg. Chem. Front.*, **2023**, 10, 3995-4007.
[5] Z. Wu, C. Dong, Y. Li, H. Hao. H. Zhang, Z. Lu, B. Yang, *Angew. Chem. Int. Ed.*, **2013**, 52, 9952-9955.
[6] Z. Wu, J. Liu, Y. Li, Z. Cheng, T. Li, H. Zhang, Z. Lu, B. Yang, *ACS Nano*, **2015**, 9, 6315-6323.
[7] J. Liu, Y. Tian, L. Ai, Z. Wu, D. Yao, Y. Liu, B. Yang, H. Zhang, *Langmuir*, **2020**, 36, 14614-14622.

ELE-PO-026

Electrospun membranes of poly ethylene furanoate derivatives for multi – purpose applications

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Polymers are a leading class of functional material suitable for high-value applications, prized for their adaptability and suitability for a wide range of high-value applications, including biomedical engineering, food packaging, and electrochemical energy storage (EES) sectors[1]. In the pursuit of reducing environmental impact and diminishing reliance on fossil fuels, there has been a significant drive to replace synthetic polymers with biopolymers, composed of repeated chemical blocks derived from renewable resources that may also be degraded in the environment. As a result, numerous types of natural or biopolymers have been developed to address the growing needs across the various applications[2]. Among the different classes of biopolymers, poly ethylene furanoate (PEF) derivatives has attracted increasing attention from the scientific community due to its potential to replace poly(ethylene terephtalate) (PET), mainly used in the packaging, film and fibre sectors. PEF can be 100% bio-based since both its monomers can be produced from biological resources, and exhibits superior mechanical properties compared to PET[3]. The purpose of this study has been to develop electrospun membranes of PEF derivatives, and perform a physico – chemical and electrochemical characterization, to evaluate the potential applications of this biopolymers in both biomedical and EES fields.

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References:
[1] E. Kabir, R. Kaur, J. Lee, K. – H. Kim, E. E. Kwon, Journal of Cleaner Production 2020, 120536
[2] A. Das, T. Ringu, S. Ghosh, N. Pramanik, Polymer Bulletin 2023, 80, 7247 – 7312
[3] K. Loos, R. Zhang, I. Pereira, B. Agostinho, H. Hu, D. Maniar, N. Sbirrazzuoli, A. J. D. Silvestre, N. Guigo, A. F. Sousa, Frontiers in Chemistry 2020, 8

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ELE-PO-027

Optimizing Synthesis and Investigating Divalent Element Doping Effects on Fe-Mn-based oxide for Sodium Ion Battery.

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Sodium-ion batteries (SIBs) are being considered as a viable alternative to lithium-ion batteries (LIBs) due to their similar physical and chemical properties. However, it is crucial to recognize the distinct differences between SIBs and LIBs, particularly in terms of ionic radii.[1]

The research presented here focuses on iron-manganese-based oxide materials doped with bivalent elements as positive electrodes for SIBs. The synergistic effect of its two elements, Fe and Mn, and their abundance make this class of material environmentally appealing.[2] Nevertheless, the material exhibits air instability and undergoes multiple phase transitions during charging and discharging. To overcome these challenges, dopants can be introduced. Our focus is on materials with an O3-type structure, which allows for higher sodium content compared to P2-type structures, thus enhancing battery performance.[3]

This project pursues two main objectives. First, to optimize the co-precipitation synthesis process by considering various factors that influence it;[4] second, to comprehensively investigate the effects of various dopants from multiple perspectives, including electrochemical performance, structural stability, and moisture sensitivity. The study aims to contribute to the advancement of SIB technology by comprehensively analyzing the aspects mentioned above.

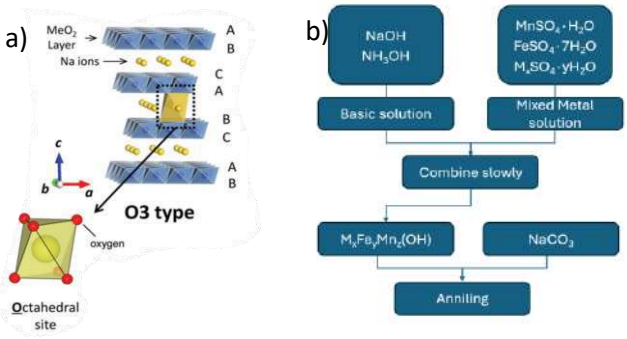

Figure 1: a) O3-type structure; b) synthesis protocol.

References:

[1] Y. Cao, et al., Chemistry–A European Journal, 2023, 29.12: e202202997.
[2] B. Peng, et al., Advanced Functional Materials, 2024, 2311816.
[3] Y. Gupta, et al., Renewable and Sustainable Energy Reviews, 2024, 192: 114167.
[4] M. Malik, K. Chan, G. Azimi, Materials Today Energy, 2022, 28: 101066.

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ELE-PO-029

Anti-corrosion coatings of TiVNbMoAl high-entropy alloy synthetized by DC-magnetron sputtering

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High entropy alloys (HEAs) are a new class of materials[1] that has attracted an increasing interest in recent years, in the form of thin films, because of their outstanding properties such as high strength/hardness, good wear resistance, high temperature strength, exceptional corrosion resistance[2]. In this work, we used pulsed direct current (DC) magnetron sputtering to fabricate HEA thin films of TiVNbMoAl 15-15-20-25-25 at%, starting from a single target of the same alloy composition. The films of 900 nm thickness were deposited on a 30 mm diameter 100Cr6 steel disk at two different temperatures of 25°C and 400°C. X-ray diffraction (XRD) analysis (Fig.1) was performed to prove the formation of a crystalline high entropy alloy film. The results showed that the films were well-crystallized (Body-Centered Cubic (BCC) Structure solid solution) at both temperatures, but the crystallite size increases with an increase of deposition temperature from 16 to 38 nm. In addition, no intermetallic phase was detected. The roughness was less than 10 nm, indicating that all the films have comparatively smooth surfaces. The chemical composition obtained by SEM-EDX analysis of the film appears to be in line with that of the starting target. The corrosion tests show an increase resistance of HEA-coated samples compared to the bare substrate, confirming the possible application of this class of materials as protective films.

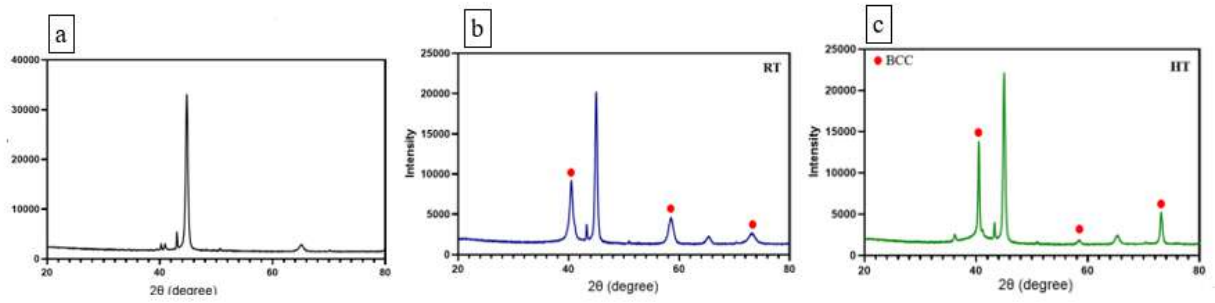

Figure 1: Comparison of XRD patterns of pristine 100Cr6 steel substrate (a), and of TiVNbMoAl HEA coatings deposited at 25°C (b) and 400°C (c). Body-Centered Cubic (BCC) Structure

References:

[1] A. Shaema, Coatings, 2021, 11, 372.
[2] X. Wang, W. Guo, Y. Fu, Journal of Materials Chemistry A, 2021, 9, 663 – 701.

ELE-PO-030

Electrochemical Nitrogen Conversion into Ammonia in the SuN2rise ERC-StG Project

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The preservation of our planet is the most urgent issue in the world and the scientific community is pushing a lot of researchers to work on technologies for the storage/conversion of CO2 into chemicals. However, it is easier not to produce CO2 than setting-up plants to treat it.

In this framework, the ERC-StG project SuN2rise proposes an alternative breakthrough based on a versatile solar-driven strategy leading to redesign industrial processes. Facing the Haber-Bosch process for ammonia production (one of the most impactful chemical processes today), we propose the electrochemical fixation of dinitrogen into ammonia, by simply using air, water and ambient conditions. The scientific aim is that of demonstrating an integrated device where a photovoltaic (PV) unit will power a regenerative electrocatalytic cell converting dinitrogen to ammonia (E-NRR). A newly proposed Li-mediated approach under mild conditions, derived from an interdisciplinary contamination between electrocatalysis and Li-batteries, will be the key towards N2 conversion, bypassing both the competitive hydrogen reduction reaction and the complete irreproducibility of recent E-NRR approaches attributed to N-contaminations or degradation of N-based catalysts.

The team will further move beyond the state-of-the-art by fabricating transparent devices, that can be integrated in greenhouses, allowing the production of ammonia and ammonium fertilizers directly in farms, bypassing the known issues related to the massive infrastructure of ammonia plants and difficulties in reaching remote communities. The proposed approach will significantly impact also the field of liquid fuels, being ammonia safer and with higher energy density than hydrogen. Achieving these goals will require multidisciplinary expertise in the field of chemical, material, process and device engineering.

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ELE-PO-031

Electric Response and Conductivity Mechanism of Solid State Hybrid Inorganic Organic Polymer Electrolytes for Sodium Secondary Batteries

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The widespread adoption of electric vehicles, smart grids, and portable electronics is foreseen to necessitate a substantial quantity of energy storage devices, surpassing the capabilities of Li-ion batteries alone. Consequently, there is an ongoing exploration for innovative electrochemical energy storage technologies [1]. Among these alternatives, sodium secondary batteries (NaBs) emerge as promising solutions due to the abundant and cost-effective nature of raw materials, the low sodium standard reduction potential, and the chemical similarities between sodium and lithium, facilitating their implementation. Currently, state-of-the-art electrolytes for reversible sodium deposition rely on flammable organic solvents, which are unstable when in contact with sodium metal.

Drawing inspiration from the groundbreaking work conducted by Di Noto and colleagues [2-4], this study introduces a family of hybrid inorganic-organic polymer electrolytes (HIOPEs) designed for advanced solid-state NaBs. The HIOPE is synthesized by reacting zirconium ethoxide with polyethylene glycol (PEG400) and sodium perchlorate, resulting in a 3D hybrid network. This network features interconnected inorganic zirconium metal nodes and organic PEO chains, ensuring structural flexibility. To further enhance flexibility and ion conductivity, the HIOPE is doped with the poly(ethylene glycol) dimethyl ether (PEGDME250) plasticizer, achieving a room temperature value exceeding 10^{-4} S cm^{-1}. The proposed solid-state electrolytes undergo comprehensive analysis of thermal and structural properties, focusing on interactions within the HIOPE components. Additionally, the conduction mechanism is elucidated through broadband electrical spectroscopy studies in a wide range of temperatures and frequencies. This comprehensive exploration provides valuable insights into the utilization of non-traditional solid-state electrochemical functional components for NaB applications.

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References:

[1] R. Dominko, J. Bitenc, R. Berthelot, M. Gauthier, G. Pagot and V. Di Noto J. Power Sourc., 2020, 478, 229027.
[2] V. Di Noto, V. Zago, S. Biscazzo and M. Vittadello Electrochim. Acta, 2003, 48, 541-554.
[3] M. Jeyapandian, S. Lavina, S. Thayumanasundaram, H. Ohno, E. Negro, V. Di Noto J. Power Sourc., 2010, 195, 341-353.
[4] V. Münchow, V. Di Noto, E. Tondello Electrochim. Acta, 2000, 45, 1211-1221.

ELE-PO-032

Oxygen Reduction Reaction *"Core-Shell"* Hierarchical Carbon Nitride Electrocatalysts: Correlation between the Features of the Precursor and the Physicochemical Properties of the Final System

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The oxygen reduction reaction (ORR) is a major bottleneck in the operation of proton-exchange membrane fuel cells (PEMFCs). Furthermore, the electrocatalysts (ECs) exhibiting the lowest ORR overpotentials are based on Pt, a very scarce critical raw material (CRM). Hence, the development of high-performing and durable ECs for the ORR is a major stepping stone towards the large-scale rollout of PEMFCs.

Our research group developed a new approach for the synthesis of ORR ECs, consisting in the pyrolysis and subsequent treatment of a precursor obtained by coupling suitable carbon species/sacrificial supports with a zeolitic inorganic-organic polymer electrolyte (Z-IOPE). The latter comprises organic binders bridging anionic complexes including the Pt *"catalyst"* and other *"co-catalysts"*. The proposed approach is extremely flexible, especially with respect to the synthesis of the initial EC precursor. In principle, it is possible to modulate a number of crucial features of such EC precursor: (i) the chemical composition (*e.g.*, in terms of Pt, other *"co-catalysts"* and N; the latter plays a crucial role to stabilize the active sites); and (ii) the morphology, that can be *"templated"* on suitable species. The very flexibility of the proposed synthetic process needs to be leveraged appropriately to maximize the performance of the final ORR ECs.

Herein it is elucidated how the modulation in the parameters involved in the synthesis of the EC precursor impact the physicochemical and electrochemical properties of the final ECs. An extensive characterization of the final ECs is carried out. ICP-AES and microanalysis are adopted to determine the bulk chemical composition. Near-ambient pressure XPS (NAP-XPS) elucidates the surface chemical composition and the chemical states of the surface elements. Cyclic voltammetry with the rotating ring-disk electrode method (CV-TF-RRDE) is used to clarify the *"ex-situ"* electrochemical performance and ORR reaction mechanism. Finally, the most promising ECs are used in the fabrication of single PEMFCs. In comparison with the Pt/C benchamark, some ECs are characterized by a much higher intrinsic kinetic performance due to the electronic and bifunctional effects bestowed by the carbon nitride support and the *"co-catalysts"*. Finally, the binder has a marked effect on the stoichiometry, size, and distribution of the PtM_x aggregates bearing the active sites.

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ELE-OR-033

Repurposing discarded porphyrin wastes as electrocatalysts for the oxygen reduction reaction

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Hydrogen is a potential alternative to fossil fuels. The broad deployment of this technology requires the development of a reliable, affordable, and efficient supply chain of water electrolyzers (WEs) and fuel cells (FCs). The latter efficiently converts hydrogen into green electricity. However, the key bottleneck in their spreading out lies at the cathode where Oxygen Reduction Reaction (ORR) exhibits sluggish kinetics and requires a high loading of precious metals (e.g., Pt). In this view, Transition Metal-Nitrogen-Carbons (TM-N-Cs) are promising electrocatalysts (ECs) to replace Pt currently used for the ORR, especially for Alkaline Exchange Membrane Fuel Cells (AEM-FCs) technology.[1]

Nowadays, TM-N-Cs are typically synthesized through pyrolysis treatment mixing transition metal, nitrogen-rich organic precursors, and carbonaceous substrates of diverse nature.[2] Among the possible metal-containing precursors, metal-porphyrins are of interest as they contain already the desired structure of single-atom transition metal coordinated with nitrogen.

The Adler-Longo method is the standard and cheapest methodology widely used to synthesize porphyrins.[3] It consists of refluxing pyrrole and an aldehyde (e.g., benzaldehyde) in propionic acid, with yields in moles around 20% in the best-case scenario, and prices around 20-40 €/g. After the product purification, the remaining mass is considered waste and discarded. However, the latter is mainly composed of polypyrromethenes, molecules with chemical structures that resemble open porphyrin rings. Interestingly, they show the same chemical composition and the ability to coordinate metal cations, due to the presence of nitrogen atoms.

This study aims to synthesize both porphyrins and polypyrromethenes, integrate them into a carbon matrix, and investigate them as TM-N-C-based electrocatalysts. A comprehensive structural and morphological characterization is provided, and the electrocatalytic activity towards ORR in an alkaline environment (0.1 M KOH) is discussed. Notably, Iron-containing precursors were investigated, and the effect of a second metal, like Manganese, was studied as well. The possibility of upcycling the as-considered waste material is shown, demonstrating the capability of polypyrromethenes to be employed as a green and cost-effective alternative to porphyrins in ECs.

References:

[1] Md. M. Hossen et al., Applied Catalysis B: Environmental 2023, 325, 121733.
[2] Y. Chen et al., Materials Today 2022, 53, 58–70.
[3] A. D. Adler et al., J. Org. Chem. 1967, 32 (2), 476–476.

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ELE-PO-034

Organic Co-Solvent Mediated Electrolyte Engineering for Improved Performance of Aqueous Sodium-Ion Batteries

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While modern lithium-ion batteries demonstrate impressive performance and market dominance, significant safety concerns persist due to their reliance on highly flammable organic electrolytes, posing substantial risks for large-scale storage deployment. Moreover, the limitations surrounding lithium availability and distribution underscore the necessity of investigating alternative battery technologies[1]. Aqueous sodium-ion batteries offer promise as a viable solution to these challenges, particularly in applications where gravimetric energy density is not the primary consideration. However, widening the electrochemical stability window (ESW) in aqueous electrolytes necessitates the use of high salt concentrations, typically ranging from 21-55 mol kg^{-1}. Although these concentrated electrolytes effectively facilitate the formation of artificial solid-electrode interfaces and enhance water stability, issues related to cost and toxicity emerge[2]. To tackle these concerns, we propose the integration of an organic solvent into the aqueous electrolyte to effectively decrease water activity by modifying hydrogen-bonding structures. In this investigation, we explore a novel hybrid electrolyte system consisting of sodium bis(trifluoromethanesulfonyl)imide (NaTFSI) and a water-miscible polymer, poly(ethylene glycol) (PEG), acting as the organic co-solvent to reduce water activity. As a result, we achieve an extended ESW reaching up to 3V, with a moderate salt concentration of 5 mol kg^{-1} (PEG:H_2O=80:20), coupled with an impressive conductivity of 2.47 mS cm^{-1} at 25°C. Thermal behaviour and flow properties of these electrolytes were examined using techniques such as differential scanning calorimetry (DSC) and Rheometry. Initial full-cell investigations employing $NaTi_2(PO_4)_3$/$Na_3V_2(PO_4)_2F_3$ yielded a specific capacity of 48 mAh g^{-1} at 0.5 C, demonstrating a favorable columbic efficiency exceeding 98%.

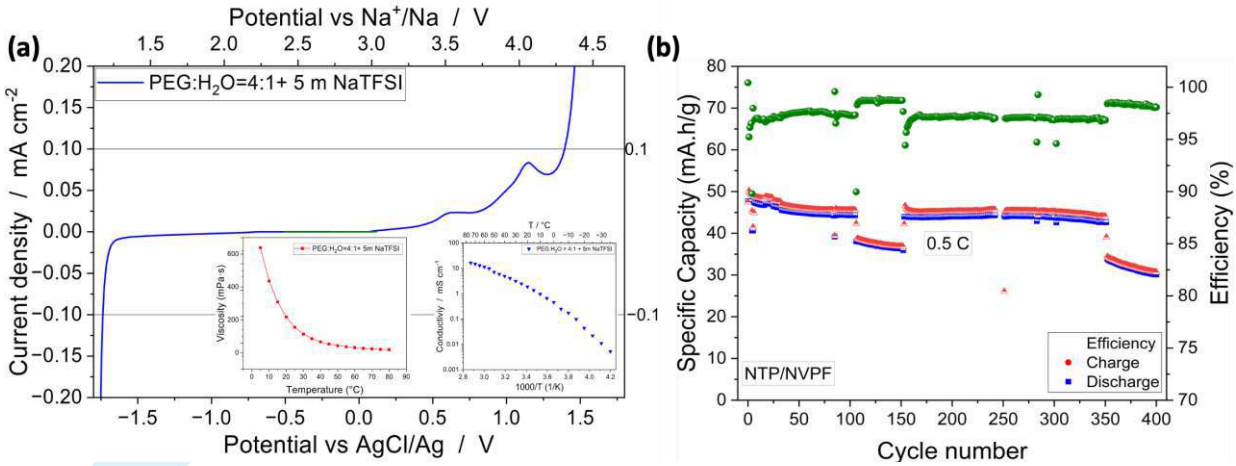

Figure 1: (a) Estimated ESW of PEG:H_2O:$NaTFSI_{5m}$ via LSV at 0.5 mV Sec^{-1} , Inset (conductivity & viscosity) (b) long cycling of NTP/NVPF full cell at 0.5 C in the PEG+H_2O + 5 m NaTFSI

References:

[1] Mauger, A.; Julien, C. M. *Ionics (Kiel)* **2017**, *23* (8), 1933–1947.

[2] Slater, M. D.; Kim, D.; Lee, E.; Johnson, . *Adv Funct Mater* **2013**, *23* (8), 947–958

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ELE-PO-035

Enhancing Lithium-ion Battery Anode Performance: Challenges and Solutions

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The quest for optimal anode materials in lithium-ion batteries has led to extensive exploration of various elements, with lithium metal, offering a theoretical capacity of approximately 3860 mAh/g, standing out as an ideal choice. However, practical constraints hinder its widespread adoption. Silicon emerges as a promising alternative due to its abundance and high nominal capacitance (3579 mAh g^{-1}), promising enhanced anode performance. However, its significant volumetric expansion (> 300%) during lithiation poses a major challenge, limiting its industrial viability[1]. Graphite, despite its lower capacity, remains favored for industrial applications owing to its abundance, cost-effectiveness, and satisfactory electrochemical properties. Recent efforts have concentrated on augmenting graphite's performance, with combined graphite-silicon electrodes gaining traction. Nonetheless, the integration of silicon introduces swelling issues, leading to the pulverization of electrode materials and subsequent performance degradation[2]. The current study aims to propose strategies for mitigating silicon-induced swelling and enhancing the performance of graphite-silicon composite electrodes. Proposed approaches include using graphene cages, surface modification, and specific binders. For instance, preliminary investigations suggest that electrodes incorporating a polymer composed of 5% by weight of a poly rotaxane (PR) and linear polyacrylic acid have shown promising results, achieving an areal capacity of 2.68 mAh cm^{-2} [3]. Furthermore, combining such binders with ionic liquid electrolytes containing lithium salts, such as LiVSi, has shown potential in significantly enhance the performance of this anode material to a capacity of 3.5 mAh cm^{-2}.

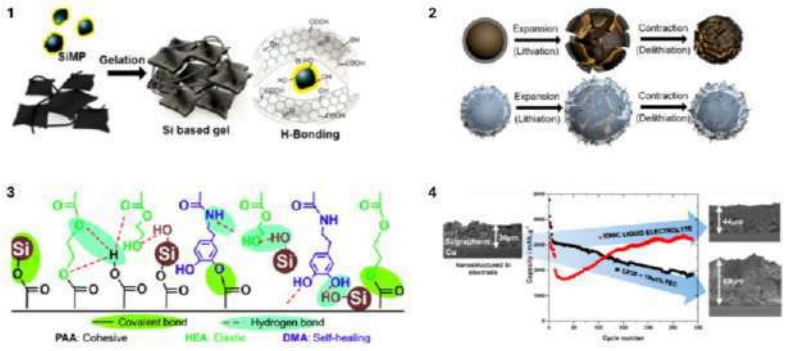

Figure 1. Possible approaches for solving the swelling problem in Silicon-based electrodes[5]

References:

1) Liu, X. H.; Wang, J. W.; Huang, S.; Fan, F.; Huang, X.; Liu, Y.; Krylyuk, S.; Yoo, J.; Dayeh, S. A.; Davydov, A. V.; et al. *Nat. Nanotechnol.***2012**, *7*(11), 749–756. DOI: 10.1038/nnano.2012.170
2) Kim, N.; Kim, Y.; Sung, J.; Cho, J. *Nat. Energy***2023**. DOI: 10.1038/s41560-023-01333-5
3) Choi, S.; Kwon, T.-W.; Coskun, A.; Choi, J. W. Science 2017, 357, 279. s.d.
4) Kerr, R.; mazouzi, D.; eftekharnia, M.; lestriez, B.; dupré, N.; forsyth, M.; guyomard, D.; howlett, P. C. ACS energy lett. 2017, 2, 1804−1809. s.d.
5) Zhu, G.; Chao, D.; Xu, W.; Wu, M.; Zhang, H. *ACS Nano***2021**. DOI: 10.1021/acsnano.1c05898

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ELE-PO-036

The Pivotal Role of Ligands Determining the Properties of Atomically Precise Gold Nanoclusters

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Since Professor Whetten's groundbreaking work on "Nanocrystals Gold Molecule" in 1996,[1] atomically precise nanoclusters (NCs) protected by ligand shells have emerged as a fascinating class of molecule-like species. Today, metallic NCs are a driving force in materials science, fueled by the ability to create novel functional materials with precisely tailored properties through ligand design.[2]

This work highlights the crucial role of ligand chemistry in manipulating NC behavior. We demonstrate how meticulous ligand design allows precise control over a broad spectrum of NC properties, including solubility, biocompatibility, electron transfer kinetic in both solution and solid state,[3] and chemosensing response for volatile organic compounds (VOCs). We also explore their potential for monolayer formation using the Langmuir-Blodgett (LB) technique. Furthermore, we report the first high-yield synthesis of a Au_{25} dimer bridged by a metal-complex moiety, that is a modified Ru(II) complex, achieved without by-product formation. This multicomponent, redox-active molecule exhibits unique properties such as quenched emission and intriguing spectroelectrochemical behavior. This feat was accomplished through a novel ligand exchange reaction (LER) strategy leveraging electrostatic forces and product precipitation.

This work underscores the importance of ligand design for synthesizing functional NCs with tailored properties, paving the way for the development of advanced materials with vast application potential.

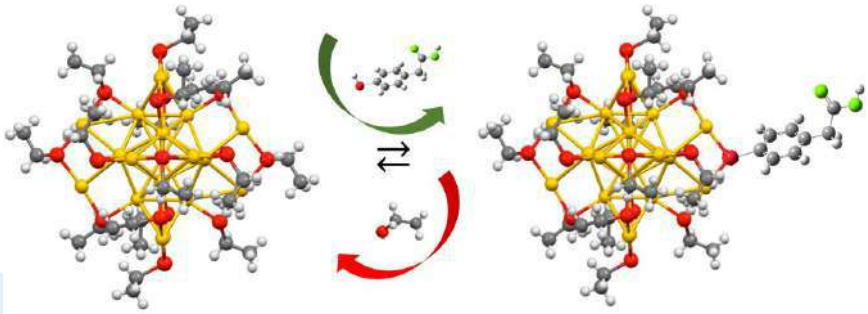

Figure 1: Example of surface modification by LER strategies on Au_{25} NC.

References:

[1] R. L. Whetten, J. Khoury, M. M. Alvarez, S. Murthy, I. Vezmar, Z. L. Wang, P. W. Stephens, C. L. Cleveland, W. D. Luedtke, U. Landman, Adv. Mater. 1996, 8, 428-433.
[2] J. Zhao, A. Ziarati, A. Rosspeintner, Y. Wang, T. Burgi, Angew. Chem. 2024, 136, e202316649.
[3] M. Reato, T. Dainese, S. Antonello, F. Maran, Chem. Mater. 2021, 33, 4177-4187.

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Development of a Fully Automated Method HS-SPME-GC-MS/MS for the Determination of Odor-Active Carbonyls in Wines: a "Green" Approach to Improve Robustness and Productivity in the Oenological Analytical Chemistry

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Volatile carbonyl compounds (VCCs) are the principal products of oxidation and are related to the characteristic pleasant scents of oxidized wines. However, apart from cases where it is a deliberate process, oxidation is commonly a side reaction whose uncontrolled advancement determines a relevant accumulation of VCCs resulting in undesirable odour defects. Accordingly, VCCs concentration represents a quality parameter for the evaluation of the correct winemaking style and proper bottling and storage[1]. To date, several analytical procedures have been developed for the quantitation of VCCs in wines but their application to the routine laboratory context is often limited by a laborious sample preparation involving the use of disposable labware and solvents, making them economically unattractive and environmentally impactful.

To overcome these limitations, an HS-SPME-GC-MS/MS method was optimised and validated. This protocol was based on a solvent-free extraction, in compliance with the Green Analytical Chemistry principles, and utilized the autosampler to perform the entire sample preparation, simultaneously achieving productivity, performance, and robustness. A total of 44 VCCs (linear, Strecker and unsaturated aldehydes, ketones, and numerous other compounds) were investigated. In solution derivatization with O-(2,3,4,5,6-pentafluorobenzyl) hydroxylamine hydrochloride (PFBHA) was used to promote recoveries especially for more complex VCCs; a mixture of 4 internal standards allowed to correct analytes of different volatilities.

All compounds exhibited satisfactory linearity ($R^2 > 0.99$) and a broad linearity range (from 0.05 to over 1000 µg/L for most VCCs), suitable intra-day and inter-day repeatability evaluated at two concentration levels (RSD < 25% in most cases) and satisfying recoveries measured in spiked samples. The method was applied to determine the evolution of VCCs in white (Gewürztraminer) and red (Teroldego) wines after accelerated ageing for 5 weeks at 50°C.[2] In all samples, furans and non-aromatic Strecker aldehydes increased in accordance with the state-of-art of ageing models. Some VCCs like many linear aldehydes and benzaldehyde accumulated at the beginning and then decreased in the second part of the ageing, being reasonably involved in equilibriums which depend on temperature and pressure. Finally, numerous VCCs exhibited no significative variation, indicating that their formation is not necessarily related to oxidation and ageing.

References:

[1] N. Moreira, S. Meireles, T. Brandão, P.G. de Pinho. Talanta, 2013, 117, 523–531.
[2] V. Pereira, J. Cacho, J. C. Marques. Food Chemistry, 2014, 162, 122–134.

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MAS-OR-001

Lipids, proteins, cells: advanced spatial multiomics to delve deeper into the complex molecular and cellular landscape of the tumour microenvironment

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The advent of mass spectrometry-based spatial multiomics has enabled the possibility to map different classes of biomolecules, such as lipids, N-glycans, and proteins, all within a single tissue section[1]. In the context of tumour biology, the application of these techniques is of particular interest when it comes to the characterisation of the Tumour MicroEnvironment (TME), which comprises heterogeneous sets of cell populations including tumour cells, immune cells, fibroblasts, endothelial cells, and more, along with their specific molecular signatures[2]. The possibility to map tumour-infiltrating lymphocytes, while also understanding their altered molecular mechanisms, could potentially unveil which factors are major contributors in the tumour-immune cell interplay which is known to mediate immunosuppression and influence the outcome of cancer treatments such as immunotherapy[2]. In this work, we apply a MALDI Mass Spectrometry Imaging (MSI) trimodal spatial omics approach for the subsequent mapping of lipids, immune cells, and proteins within a single clear cell Renal Cell carcinoma (ccRCC) tissue section. The visualization of immune cells was performed with MALDI-HiPLEX-IHC, a targeted imaging approach which is aided by immunostaining with antibodies linked to photocleavable mass tags. This targeted imaging step was used to map the relative position of different cell populations within the TME, and to subsequently individuate regions of interest on tissue where the presence of regiospecific lipids and proteins could be assessed in an untargeted way to understand the molecular alterations which characterise aberrant cell-cell communication. The application of this protocol on lymphocyte-rich ccRCC samples enabled the relative distribution of tumour cells and lymphocytes, including immunosuppressive T regulatory cells, to be mapped. Moreover, their lipidomics and proteomics alterations could be characterised and features of interest tentatively annotated by higher resolution mass spectrometry-based techniques. Whilst preliminary, our results are promising in determining the molecular signals which are crucial in determining the immunosuppressive state which characterises the TME and that could contribute to failure to immunotherapy.

References:

[1] V. Denti, G. Capitoli, I. Piga, et al. Spatial Multiomics of Lipids, N-Glycans, and Tryptic Peptides on a Single FFPE Tissue Section. J Proteome Res 2022, 21 (11).

[2] N.J. Mackenzie, C. Nicholls, A.R. Templeton, et al. Modelling the tumor immune microenvironment for precision immunotherapy. Clinical and Translational Immunology. John Wiley and Sons Inc 2022.

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MAS-OR-002

Cross-linking Mass Spectrometry: a Tool for Revealing Potential *de novo* Protein-Protein Interactions at Plasma Membrane

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Functional interactions among proteins are fundamental in driving regulatory activities for cell biology, including mechano-transduction, cell-to-cell communication/recognition, endocytosis and secretion. Since the plasma membrane proteins (PMPs) constitute ~30% of the mammalian proteome and 60% of all drug targets [1], have access to the complete "membranome" PPIs network would represent an unbiased approach to depict regulatory pathways controlling cell behaviour.

Recently, cross-linking mass spectrometry (XL-MS) has emerged as a powerful and versatile technique in the field of structural and functional biology, enabling the elucidation of protein-protein interactions (PPIs), protein conformational changes, and the mapping of intricate networks within biological systems [2].

Hence, we decided to apply an XL-MS approach to map, on a system-wide scale, the PMPs networks of He-La cells, used as cellular reference model. Our strategy included cross-linking of PMP-enriched fractions, label-free nanoLC-MS/MS analysis, and bioinformatics data elaboration.

Specifically, we present a cross-linked MS dataset of cells before (native) and after (disrupted) plasma membrane (PM) dissolution, applying the MS-cleavable cross-linker disuccinimidyl dibutyric urea (DSBU). We defined the best experimental settings in terms of DSBU concentration, cross-linking reaction time, PM enrichment, MS acquisition and elaboration. Based on all detected inter-links, we constructed a global network composed of unique residue-to-residue pairs originating from more than 300 proteins assigned to the PM compartment. The comparison to known interactions revealed an overlap of 25%, confirming the accuracy of our dataset. With respect to PM-associated proteins, we detected the highest number of PPIs for specific PM member families: ATP-binding cassette (ABC) transporters, solute carrier (SLC) transporters family, ATPase Na^+/K^+, Cu^{2+} and phospholipid transporters. The remaining cross-links were identified for proteins which are currently not described as interacting with each other, presenting potentially *de novo* partners.

At present, we are applying XL-MS for the characterisation of PPIs changes occurring at the PM in response to micro-environment stimuli and in cell models of inherited metabolic diseases.

References:

[1] I. Levental, E. Lyman, Nature Reviews Molecular Cell Biology. 2023, 24(2),107-122.
[2] L. Santorelli, M. Caterino, M. Costanzo, Omics: a journal of integrative biology, 2022, 26(12), 633-649.

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MAS-OR-003

Pollution and Exposome: description of search for biomarkers of effect of oxidative stress; preliminary results

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Pollution and oxidative stress have characteristics in common: both are originated by several factors, for their characterization it is necessary to quantify and compare more biomarkers, differing are the adverse effects on health and exposure to pollutants causes oxidative stress. To describe the contribution of both (air pollution and oxidative stress) in healthy subjects compared to patients with respiratory diseases are important identify specific biomarkers of exposure to environmental toxics and of effects to oxidative stress [1].Asthma is one of the most common respiratory diseases in the world, with an estimated 300 million asthmatic patients of all ages; for this type of pathology, the pollution probably causes a direct irritating effect and a consequent oxidative damage to the neuroreceptors and the epithelium of the airways, resulting in chronic inflammation, remodelling and increased risk of hyper-bronchial reactivity, aggravating pre-existing respiratory diseases such as asthma or inducing its occurrence. The role of air pollutants in triggering asthma exacerbations in young and adult asthma patients was established and investigated by several studies that support the role of air pollution in the development of asthma in childhood [2].For this purpose, the study design provides for the recruitment of both healthy subjects (200 adults and 100 children) and asthmatic ones (100 adults and 50 children) and for both the collection of spot urine samples and brush samples. Urinary concentration levels of Benzene, Toluene, Ethylbenzene and Xylenes (BTEX), Styrene and Methyl-tert-butylether (MTBE) and their metabolites will be quantified to characterize the environmental exposure; as biomarkers of nucleic acids damage, the oxidative forms of guanine, guanosine and 2'deoxyguanosine, and the methylated forms of cytosine, cytidine and deoxycytidine will be determined in urinary samples. All the analyses will be performed by GC-MS and LC-MS/MS techniques [3]. In the brush the main polymorphisms of biotransformation enzymes involved in the metabolization of toxic related to pollution were characterized in order to describe the individual susceptibility of the subjects recruited. The non-invasiveness of the matrices allows to quantify the levels of the biomarkers also children and in fragile subjects. We had validated the analytical methods used to the quantification of biomarkers of exposure and of effects, we quantified in urinary samples HMGB-1, markers of inflammation, and we found a different between healthy and asthmatic subject.

References:

[1] Sierra-Vargas MP,et all., Int J Mol Sci. 2023 Jan 3;24(1):853.
[2] Jacquemin B, et all., Environ Health Perspect. 2015 Jun;123(6):613-21. Epub 2015 Feb 24.
[3] Winnik WM, Kitchin KT., Toxicol Appl Pharmacol. 2008 Nov 15;233(1):100-6.

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MAS-OR-004

The metabolic role of trehalose in autophagy induction in central nervous system

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Trehalose is a non-reducing disaccharide made of two glucose molecules linked by an alpha-1,1-glycosidic bond. In the last years, trehalose applications increased exponentially, and now it is widely used in various industrial applications[1], leading to an increased "involuntary" intake. Different works indicated that trehalose reaches the central nervous system, where it is probably metabolized by neurons[2] and exerts neuroprotective roles since its ability to induce m-TOR-independent autophagy[3], but the molecular mechanism behind the autophagy activation is still unclear. Preliminary experimental data highlighted that trehalose might induce autophagy through a metabolic mechanism occurring in lysosomes organelles.

In this study, we propose to clarify the molecular pathways underpinning trehalose-induced autophagy. Rat hippocampal neurons were treated with trehalose, and with glucose as control. At the same time, lysosomes were isolated from treated and non-treated rat hippocampal neurons with immunoprecipitation assay protocol.

Neuronal cell and isolated lysosomes have been analyzed with untargeted LC/MS-based lipidomics and metabolomics approaches. Our preliminary results showed an augmented concentration of short-chain carnitines and a down-regulation of metabolites involved in energetic metabolism and aminoacidic metabolism in trehalose-treated cells. We also highlighted increased levels of lysophosphocholines and lysophosphatidylethanolamines in cells treated with trehalose, suggesting that the mobilization of membrane lipids happened, probably due to phosphatases activity. Results on lysosomes exhibited variations in polar metabolites involved in aminoacidic and energy metabolism.

Overall, our preliminary results show that the trehalose perturbation cause important metabolic variations that could be linked to autophagy induction.

References:

[1] Z. Zheng Z, Y. Xu, Y. Sun, W. Mei, J. Ouyang, PLoS One 2015, 10, e0140477.
[2] P. Lotfi, D.Y. Tse, A. Di Ronza, M.L. Seymour, G. Martano, J.D. Cooper, F.A. Pereira, M. Passafaro, S.M. Wu, M. Sardiello. Autophagy 2018, 14, 1419–1434.
[3] P. Rusmini, K. Cortese, V. Crippa, R. Cristofani, M.E. Cicardi, V. Ferrari, G. Vezzoli, B. Tedesco, M. Meroni, E. Messi, M. Piccolella, M. Galbiati, M. Garrè, E. Morelli, T. Vaccari, A. Poletti. Autophagy 2019, 15, 631–651.

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Using High-Resolution Mass Spectrometry to Investigate Supramolecular Architectures in Gas Phase

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Non-covalent molecular interactions are crucial in both biological systems and their synthetic counterparts, facilitating various applications like drug delivery, nanoreactor development, and molecular sensor innovation.[1] Within this domain, supramolecular chemistry has been pivotal in crafting bioinspired architectures for many applications in different fields.[2]

The primary advantages of MALDI-MS or ESI-MS for studying host-guest complexes lie in their ability to ionize under relatively mild conditions. This facilitates the direct ionization of solution-phase samples under native conditions, enabling the preservation of secondary interactions. Additionally, these techniques offer rapid response times, enhancing efficiency in analysis.[3]

Regarding supramolecular systems, mass spectrometry can give crucial insights into supramolecular associations in the gas phase,[4,5] the kinetic stability of complexes, and reactions occurring within molecular containers. [6]

In this communication, we will show our recent results regarding the characterization of supramolecular systems utilizing high-resolution mass spectrometry. Our aim is to show novel aspects pertaining to the encapsulation phenomena in gas phase within supramolecular systems.

References:

[1] a) M. Raynal, P. Ballester, A. Vidal-Ferran, P. W. N. M. van Leeuwen, Chem. Soc. Rev. 2014, 43, 1734 – 1787; b) R. Gaeta, C.; La Manna, P.; De Rosa, M.; Soriente, A.; Talotta, C.; Neri, P in Reactivity in Confined Spaces 2021 The Royal Society of Chemistry.

[2] C. J. Bruns, J. F. Stoddart in The Nature of the Mechanical Bond: From Molecules to Machines 2017, John Wiley & Sons.

[3] J. L. Casas-Hinestroza, M. Bueno, E. Ibáñez, A. Cifuentes Anal. Chim. Acta 2019, 1081, 32 – 50.

[4] N. K. Beyeh, M. Kogej, A. Ahman, K. Rissanen, C.A. Schalley, Angew. Chem. Int. Ed. 2006, 45, 5214 – 5218.

[5] C. A. Schalley Mass Spectrom. Rev. 2002, 20, 253 – 309.

[6] a) V. Iuliano, P. Della Sala, C. Talotta, M. De Rosa, A. Soriente, C. Gaeta, P. Neri, Curr Opin Colloid, 2023, *65*, 101692. b) C. Gaeta, C. Talotta, M. De Rosa, A. Soriente, A. Rescifina, P. Neri in Supramolecular Catalysis New Directions and Developments 2022 John Wiley & Sons.

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MAS-OR-006

A new comparative metabolomic approach to characterize the standardization of the UVCB production process

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REACH is the regulation (CE n. 1907/2006) which governs the registration, evaluation, authorization and restriction of chemical substances. Substances can be divided between "*well-defined substances*" with a 100% defined qualitative and quantitative composition and "*UVCB substances*".

Substances of unknown or variable composition, complex reaction products or biological materials (UVCB) represent all complex chemical mixture whose number of constituents is high, whose composition is largely unknown or the variability of the composition is unpredictable. In this case, a complete identification based on chemical composition is not possible. Typical examples of UVCB are natural complex matrices (NCMs), essential oil, resins and petroleum products[1]. The challenge regulatory framework is to find the way to characterize the whole substance by developing new analytical approaches. Here we present the workflow for metabolite fingerprint and profiling (untargeted metabolomics) and relative quantification (targeted metabolomics) of the principal characteristic metabolites in NCMs. In untargeted metabolomic approach a huge number of known and unknown metabolites are detected and all the obtained variables are considered simultaneously, in agreement with the minimum reporting standard of the Metabolome Standard Initiative (MSI), allowing the detection of interactions between variables (e.g. synergic effects). This approach can be useful both to develop new complex products with NCMs, to monitor the standardization of their production process and to confirm the maintenance of the quali-quantitative profile from batch to batch. By Variable Selection algorithms[2], it is possible to select a sub-set of relevant features representative of the entire initial dataset. In this work, we focused the attention on a selected number of compounds and we demonstrated that statistically the data set of the relevant features has the same trend of the original one. The most relevant features of the untargeted model were than selected for a targeted metabolomic approach that was further relative quantified with respect to a reference sample serially diluted to gain corresponding calibration curves. This innovative workflow is the rapid and less expensive way to characterize NCMs by the screening of identified or annotated suspect compounds[3].

References:

[1] D. Salvito, M. Fernandez, K. Jenner, D.J. Lyon, Environmental Toxicology and Chemistry 2020, 39, 2097 – 2108.
[2] M. Stocchero, Journal of Chemometrics 2020, 34, e3237.
[3] M. Burico, G. Fodaroni, E. Flamini, N. Ascani, G. Proietti, S. Tamimi, C. M. Quintiero, L. Massa, M. Gianni and L. Mattoli, Journal of Mass Spectrometry 2022, 57, 1-15.

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MAS-OR-007

The interplay between UV spectroscopy and high-resolution mass spectrometry for the confident identification of Cucurbitacins in unexpectedly bitter Scopatizzo melons

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Have you ever experienced a surprisingly bitter taste when biting into a Scopatizzo melon (*Cucumis melo* L.)? Apulian producers have faced this issue since 2022, due to the appearance of Scopatizzo fruits exhibiting such an unpleasant characteristic[1]. The bitterness is caused by the production of cucurbitacins, *i.e.*, a natural defence mechanism found in cucurbitaceous plants. Cucurbitacins are a group of bitter and highly oxygenated tetracyclic triterpenes, that are mainly produced in plants belonging to the Cucurbitaceae family such as cucumbers, melons, and watermelons. These secondary metabolites make the plant unappealing to predators, protecting its stems, leaves, and fruits. However, the ingestion of cucurbitacins can be harmful to humans. It might determine the outbreak of gastrointestinal disorders and even lead to more serious health risks[2]. For generations, careful plant breeding has ensured Scopatizzo melons to be deliciously sweet[3]. Nevertheless, the distinctive unpleasant taste of the wild ancestors can still appear due to random genetic backmutation and cross-pollination phenomena[1]. Hence, it is crucial to assess the presence of cucurbitacins in these fruits to protect both the consumer's health and the economic losses of local producers.

In this communication, the hyphenation of hydrophilic interaction liquid chromatography (HILIC) with UV detection and atmospheric pressure chemical ionization (APCI) high-resolution mass spectrometry (HRMS) was successfully exploited for the identification of all the major cucurbitacins occurring in bitter-tasting Scopatizzo samples. The UV spectra interpretation of cucurbitacins, along with the rationalization of MS/MS spectra resulting from the collision-induced dissociation of carbocations resulting from the in-source fragmentation of cucurbitacin ions as protonated molecules, returned precious information about the discriminating structural traits between the diverse cucurbitacin molecules. Four cucurbitacins were recognized in Scopatizzo fruits, *i.e.*, cucurbitacin R, cucurbitacin D, cucurbitacin B, and 23,24-dihydrocucurbitacin B. The identification was corroborated by the few available analytical standards, and the comparison with the cucurbitacin profile of the cucumber *Ecballium elaterium* L., representing a well-known and studied natural source of cucurbitacins.

References:

[1] O.D. Palmitessa *et al.*, Horticulture (2023), 9(11), pp. 1206 – 1214.
[2] C.H. Ho *et al.*, The Journal of Emergency Medicine (2014), 46(6), pp. 772 – 775.
[3] Y. Shang *et al.*, Science (2014), 346(6213), pp. 1084 – 1088.

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MAS-PO-001

Advances in thyroglobulin measurement: exploring dried blood spot mass spectrometry for enhanced clinical utility

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In contemporary medical practice, human thyroglobulin (Tg) represents the primary tumour biomarker for detecting the recurrence of differentiated thyroid carcinoma (DTC) in patients who have undergone thyroidectomy[1]. Tg is a large and highly glycosylated tissue specific protein exclusively produced by both healthy and tumour thyroid follicular cells in the thyroid gland[2]. Different techniques, including immunometric assays (IMA) and radioimmunoassays (RIA), have been implemented in clinical settings to gauge Tg levels in blood samples collected through venipuncture[3]. However, the reliability of these methods is compromised by the presence of antibodies, including antithyroglobulin antibodies (TgAbs) and heterophile antibodies (HAs), resulting in frequent inaccuracies in the quantification of T due to either the under or overestimation of the actual values[4,5]. In recent years, liquid chromatography tandem mass spectrometry (LC-MS/MS) has emerged as a distinctive and alternative tool aimed at overcoming the challenges posed by antibody interference[6]. Despite its potential, the effectiveness of LC-MS/MS has yet to be fully explored and, if performed, could improve our knowledge regarding the potentiality of this tool for the detection of Tg[3, 6].

In this work, we present a workflow, based upon LC-MS/MS and Stable Isotope Standards and Capture by Anti-Peptide Antibodies (SISCAPA®) technology, to quantify Tg in patients with thyroid cancer, indicating greater sensitivity and specificity with respect to the routinely available protocols. Moreover, this workflow is also currently being translated and tested for use with samples obtained with DBS (dried blood spot) devices, a simple, cost effective, and minimally invasive alternative to those obtained by venipuncture[7]. Based upon these findings, this LC-MS/MS and SISCAPA® based approach not only shows the potential for improving the accuracy of Tg quantification but may also simplify this process for patients living in remote areas who could independently collect DBS samples for Tg monitoring.

References:

[1] Haugen BR, Alexander EK, Bible KC, Doherty GM, Mandel SJ, Nikiforov YE, et al. 2015 Thyroid. 2016;26: 1–133
[2] Beynon ME, Pinneri K. Acad Forensic Pathol. 2016;6: 217–236
[3] Algeciras-Schimnich A.. Crit Rev Clin Lab Sci. 2018;55: 205–218
[4] Rahmoun MN, Bendahmane I. Ann Endocrinol. 2014;75: 15–18
[5] Giovanella L, Ghelfo A. Clin Chem. 2007;53: 1871–1872
[6] Hoofnagle AN, Roth MY. J Clin Endocrinol Metab. 2013;98: 1343–1352
[7] Lei BUW, Prow TW.. Biomed Microdevices. 2019;21: 81.

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MAS-PO-002

Efficient Photooxidation Processes for the Removal of Sildenafil from Aquatic Environments: A Comparative Study

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The erectile dysfunction drug sildenafil has attracted a great deal of attention in recent years due to its widespread legal and illegal use around the world and its increasing use by young people for recreational rather than medical purposes[1]. Due to sildenafil's high stability in various environmental conditions and its accumulation or phototransformation in receiving waters, this dangerous trend poses a significant risk to both human health and the environment[2]. Therefore, in-depth studies are needed to find innovative methods for completely removing sildenafil from the aquatic environment, while limiting the formation of more toxic derivatives. This study investigated the efficacy of photooxidation processes for removing sildenafil and its potentially toxic derivatives from water. Distilled water and synthetic wastewater were treated with three different oxidants: peroxymonosulphate (PMS), peroxide sulphate (PS) and hydrogen peroxide (H_2O_2), and a heterogeneous catalyst, TiO_2. The investigation also considered the formation of potentially toxic phototransformation products, performing a tentative structural identification by LC-ESI-MS and MS^n. The results proved that the Sunlight/PMS system is the most effective for entirely and environmentally friendly removal of this drug and its transformation products from aquatic environments, achieving complete degradation in distilled water and synthetic wastewater after 80 and 130 minutes of irradiation, respectively. Toxicity bioassays on *Vibrio fisheri* and *in silico* tests using the software ECOSAR confirmed the non-toxic nature of the phototransformed products. This study highlights the potential of Sunlight/PMS photooxidation as a promising strategy for mitigating the environmental risks associated with sildenafil contamination.

References:

[1] M. Wanjari and S. Late, "Use of Sildenafil in young adults: a growing health problem," *Pan Afr. Med. J.*, 2023, 44, doi: 10.11604/pamj.2023.44.113.39168.

[2] D. Chen, X. Deng, and S. Jin, "A Review on Epigenetic Toxicological Mechanisms of Sildenafil and Its Metabolites, the Emerging Pollutants," *Rev. Environ. Contam. Toxicol.*, 2023, 26, doi: 10.1007/s44169-023-00050-0.

MAS-PO-003

Pea plants communication mediated by volatile organic compounds

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Plants are members of communities inhabiting an environment within which they can share or compete for resources as well as communicate [1,2]. Plants have evolved various mechanisms to explore the environment and interact with neighbouring plants. Among these the most effective being the release of arrays of volatile organic compounds (VOCs) from their leaves, flowers, and fruits into the atmosphere and from the roots into the soil[1].

These communicative responses are well documented[1,2,3,4], but what precedes them and the mechanisms that are actively involved, have yet to be identified. To fill this gap the present work will measure the changes in VOC emission of pea plants acting with either a cooperative or competitive attitude.

Two varieties of *Pisum sativum*, L. (*sativum sativum* and *sativum macrocarpon*), were chosen as model plants, to compare the behavior and emissions within the same or different genotypes belonging to the same species or genus. Pea plants were grown in a phytotron with eight climatic chambers. An untargeted metabolomics approach was applied using a Proton Transfer Reactor - Time of flight - Mass Spectrometer (PTR-MS-TOF) analysis. Preliminary results reveal differences in VOC emissions when comparing cooperating and competing pea plants. This study shed definite light on the physiological and molecular events occurring in interacting plants.

References:

[1] N. Dudareva, F. Negre, D. A. Nagegowda, I. Orlova, Critical reviews in plant sciences, 2006, 25(5), 417-440.
[2] R. Pierik, C. L. Ballaré, M. Dicke, Plant, Cell & Environment, 2014, 37(8), 1845-1853.
[3] M. Stolarz, Plant signaling & behavior, 2009, 4(5), 380-387.
[4] S. Guerra, A. Peressotti, F. Peressotti, M. Bulgheroni, ... U. Castiello, Scientific Reports, 2019, 9(1), 16570.

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MAS-PO-004

Sustainable food packaging solutions from tea waste: mass-spectrometry based analysis for molecular fingerprinting and safety assessment

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Packaging plays a crucial role in facilitating modern food systems. Although conventional plastics find wide applications in the field of food packaging, the negative environmental impact caused by the disposal of "single-use plastics" is currently driving the market towards alternative solutions[1]. Consequently, the demand to develop and produce eco-friendly alternatives for food packaging is increasing. The most recent research concerning bioplastic production focuses on by-products and waste materials from food industries[2]. In this work, tea waste (TW) extract has been added to a polylactic acid (PLA) polymeric matrix in order to fabricate new active bio-materials for packaging applications, able to extend food shelf-life avoiding moisture loss and colour and textural changes. Liquid chromatography coupled to tandem mass spectrometry with electrospray ionization in negative ion mode (LC-ESI(-)-MS/MS) has been used to provide an untargeted characterization of the bioactive compounds occurring in TW extract, which could be freely released in the head-space of packaging, acting as antioxidants. Data-dependent acquisition offered the possibility to get selective MS/MS spectra, allowing the identification of several metabolites with well documented biological activity that accounted for the high antioxidant properties of the fabricated bioplastics (radical scavenging activity up to 60% against DPPH radical). As food contact materials should comply with the specific conditions described in the EU Regulation 10/2011, which lists all the permitted substances that can migrate into food or food simulants[3], an evaluation of the non-intentionally added substances (NIAS) released from TW based plastics was carried out. An HS-SPME-GC-MS method, using a polydimethylsiloxane fiber (100 µm), was optimized to analyse the volatile organic compounds released from PLA and PLA/TW composites. The results obtained from the molecular fingerprint of PLA volatiles, mainly comprising aldehydes and few substances of health concerns, showed that VOC emission was reduced by TW extract addition, thus increasing the safety of the fabricated materials for food contact purposes.

References:

[1] Cruz R. M. S. *et al.*, *Foods*, 2022, 1–39,
[2] Acquavia M. A.*et al.*, *Food Chem.*, 2023, 1-12
[3] Riboni N. *et al.*, *Separations*, 2023, 1-21 ,

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MAS-PO-005

NIR and HR-MS techniques for the prediction of physical, chemical and biological properties of honey

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Natural Complex Products (NCPs) based on Natural Complex Matrices (NCMs), derived from medicinal plants are used to realize substance-based medical devices. In recent years, thanks to the evolution of the regulatory framework about medical devices in EU (Reg 2017/745) is of great importance increasing the knowledge about complex systems emerging properties that can be related to their biological activity. Therefore, new analytical approaches need to be applied for a complete characterization of NCPs that is not limited to a single compound[1,2].

In this scenario, an exhaustive characterisation of the physical, chemical and biological properties of honey as NCMs, which depend on its botanical origin and geographical production area, is of growing interest to monitor the quality of the product and guarantee its characteristics[3].

Despite the number of studies on honey, a comprehensive approach that describes with analytical tools the specific physical, chemical and biological properties associated with its composition is still lacking.

To identify an approach that describes the complexity of honey as much as possible, in the present work NIR and HR-LC-MS fingerprint analyses on several samples of honey (blend of polyfloral and Acacia) coming from different geographical areas (Europe and South America) were carried out and their correlation with various physical, chemical and biological properties were evaluated. In particular, electrical conductivity, glucose and fructose content, antioxidant activity, abiotic adhesion were measured.

Unsupervised multivariate statistical analysis on NIR and UHPLC-qToF metabolomic fingerprint was applied for a preliminary description of the behaviour of the different types of honey.

Partial Least Square regression (PLS-r) was used to correlate electrical conductivity, glucose and fructose content, antioxidant activity, abiotic adhesion with NIR and UHPLC-qToF data. The statistical models created highlighted the presence of some different honey samples, which were further subjected to targeted analyses of phenolic compounds.

In conclusion, the studied approach is suitable for identifying the correlation existing between chemical and physical/biological characterization data.

References:

[1] M. Burico, G. Fodaroni, E. Flamini, N. Ascani, G. Proietti, S. Tamimi, C.M. Quintiero, L Massa., M. Gianni, L. Mattoli, Journal of Mass Spectrometry, 2022, 57, e4878.
[2] L. Mattoli, M. Gianni, M. Burico, Mass Spectrometry Reviews, 2022, e21773.
[3] E. Schievanoa, M. Stocchero, V. Zuccato, I. Conti, L. Piana, Food Chemistry, 2019, 288, 96–101

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MAS-PO-006

Comparison of different methodologies for batch effect correction for an Untargeted Metabolomics analysis by UHPLC-MS-qToF

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It has estimated that plants produce from 90,000 to 200,000 different compounds classified into primary and secondary metabolites. To define the plants metabolome, it is necessary the development of metabolomic approaches, to increase the identification and quantification of plants metabolites, their patterns and relationships as part of Natural Complex Matrices (NCMs)[1]. In this way untargeted and targeted metabolomics approach using hyphenated methods, such as UHPLC-qToF, are widely applied to obtain high resolution mass data.

Untargeted metabolomic data obtained by HR-LC-MS techniques are affected by intra-batch and inter-batch effects, which are the major confounding factors in data interpretation[2]. Batch effects lead to results that are not reproducible along the analytical sessions; this is why experimental data-processing and data pre-treatment strategies are necessary to minimize its impact.

In this study fourteen samples composed by NCMs were analysed in three different analytical sessions. Each sample was stored at -80°C before acquisition and acquired in randomized sequences. The following correction strategies for batch effect were applied:

- The use of different internal standards (ISTD)[3] added to the samples to normalize the response in specific regions of the entire chromatogram depending on chemical similarity associated to the analytical method.

- The use of quality controls sample (QC) at the same concentration randomly included along the analytical session as reference for apply the substraction of the mean responses to all the compounds detected (mean centering) and the probabilistic quotient normalization (PQN)[4].

- The use of quality controls sample (QC) at different concentrations randomly included along the analytical session that generate for each compound a linear regression model to estimate the compound response.

This study highlights the best way to correct batch effect to characterize and monitor the quality and manufactoring process of products based on NCMs.

References:

[1] L. Mattoli, M. Gianni, M. Burico, Mass Spectrometry Reviews 2022, 42, 1358-1396.
[2] W. Han, L. Li, Mass Spec Rev. 2020, 1 – 22.
[3] D.T. Burns, M.J. Walker, Anal Bioanal Chem 2019, 411, 2749–2753.
[4] F. Dieterle, A. Ross, G. Schlotterbeck, H. Senn, Anal. Chem. 2006, 78, 4281-4290.

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MAS-PO-007

Comparative proteomic analysis by shotgun approach of two cultivars of *Lupinus angustifolius:* "Polo" and "Boregine"

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Lupin belongs to the legume family (*Fabaceae*) and it has both health and commercial values in the food industry in relation to their high protein content, high concentration of essential amino acids and dietary fiber, and negligible starch contents.[1] In addition, lupin seeds have many nutraceutical properties, including hypoglycemic activities or the ability to maintain low-level of both cholesterol and blood pressure. Therefore, during the last years there has been a growing interest for this legume which is considered as a target food for healthy living.[2] On the other hand, with the rapid introduction of novel foods and new ingredients in traditional foods, the number of people allergic to lupin is also rising, but the frequency of sensitization and allergic reactions to lupin in the general population is still unknown.[3] All legumes contain various anti-nutritional substances but, unlike other legumes, lupin has anti-nutritional components which are represented by quinolizidine alkaloids causing a bitter taste. They can be toxic and therefore are removed through specific technological processes.[4] Taking into account consideration that lupin seeds are recognized as a protein-rich crop and their use as a dietary protein source is of increasing interest, in the present work a comparative proteomic analysis, both at a qualitative and quantitative level, of two different cultivars of narrow-leaf lupin (*Lupinus angustifolius*), namely "Polo" and "Boregine", was carried out. Particularly, the "Polo" variety is naturally free or almost free of quinolizidine alkaloids. These cultivars show a good resistance to water stress, lodging, and are mainly, but not only, used for the production of feed and fodder. The preliminary results of this investigation highlighted that, although the two cultivars show a very similar protein composition, some differences related to the different expression level of some genes are still present. Particularly, "Boregine" shows a higher amount of a group of proteins having allergenic properties, whereas "Polo" contains a higher amount of proteins involved in antioxidant activity. These finding might be correlated to a major resistance of the cultivar for "Polo" against biotic and abiotic stresses, and to a potential major allergenic property of the cultivar "Boregine".

References:

[1] N. Al-Saedi, M. Agarwal, W. Ma, S. Islam, Y. Ren, Molecules 2020, 25, 1782.
[2] A. Tahmasian, J. A. Broadbent, A. Juhasz, M. Nye-Wood, T. T. Le, U. Bose, M. L. Colgrave, Food Chemistry 2022, 367, 130722.
[3] J. C. Jimenez-Lopeza, R. C. Foleyc, E. Breard, V. C. Clarked, E. Lima-Cabelloa, J. F. Floridoe, K. B. Singh, J. D. Alché, P. M. C. Smith, Food Chemistry 2018, 244, 60-70.
[4] T. A. El-Adawy, E. H. Rahma, A. A. El-Bedawey, A. F. Gafar, Food Chemistry 2001, 74 (4), 455-462.

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MAS-PO-008

Exploring the interaction between gonads and sex chromosome complement on plasma, hippocampus and hypothalamus neuroactive steroid levels

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Neuroactive steroids are steroid hormones, such as pregnenolone, progesterone, testosterone, and their metabolites, with important modulatory actions on behavior and nervous functions[1]. They are produced both in peripheral glands and in the nervous system through the steroidogenic process[1]. Previous studies have reported that plasma neuroactive steroid levels do not exactly reflect what occurs in the central nervous system and those levels are different based on the brain region analyzed[3] and sex[2]. These concepts have been described in physiological and in pathological situations[3], and even after a period of gonadectomy, suggesting that other factors may be involved in the regulation of their levels[2]. Interestingly, sex steroid levels are influenced by sex chromosome complement[4]. However, the effect of sex chromosomes on neuroactive steroids in the two sexes has not been evaluated yet.

The four core genotype (FCG) mouse is an experimental model in which the sex chromosome complement is unrelated to the animal's gonadal sex[5]. Therefore, this experimental model allowed us to investigate the effect of gonads in relation to chromosome complement on the levels of neuroactive steroids in plasma, hippocampus, and hypothalamus assessed by liquid chromatography coupled with tandem mass spectrometry[6].

Data obtained showed a tissue-specific involvement and a regional-specific interaction of sex chromosomes and gonads, resulting in neuroactive steroid level differences in plasma, hippocampus, and hypothalamus based on the genotype.

Due to the high number of neurological and psychiatric disorders associated with sex- and regional-specific alterations of neuroactive steroid levels and the implication of sex chromosome genes in pathological conditions, the results of this study may help to improve the knowledge of related brain disorders.

References:

[1] R.C. Melcangi, L.M. Garcia-Segura, A.G Mensah-Nyagan, Cell Mol Life Sci, 2008 Mar;65(5):777-97.
[2] D. Caruso, M. Pesaresi, O. Maschi, S. Giatti, L.M. Garcia-Segura, R.C. Melcangi, J Neuroendocrinol. 2010;22(11):1137-1147.
[3] M. Pesaresi, O. Maschi, S. Giatti, L.M. Garcia-Segura, D. Caruso, R.C. Melcangi, Horm Behav. 2010;57(1):46-55.
[4] R.A.J. Miller, A.P. Williams, S. Kovats, Front Pharmacol, 2023 Mar 30, 2023;14:1150282.
[5] A.P. Arnold, X. Chen, Front Neuroendocrinol. 2009;30(1):1-9.
[6] D. Caruso, M. Pesaresi, F. Abbiati, et al., Psychoneuroendocrinology, 2013;38(10):2278-2290.

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MAS-PO-009

Oral fluid as a new investigative matrix to determinate IGSR and OGSR exposure

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The increased use of ammunition without lead and heavy metals was observed, leading to a growing interest in the detection of organic gunshot residues (OGSR) as evidence of firearms related crimes; however metal determination helps us to determine the type of ammunition used.[1,2]

The purpose of this work is the development of a reliable analytical method by means of ICP-MS for the determination in oral fluids (OF) of the most common metals used found in ammunition and gun cleaning oils.

For this purpose, acid extraction in microwave was used for the OF clean-up and metals extraction before ICP-MS analysis.

The method was tested on real samples: a shooting session was performed in an open shooting range; the shooters fired from 2 to 200 rounds with a 9x21 caliber, after which they were sampled. Samples were analyzed confirming that metals explosives may be detected in OF, the use of this matrix may be of great interest for investigative purposes as it is not affected by secondary transfer. and the sampling is fast, not invasive and can be performed by non-medical staff. The study demonstrates how the most commonly used metals both in the ammunition and in the primer are found in different concentrations depending on the type of cartridge used and the number of shoots. The study also showed that people in close contact with the shooters (example: shooting instructor) still inhaled a large amount of metals and allows us to assess the presence of the risk factors of the exposed subjects. The presented method allows the determination of very low traces of analytes, providing evidence of a direct contact with IGSR.

This represents an interesting starting point for the assessment of the potential exposure to IGSR or the use of firearms at a crime scene.

In this work also the persistence of IGSRs in OF was investigated. The preliminary results obtained during this trial are very promising, as a close correlation between the concentration of IGSR in saliva and the time elapsed between sampling and exposure was observed.

References:

[1] N. Surname, N. Surname, Journal Year, Volume, initial page – last page. R.V. Taudte, A. Beavis, L. Blanes, N. Cole, P. Doble, C. Roux, Detection of gunshot residues using mass spectrometry, Biomed Res. Int. 2014 (2014) 1–16.

[2] J. Yinon, S. Zitrin, Modern Methods and Applications in Analysis of Explosives - Jehuda Yinon, Shmuel Zitrin -. Google Books, j.%2C Zitrin., Wiley, Chichester, 1993.

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MAS-PO-010

Method optimization for the analysis of thyroid hormones and their main metabolites

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In recent years, the number of athletes subjected to doping control who have declared the use of thyroid hormones has significantly increased[1,2]. There appears to be a necessity to investigate and assess whether the use of thyroid hormones could constitute a substance of abuse in sports, along with the potential consequences that this may provoke. The present study aims to develop an analytical method with an adequate recovery of all the components of the thyroid metabolic pathway and then apply it to real urine and serum samples from individuals who have assumed thyroid hormones[3]. Indeed, the purpose is to investigate if, compared to euthyroid subjects, there are different metabolic ratios, i.e. T3AA (3,3′,5-triiodothyroacetic acid) /T4AA (3,3′,5,5′-tetraiodothyroacetic acid), T3/T3AA and T4/T4AA that could indicate an abuse of these hormones[3]. The evaluation of different organic solvents, with or without additives, for the mobile phases, comparison between liquid-liquid extraction, with different solvents and at different pH, and solid phase extraction, with different types of cartridges, were evaluated. Raw data were acquired in positive and negative electrospray ionization modes using an Agilent Technologies 1290 Infinity II series HPLC coupled to an Agilent QTOF 6546 acquiring in Full scan and Product Ion Scan acquisition modes and an Agilent Technologies 1290 Infinity II series HPLC coupled to an Agilent Ultivo LC/QT operating in MRM (Multiple Reaction Monitoring) acquisition mode. Preliminary results suggest that a good compromise for the recovery of the main thyroid hormones and their acidic and basic metabolites was obtained using Oasis WAX (Weak Anion Exchange) cartridges, applying two different elutions that enable the differentiation between neutral and basic compounds and acidic compounds (including acidic metabolites containing carboxylic functional groups). The Full scan mode was used to optimize parameters as capillary voltage, nebulizer gas pressure, nozzle voltage, sheath gas flow, sheath gas temperature, drying gas flow, and drying gas temperature for the ionization source. In particular, the parameters were set to avoid in-source fragmentations, especially for acid metabolites such as T3AA and T4AA. The Product Ion Scan mode was used to study the analytes fragmentation process to find the most abundant fragments formed. This step was necessary to select the most relevant transitions in the MRM acquisition method. Adding ammonium formate, ammonium fluoride, and acetic acid to the mobile phase showed no improvement in responses compared to classic 0.1% formic acid. In conclusion, thyroid hormones and their derivatives are structurally related to the non-essential amino acid tyrosine. However, physicochemical differences make it challenging to apply an analytical procedure for their simultaneous extraction and detection. In this study, an LC-MS/MS method was optimized to detect TH and derivatives with a unique pretreatment procedure and in a single chromatographic-mass spectrometric run.

References:

[1] Martínez Brito, D., et al., Drug Testing and Analysis, 2022, Vol. 14 (8), 1438-1450.
[2] Chiovato L., et al., Advances in Therapy, 2019, Vol. 36, 47-58.
[3] Martínez Brito D., et al., Drug Testing and Analysis, 2022, Vol. 14 (7), 1176-1186.

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MAS-PO-011

Occurrence of ChloroPerFluoroPolyether Carboxylates (PFPECAs) in environmental and biota samples: evaluation of toxicity profile of ClPFPECA-N2 by lipidomics approach

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Per- and Poly-FluoroAlkyl Substances (PFASs) constitute a broad class of man-made chemicals related to some human diseases[1]. In the last years, alternative compounds deemed safer than the called "legacy" PFASs (PFOA, PFOS...) were synthetized. An example is the "emerging" class called ClPFPECAs which were recently founded in both environmental[2] and biota[3,4] samples. Herein, we report the evaluation of toxicity profile of ClPFPECA-N2 by lipidomics approach. HepG2 cells were expose to increasing concentrations and after extraction, lipidomics analysis was performed by UHPLC-HRMS. Data were elaborated using Lipostar2[5] (Molecular Discovery Ltd.) and the obtained results shown lipids dysregulation for ClPFPECA-N2 compared to the control samples. Particularly, MUFA and PUFA cardiolipins and triacylglycerols were the lipidic classes mainly responsible for the separation in the multivariate statistical analysis (PCA and PLS-DA) between treated samples and control.

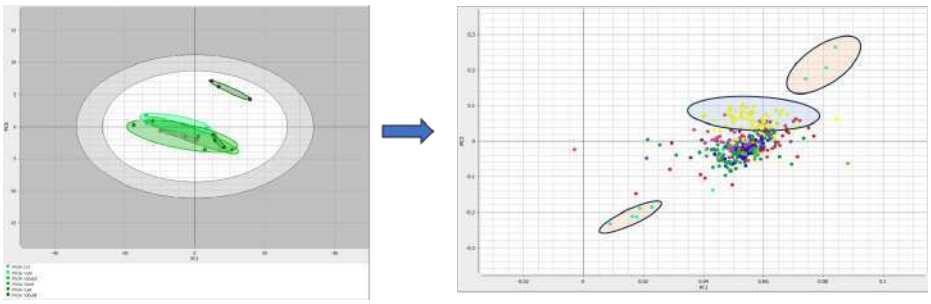

Figure 1: Multivariate statistical analysis (PCA) of HepG2 cells treated with ClPFPECA-N2.

References:

[1] R. C Buck, J. Franklin, U. Berger, J. M. Conder, I. T. Cousins, P. de Voogt, A. A. Jensen, K. Kannan, S. A. Mabury, S. PJ van Leeuwen. Integrated environmental assessment and management vol. 7,4 (2011): 513-41.

[2] J.P. McCord, M.J. Strynar, J.W. Washington, E.L. Bergman, S.M. Goodrow. Environ. Sci. Technol. Lett., 7 (2020), pp. 903-908

[3] S. Moretti, C. Barola, D. Giusepponi, F. Paoletti, A. Piersanti, O. Tcheremenskaia, G. Brambilla, R. Galarini. Chemosphere, Volume 312, Part 1, 2023,137214

[4] S. Moretti, G. Brambilla, F. Maffucci, C. Barola, E. Bucaletti, S. Hochscheid, S. Canzanella, R. Galarini, M. Esposito. Environmental Pollution, Volume 343, 2024, 123257

[5] L. Goracci, S. Tortorella, P. Tiberi, R.M. Pellegrino, A. Di Veroli, A. Valeri, G. Cruciani. Anal. Chem., 2017, 89 (11), pp 6257–6264]

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MAS-PO-012

Untargeted metabolomic-guided phytochemical investigation of *Morus alba* L. twigs extract and evaluation of antimicrobial activity.

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In the field of public health, a pressing concern is antimicrobial resistance, a significant global threat[1]. Plant natural products offer promise in combating multi-drug resistance by acting as antibacterial agents through various mechanisms[2]. Widespread natural product classes, such as terpenes, flavonoids, alkaloids, and phenolics have demonstrated antimicrobial activity[3].

Morus alba L. (Moraceae) twigs have historical use in traditional medicine for muscle-related symptoms, yet their chemical constituents and clinical potential remain underexplored[4]. Here, we conducted a metabolomic-guided phytochemical investigation, based on a LC-HRMS/MS and Molecular Networking combined approach, of an industrial extract of *M. alba* L. twigs, obtained in the field of our scientific partnership with Indena Spa (Milan, Italy). Molecular networking uncovered different clusters of prenylated polyphenols, glycosylated phenolic compounds and Diels-Alder dimers guiding the phytochemical profiling of this extract. Our analysis allowed us to swiftly annotate and isolate 17 secondary metabolites including stilbenoids, flavonoids, and flavanones.

Isolated metabolites were tested for their antimicrobial activity against *Staphylococcus* spp. The most active compound resulted to be kuwanon C, exhibiting a MIC of 8 µg/mL against *S. aureus* ATCC 43300 (methicillin resistant, MRSA) and *S. epidermidis* ATCC 3598 (a biofilm producers' strain). The same concentration resulted bactericidal. We also observed an additive interaction between 4 µg/mL kuwanon C in combination with low oxacillin dosage against the MRSA. Due to the high chemical structure similarity of isolated metabolites, structure-activity relationships of these versatile scaffolds have been postulated.

References:

[1] De Oliveira D. M. P., Forde B.M., Kidd T.J., Harris P.N., Schembri M.A., Beatson S.A., Patersona D.L., Walker M.J., Clinical Microbiology Reviews, 2020, 33 (3).
[2] Woo S., Marquez L., Crandall W.J., Risener C.J., Quave C.L., Natural products report, 2023, 40, 1271–1290.
[3] Drasar P. D., Molecules, 2020, 25(1), 6.
[4] Kwak, H.J., Kim, J., Kim, S., Park S., Choi J., Kim S.H., Scientific Reports, 2023, 13, 20570.

MAS-PO-013

Natural acidic aqueous extracts of *Vicia faba* L. pod valves: an innovative source of bioactive compounds to use as adjuvant in the pharmacological treatment of Parkinson's disease

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Broad bean (*Vicia faba* L.) is a vegetable belonging to Leguminosae family and nowadays it's consumed worldwide for human and animal nutrition because of its low cost, ease of cultivation and edible seeds, which are rich in several nutritional compounds, e.g. carbohydrates, proteins, fibres and some specific secondary metabolites i.e. polyphenols. It's also well known as an important natural source of L-Dopa, the dopamine precursor to be used in first-line treatment of Parkinson's symptoms[1]. Due to the neurotoxic effect of synthetic L-dopa and its side effects, natural sources of this bioactive compound should be preferred for the "on-off" motor fluctuations inhibition. Recent studies confirmed that also broad bean by-products could be an attractive natural source of bioactive compounds[2]. Because of the huge presence of health beneficial compounds also in *Ribes rubrum* L., *Punica granatum*, *Phyllanthus emblica*, this work was focused on the characterization of pod valves extracts in these acidic aqueous matrices. 2D van Krevelen diagrams were used as a tool to obtain molecular formula maps useful for a rapid and comprehensive analysis of the more representative metabolite classes[3-5]. An LC-ESI/LTQ-Orbitrap/MS^2 approach was used to identify L-dopa and major polyphenolic compounds in each extract. This study confirmed the higher content of L-dopa in pods compared to beans, with values even comparable to those of *Mucuna pruriens*[1]. It also highlighted the very low content of pyrimidine glycosides vicine and convicine, the two metabolites responsible for the haemolytic crisis in favism patients[6]. To evaluate the potential use of pod valve extracts as an adjuvant in the treatment of Parkinson's disease, a neuroprotective assay was carried out against the human neuroblastoma cell line SH-SY5Y. All different tested extracts showed to be good candidates as adjuvants as no cytotoxic activity even at relatively high concentrations was observed.

References:

[1] C. Tesoro, R. Ciriello, F. Lelario, A. Di Capua, R. Pascale, G. Bianco, M. Dell'Agli, S. Piazza, A. Guerrieri, L. Scrano, S. A. Bufo, M.A. Acquavia, Molecules 2022, 27, 1-14.
[2] L.M.M. Krenz, S. Grebenteuch, K. Zocher, S. Rohn, D. Pleissner, Biomass Conversion and Biorefinery 2023, 1-18.
[3] B. Ahmad, N. Hafeez, A. Rauf, S. Bashir, H. Linfang, M. Rehman, M. Mubarak, M. Uddin, S. Bawazeer, M. Ali Shariati, M. Daglia, C. Wan, K. Rengasamy, South African Journal of Botany 2021, 138, 278-310.
[4] Z. Zorenc, R. Veberic, D. Koron, S. Miosic, O. S. Hutabarat, H. Halbwirth, M. Mikulic-Petkovsek, Planta 2017, 246, 217–226.
[5] G. Gülmez, A. Şen, T. Şekerler, F. Kader Algül, Ö. T. Çilingir-Kaya, A. Şener., J Food Biochem. 2022, 46, 1-11.
[6] Y. Huang, Nutritional Toxicology 2022, pp. 355-384.

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MAS-PO-014

Tackling the diagnostic challenge of thyroid lesions with advanced MS-based spatial proteomics

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Thyroid nodules present a diagnostic challenge due to their diverse morphological appearances, which often overlap between benign and malignant entities. In this study, we aimed to define the molecular profiles of different thyroid lesions, ranging from benign to malignant, that could aid in the better characterisation of the indeterminate thyroid lesion named as non-invasive follicular thyroid neoplasm with papillary-like nuclear features (NIFTP). Our group have previously shown the potentiality of MALDI-Mass Spectrometry Imaging (MSI) in the characterisation of NIFTP lesions using both cytological[1] and histopathological tissue samples[2].
In this work we analysed a tissue microarray (TMA) containing 88 cores from 44 donors, using a MALDI-MSI approach using a TIMS-TOF-FLEX instrument, and we investigated the tryptic peptides profiles of papillary thyroid carcinoma (PTC), follicular variant of PTC (FVPTC), follicular adenoma (FA), Hürthle adenoma (HA), and NIFTP thyroid lesions. Our analysis provided high-resolution proteomic profiles specific to each lesion type, along with spatial characterization within the tissue microenvironment.
Characterizing NIFTP poses a challenge due to its histological similarity to both benign FA and malignant PTC and this overlap could find confirmation in our results when comparing their proteomic signature. The subtle morphological differences between NIFTP and encapsulated follicular variant of PTC further complicate diagnosis, necessitating additional molecular markers for accurate classification. Hence, integrating molecular profiling techniques like MALDI-MSI could provide valuable insights to enhance the diagnostic accuracy of NIFTP lesions. The integration of these findings into a larger patient cohort, as part of an ongoing project initiated several years ago, promises to enrich our understanding of thyroid pathology and facilitate more accurate diagnostic and therapeutic strategies in thyroid cancer management[1]. This work underscores the value of molecular characterization in complementing morphological assessments for improved diagnostic accuracy in thyroid nodules.

References:

[1] I. Piga, F. Pagni, Biochimica et Biophysica Acta (BBA)-Proteins and Proteomics 2020, 11, 1868.
[2] I. Piga, F. Pagni, Int J Mol Sci 2023, 24, 2567.

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MAS-PO-015

Hydroxyanthracene derivates citotoxicity: A differential evaluation between single molecule and whole plant extract

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Hydroxyanthracene derivates (HADs) are a group of natural or synthetic compounds with a wide range of biological activities (for instance, anti-inflammatory, antibacterial, and antiarthritic). In addition, because of their properties for helping the normal bowel function, HADs are widely used in constipation as pharmacological drugs and nutritional supplements. Nevertheless, during the past years, a safety usage of HAD products has been placed under consideration from European Food Safety Authority (EFSA) because some scientific studies reported that HADs are not lacking toxicity. In particular, the safety of the use of medicinal plants containing HAD in dietary supplements was re-evaluated concluding that HAD emodin, aloe-emodin, and the structurally related substance danthron have been shown to be genotoxic and carcinogenic until proven otherwise based on other studies. Thus, the first objective of this study was to shed light on the large variability in composition of botanical food supplements containing HAD by a systematic analysis of the qualitative and quantitative composition of a cohort of extracts and raw materials of plants with high levels of anthraquinones commercially available (Cassia angustifolia, Rhamnus purshiana, Rhamnus frangula, Rheum palmatum, and Rheum raponticum) using UPLC-MS/MS[1]. Specifically, the targeted analysis was performed by parallel reaction monitoring (PRM). Since, the current investigations of HAD toxicity were based on in vitro and in vivo studies conducted mainly on the use of the single molecules (emodin, aloe-emodin, and rhein) rather than on the whole plant extract, the qualitative quantitative characterization was the starting point to select the most appropriate products for the treatments for an in vitro cell studies. Thus, the second objective of this study was the investigation, for the first time, of the toxic events of HAD used as single molecule in comparison with the whole plant extracts containing HAD occurring in an intestinal in vitro model of human colorectal adenocarcinoma cells (Caco- 2). A shotgun proteomics approach followed by a bioinformatic elaboration was applied to investigate the differential protein expression in the Caco-2 cells after a single-HAD or whole–plant extract treatment to fully understand the potential targets and signaling pathways. In conclusion, the combination of a detailed phytochemical characterization of HAD products and a largely accurate analysis of the proteomic profile of intestinal cells treated with HAD products provided the opportunity to investigate their effects in the intestinal system.

References:

[1] Tinti L, Cicaloni V, Nezi P, Isoldi G, Etiope P, Barlozzini B, Pecorari R and Salvini L (2023) Hydroxyanthracene derivates citotoxicity: A differential evaluation between single molecule and whole plant extract. Front. Plant Sci. 14:1166075. doi: 10.3389/fpls.2023.1166075

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MAS-PO-016

Evaluation of Protein Aggregation Capture Protocol for Thermal Proteome Profiling Analysis

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Thermal proteome profiling (TPP) is an emerging strategy that combines the cellular thermal shift assay (CETSA) with quantitative proteomic mass spectrometry (MS) to investigate proteome-wide interactions of therapeutic molecules[1]. Ligand-target engagement is determined by detecting changes in protein thermal stability, which requires high quantitative accuracy and reproducible analysis for construction of successful melting curves[2]. Thermal denaturation curves are profiled by using isobaric tandem mass tags (TMT) that enable to multiplex samples and increase quantification precision[1]. A crucial step prior TMT labeling is to remove compounds of lysis buffer, such as detergents, chaotropic agents, and salts, which may affect the labeling efficiency. However, the removal of interferents represents a major source of sample losses and experimental variability[3].

In this study, protein aggregation capture (PAC) approach[3] was employed to provide a rapid and efficient sample preparation for TPP analysis and the performance of quality data was compared to the traditional in-solution digestion method. Protein identifications were comparable for both protocols, but PAC yielded an increased number of peptides (4626 protein groups; 35226 peptides) compared to in-solution protocol (4686 protein groups; 26824 peptides).

Although the melting curves were fitted for all proteins quantified with minimum 2 valid fold changes, only sigmoidal curves with a minimum coefficient of determination (R^2) of 0.8, indicating how well the fold changes fit the melting curve, and a plateau of < 0.3 were included in the statistical analysis[2]. Thus, the number of well-modelled proteins for each experiment was investigated. PAC protocol accurately quantified melting temperature in 88% of proteins identified, versus 83% for the in-solution method. Furthermore, reproducibility was assessed by correlating the melting point (T_m) values of replicate samples. A high correlation of 0.87 was achieved with PAC protocol which outperformed 0.71 for the in-solution method.

Results showed the ability of PAC protocol to profile melting curves with high quantitative accuracy and reproducibility.

References:

[1] M.M. Savitski, B.M. Reinhard, H. Franken, T. Werner, M.F. Savitski, D. Eberhard, D.M. Molina, R. Jafari, R.B. Dovega, S. Klaeger, B. Kuster, P. Nordlund, M. Bantscheff, Science, 2014, 346(6205).
[2] A.L. George, F.R. Sidgwick, J.E. Watt, M.P. Martin, M.Trost, J.L. Marín-Rubio, M.E. Dueñas, J. Proteome Res, 2023, 22(8), 2629–2640.
[3] T.S. Batth, M.A.X. Tollenaere, P. Rüther, A.G. Franquesa, B.S. Prabhakar, S.B. Jensen, A.S. Deshmukh, J.V. Olsen, Mol Cell Proteomics, 2019, 18(5), 1027–1035.

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MAS-PO-017

Blood microsampling for untargeted metabolomics: a preliminary study on patients affected by myocardial infarction

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Blood microsampling is a promising tool for blood collection as it is simple and minimally invasive. It allows multiple sampling and is optimal for longitudinal studies[1]. For these reasons, it has gained attention and has been applied to metabolomics studies. Physical activity induces metabolic changes and a correlation between metabolism and cardiovascular risk has been demonstrated. For example, physical exercise has been shown to improve the catabolism of branched-chain amino acids (BCAA)[2]. The involvement of BCAA in ischemic cardiomyopathy is well known: their plasma levels correlate with the presence and severity of the disease[3]. In this preliminary study, blood samples were collected with Dried Blood Spots (DBS) from patients affected by myocardial infarction participating in a physical rehabilitation program. Blood was collected at 7 time points: before the start of the rehabilitation protocol, before and after the first training, before and after training halfway through the rehabilitation protocol, and before and after the last training. Untargeted metabolomic analysis was performed to assess exercise-induced changes, correlation with clinical outcome and cardiovascular risk factors in these patients. Polar metabolite analysis was performed on DBS with UHPLC-MS. The results showed the most altered metabolic pathways were associated with purine metabolism and histidine metabolism. In particular, xanthine and histidine levels were high at the beginning of rehabilitation and gradually decreased with the training time. Comparing the metabolic phenotype at the beginning and at the end of rehabilitation highlighted a reduction of xanthine, urocanic acid and C5-carnitine. Overall, the use of DBS simplified longitudinal blood sampling and allowed the investigation of metabolic changes during the physical rehabilitation program after myocardial infarction.

References:

[1] C. Nix, M. Hemmati, G. Cobraiville, A-C. Servais, M. Fillet, Frontiers 2021, 8, 681400.
[2] G. Wu, Y. Guo, M. Li, C. Li, Y. Tan, Y. Li, J. Li, L. Wang, X. Zhang, F. Gao, Cells 2022, 11, 1706.
[3] X. Du, Y. Li, Y. Wang, H. You, P. Hui, Y. Zheng, J. Du, Life Sciences 2018, 209, 167-172.

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GC-MS Investigation of Endogenous Lactonization of 2-Hydroxyglutarate in Acute Myeloid Leukemia Patients

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Introduction: 1/5 cases of acute myeloid leukemia (AML) are affected by a mutation relating to genes encoding for isocitrate dehydrogenase (IDH), responsible for oxidative decarboxylation of isocitrate to alpha-ketoglutarate (α-KG). Instead, the mutated IDH enzymes catalyze reduction of α-KG to the metabolite 2-hydroxyglutarate (2-HG), an oncometabolite.[1] A certain amount of R-2-HG-lactone is known to be present in urine specimens of IDHmt brain tumor patients after 2-HG derivatization with (trimethylsilyl)diazomethane for GC-MS analysis.[2] However, it is yet to be clarified whether this metabolite has an endogenous or exogenous origin and the related diagnostic implications. Thus, aim of the study was to ascertain the origin of R-2-HG-lactone comparing lactone formation in solvent, plasma matrix and PBMCs suspension.

Materials and Methods: The analytical workflow has been designed in accordance with UNI EN ISO 15189:2022 and Eurachem Guidelines. The chromatographic run was performed on Crossbond 5% diphenyl / 95% dimethyl polysiloxane and performed with GCMS-QP2020 (Shimadzu) in SIM mode. Identified ions for TMS-derivative of 2-HG were 247 (quantifier), 203, 129, 157 m/z; whilst 159 (quantifier), 115, 131, 85, 101 m/z were the selected ions for TMS-derivative of lactone. Known amounts of 2-HG, at two concentration levels, were spiked in aqueous solution, plasma and PBMCs of healthy subjects and AML IDHmt patients. Subsequently, samples were incubated at 37 °C and GC-MS analysis was performed at three timings: T0, T1 (1h-post), T2 (3h-post).

Results and Discussion: A different decrease in the concentration of 2-HG has been observed at T2, reaching 15%, 35% and 47% in solvent, plasma and PBMCs suspension, respectively. Conversely, there was an increase in lactone proportional to the decrease in concentration of 2-HG. These measurements were elaborated through a Michaelis-Menten kinetic model, obtaining v_{max}, k_{cat} and Km values for each biological matrix. Our data seemed to confirm the hypothesis of an endogenous enzyme capable of catalyzing the 2-HG lactonization. The decrease of 2-HG in non-biological environment also suggested lactone formation *via* autoxidation process.

Conclusion: Lactone appeared to be present endogenously. However, a small amount formed spontaneously even *in vitro*. Further investigations will be necessary to establish with certainty the endogenous origin of lactone and its usefulness in the diagnosis of AML IDHmt.

References:

[1] D. Golub, et. al., Front Oncol. 2019, 9:417.
[2] RS. Berger, et al., Cancers (Basel) 2021, 13(8):1756.

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TEF-KN-01

Nano/micro composite polysaccharide-based stimuli-responsive hydrogels for release of antimicrobial agents in the treatment of skin wounds

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Skin wound healing is a physio-pathological process that involves various steps with the function of restoring the physiological barrier-role of skin (1).

Bacterial infections represent one of the main factors that plays a significant role in delaying the healing of both acute and chronic wounds. This phenomenon has becoming particularly challenging because of the emergence of multi-antibiotic resistant bacteria that makes ineffective the topical administration of common antibiotics (2).

For this reason, there is an urgent need to develop new molecules with broad-spectrum antimicrobial effect or to develop drug delivery systems capable of potentiate the effectiveness of available drugs.

For several decades, hydrogels, particularly those obtained using polysaccharide as starting biomaterial, have been regarded as the gold standard for treating cutaneous wounds, owing to their chemical, physical, and morphological properties that make them exceptionally well-suited for interfacing with tissue lesions and serving as a vehicle for the release of bioactive molecules that stimulate tissue regeneration (3).

In the past years our group has focused high effort in the development of polysaccharide hydrogels (mainly using gellan gum and xanthan gum derivatives) with stimuli responsive features, that be exploited to potentiate the effect of commonly used antibiotics, or with peculiar rheological, physicochemical and morphological properties to release wide spectrum antimicrobial agents (4).

For example, loading the hydrogel with photothermal nanoparticles enabled to obtain near infrared (NIR) sensitive materials capable to generate local heat after laser irradiation that adjuvate and potentiate the pharmacological effect of antibiotics. Still, we have demonstrated that composite hydrogels, obtained by dispersing in the gelling solution nano or microparticles, can give rise to production of therapeutic tools with high versatility and application potential (5).

References:

1. doi.org/10.1016/j.ijpharm.2022.122257
2. doi.org/10.1016/J.IJBIOMAC.2021.08.040
3. doi.org/10.1016/j.cej.2024.149493
4. doi.org/10.1016/j.ijpharm.2021.121231
5. doi.org/10.1016/j.ijbiomac.2023.128766

TEF-KN-02

Rational design of intra-articular drug delivery systems

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Local administration of drugs by intra-articular (IA) injections represents one of the major treatments for arthritis, osteoarthritis or musculoskeletal disorders to reduce pain and inflammation, facilitate motion and function. However, in most cases, the systemic bioavailability of after IA and intra-muscular administration overlaps[1] due to the rapid elimination of drugs and macromolecules through the microvasculature and/or the lymphatic pathway, respectively.

The maintenance of an effective therapeutic concentration of the drug in the joint for prolonged time cannot be achieved by frequently repeated injections which present some risks, such as bacterial infection, bleeding, nerve damage and synovial membrane inflammation. To address this issue, several successful strategies have been proposed, including the synthesis of water insoluble prodrugs and the design of drug delivery systems.

In other words, to deliver sufficient therapeutic doses to the site of action a drug suspension has to be injected tacking into account the following parameters. First, the particle size determines fate of the drug in the joint: nano- and microparticles sizing lower than 3 μm are easily drained by the lymphatic system in both inflamed and naïve models; whereas 10 μm-particles are essentially retained, even if they can activate the biological response of macrophages. However, particle size up to 50 μm should be avoided due to difficulties in injections (i.e. needle diameters range from 25 to 22 G depending on the location) and those up to 100 μm can cause abrasion of the synovia. Thus, the optimal size falls within the narrow 30-50 μm range. Secondly, the optimization of the drug release rate from a suspension or a drug delivery system is challenging because (i) *in vitro* testing methods are not described in the main Pharmacopoeias, (ii) long evaluation time is required and (iii) animal models to establish an *in vitro in vivo* correlation are lacking[2]. Moreover, the achievement of this goal is complicated not only by the features of anatomical district, but also by the quali-quantitative differences of joints synovial fluids of healthy subjects and osteoarthritic patients[3].

Through the presentation of case material taken from our experience on methylprednisolone[2-4], an in-depth analysis on the IA administration of insoluble pro-drugs or long acting injectables will be provided in the attempt to highlight the critical points in the prediction of drug release and in vivo biodistribution.

References:

[1] F. Selmin, U.M. Musazzi, G. Magri, P. Rocco, F. Cilurzo, P. Minghetti, Drug Discovery Today 2020, 25, 321-329.
[2] G. Magri, F. Selmin, F. Cilurzo, N. Fotaki, Eur J Pharm Biopharm 2019, 139, 115-122.
[3] A Panusa, L Regazzoni, G Aldini, M Orioli, A Giombini, P Minghetti, C Tranquilli, M Carini, Anal Bioanal Chem. 2011, 1, 255-267.
[4] A Panusa, F. Selmin, G. Rossoni, M Carini, F. Cilurzo, G. Aldini. J Pharm Sci 2011, 110, 4580-4586.

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TEF-OR-001

How to assess the quality of complex drug products and their copies: the case study of semisolid preparations

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Nonbiological complex drugs (NBCDs) are medicinal products that exhibit intrinsic complexity in terms of their active substance, formulation, or route of delivery, and that cannot be fully characterized using conventional physicochemical analytical methods. An example of NBCDs is topically applied drug products (e.g., semisolid preparations for cutaneous application), where even slight changes in formulation components can significantly impact the quality target profiles of the drug product. Recognizing this complexity, both the FDA and the EMA have recently updated their guidelines for assessing the equivalence of topically applied drug products. According to the FDA, copies of these products must demonstrate both qualitative (Q1) and quantitative (Q2) equivalence to the reference product [1]. In addition, similar semisolid preparations must prove their structural and functional similarity (Q3). This involves comparing their in vitro release and rheological patterns. In 2018, the EMA introduced a draft guideline proposing the concept of "extended pharmaceutical equivalence" as an alternative to traditional bioequivalence studies [2]. This extended approach requires demonstrating the sameness of two formulation in terms of the pharmaceutical form, the qualitative and quantitative composition, the equivalence of the microstructure/physical properties, and in vitro release profile (IVRT). However, if dealing with complex formulations (e.g., creams), equivalence can be established through permeation kinetic studies [e.g., in vitro permeation studies (IVPT)], pharmacodynamic equivalence tests or clinical trials. This work contributes to the existing knowledge on how to assess the Q3 similarity of not Q1/Q2 equivalent semisolid preparations, in terms of in vitro release studies (IVRT), in vitro permeation (IVPT) and rheological behaviour [3]. In this light, Ibuprofen (IB) creams at two different strengths (i.e., 1% and 10%) were used as a model formulation. Starting from reference formulations two changes were made simulating: a minor variation (addition of the humectant), and a major variation (modification of the surfactant). The experimental results highlighted that these variations impacted only in 1% IB formulations where both the equivalences of rheological data and J-values failed. At the highest concentration, the presence of IB crystals broke down the differences in rheological patterns and lead the IB thermodynamic activity at the maximum figuring out an overlapping of the J-values. Such data suggest the combination of these studies, which are thought for the development of copies, could be also applied to the management of post-marketing variations that involve product composition.

References:

[1] FDA, Physicochemical and Structural (Q3) Characterization of Topical Drug Products Submitted in ANDAs, 2022.
[2] EMA, Draft guideline on quality and equivalence of topical products, 2018.
[3] P. Volontè, U.M. Musazzi, et al. Eur. J. Pharm. Sci. 2024, 195, 106726, doi: 10.1016/j.ejps.2024.106726.

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Targeted nanomemedicine: tailoring drug delivery systems for specific diseases

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Nanomedicine advances medical research through improved drug delivery for challenging diseases. Surface modifications enhance NMeds' biodistribution and effectiveness. However, personalized nanomedicine systems are necessary due to disease complexities. TeFarTI's projects focus on tailoring NMed targeting for better therapeutic outcomes. For instance, we optimized hybrid NMeds for retinal targeting[1], delivering a neuroprotective peptide with precision. In another project targeting Huntington's disease (HD)[2], we developed hybrid NMeds with consistent efficacy, eventually transitioning to cholesterol-based NMeds. Moreover, we synthesized novel ligands to improve BBB penetration. Our BBB and GBM co-targeting project[3] tested four ligands, revealing enhanced uptake in GBM cells, particularly with one antibody promoting astrocyte growth. This augmented the efficacy of paclitaxel-loaded NMeds, with successful BBB penetration observed in vivo. These projects underscore the importance of understanding disease and microenvironment intricacies for effective NMed design.

References:

[1] I. Ottonelli, I. Bighinati, E. Adani, F. Loll, R. Craffi, MA. Vandelli, F. Boury, G. Tosi, JT. Duskey, V. Marigo, B. Ruozi, Pharmaceutics 2022, 15(1), 25.
[2] G. Birolini, M. Valenza, I. Ottonelli, F. Talpo, L. Minoli, A. Cappelleri, M. Bombaci, C. Caccia, C. Canevari, A. Trucco, V. Leoni, A. Passoni, M. Favagrossa, MR. Nucera, L. Colombo, S. Paltrinieri, R. Bagnati, JT. Duskey, R. Caraffi, MA.Vandelli, F. Taroni, M. Salmona, E. Scanziani, G. Biella, B. Ruozi, G. Tosi, E. Cattaneo, Pharmacol Res. 2023, 194:106823.
[3] JT. Duskey, A. Rinaldi, I. Ottonelli, R. Caraffi, CA. De Benedictis, AK. Sauer, G. Tosi, MA. Vandelli, B. Ruozi, AM. Grabrucker, 2022, 12;14(7):1450.

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TEF-OR-003

Leveraging (bio)active lipid nanoparticles for biomaterials design and drug delivery applications

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The design of (bio)active nanoparticles which undergo changes in response to an applied stimulus or possess intrinsic therapeutic activity is particularly relevant for biomedical applications. In this talk, I will discuss two key examples: (i) the development of ultrasound-responsive nanoparticles to control enzymatic activity and hydrogel formation and (ii) the use of nanoparticles with bioactive lipidic and inorganic components for the treatment of neurodegenerative diseases.

In a first example, we propose lipid nanoparticles able to trigger the formation of hydrogels[1]. An underexplored trigger for hydrogelation is ultrasound, which is well-established in clinical settings for imaging purposes. We used calcium-loaded liposomes able to release their payload upon ultrasound exposure were used to activate a calcium-dependent tissue transglutaminase, which could in turn catalyze the formation of fibrinogen hydrogels. Precise control over these processes could be achieved, with the calcium release, catalysis rate, and hydrogelation rate all shown to be dependent upon the ultrasound exposure time[2].

(Bio)active nanoparticles can also be exploited for drug delivery purposes in the context of neurodegenerative diseases such as amyotrophic lateral sclerosis (ALS), whose complexity demands multi-functional therapeutic approaches. Here, we engineered lipid self-assembling nanoparticles (SANP) with bioactive lipidic and inorganic components, which we combined with RNA payloads. We used a phosphatidylinositol (PIP) derivative which could restore lysosomal calcium homeostasis and autophagy flux and an antisense microRNA (anti-miRNA) able to prevent the progression of neurodegenerative damage. We further modified the SANP core with cerium to scavenge reactive oxygen species (ROS), which are involved in ALS pathology. *In* vitro, cerium-SANP were able to prevent ROS-induced death of neuronal cells[3], while SANP co-encapsulating PIP and anti-miRNA yielded a synergic reduction of the expression of an ALS protein marker on motoneurons (unpublished). *In vivo* studies in a mouse model of ALS showed that the PIP-SANP formulations were able to improve the overall survival of the mice, which also retained part of their motor skills (unpublished).

Taken together, these examples highlight the tremendous potential of (bio)active lipid-based nanoparticles in tuning the properties of biomaterials and enabling combinatorial drug delivery approaches.

References:

[1] V. Nele, *et al.* Tailoring Gelation Mechanisms for Advanced Hydrogel Applications, Adv Funct Mater 30 (2020).
[2] V. Nele, *et al.* Ultrasound-Triggered Enzymatic Gelation, Advanced Materials n/a (2020) 1905914.
[3] V. Nele, *et al.* Cerium-Doped Self-Assembling Nanoparticles as a Novel Anti-Oxidant Delivery System Preserving Mitochondrial Function in Cortical Neurons Exposed to Ischemia-like Conditions., Antioxidants (Basel) 12 (2023).

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Well-established and new smart nanovesicles for selective Phenformin (POSV) targeting in Medulloblastoma

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Medulloblastoma (MB) is a pediatric brain tumor often associated to activating mutations of the Sonic Hedgehog (SHH) pathway [1]. Inhibitors of SHH pathway are available on the market but have shown limited clinical efficacy, due to compensatory mechanisms restoring downstream activation. We have previously demonstrated that the antidiabetic drug phenformin significantly inhibits the downstream hedgehog-dependent transcription factor Gli1 in preclinical models of SHH MB, causing a substantial reduction of tumor growth. However, phenformin is also associated with high risk of lactic acidosis, due to its intrinsic ability to inhibit hepatic gluconeogenesis. Hence, phenformin loading into carriers, specifically able to bypass the liver and target the brain, would be a suitable strategy.

Here we tested both liposomes and liposome-like delivery systems (niosomes) and showed that encapsulating phenformin into these formulations efficiently allows its delivery to SHH medulloblastoma tumors.

Compared to liposomes, niosomes show several advantages for drug delivery such as lower costs, higher stability and ease of preparation [2]. In particular, Phen loaded liposomes and niosomes have been prepared with suitable characteristics to load proper amounts of the lipophilic drug and to be administered intravenously. We show that phenformin-loaded vesicles are efficiently incorporated into Med1-MB SHH medulloblastoma cells, where they induce a significant decrease of cell proliferation, associated to the activation of the energy stress pathway at the highest concentrations. Consistently, both phenformin-loaded nanocarriers induce a robust decrease of Hedgehog signaling, as documented by the significant decrease of the Hh target gene Gli1. Remarkably, when phenformin-loaded vesicles are administered to mouse models of SHH MB, the concentrations of phenformin are strongly reduced in liver and plasma but significantly increased in the cerebellar tumors, compared to the drug alone, being the effect stronger with niosomes. Accordingly, the intratumor levels of Gli1 mRNA are strongly downregulated, documenting the efficacy of this approach in targeting the Hh signaling *in vivo*.

Together, these data illustrate a novel nanodelivery-based approach to inhibit the oncogenic Hedgehog signaling and to improve the biodistribution of phenformin, potentially reducing its side effects.

References:

[1] J. Briscoe , P.P. Thérond, Nat Rev Mol Cell Biol 2013, 14(7), 416-29
[2] C. Marianecci et al., Adv Colloid Interface Sci 2014, 205, 187-206

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Lipid-based nanocarriers to target brain tumours: recent evidences from preclinical studies

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Gliomas are the commonest brain tumours, which can be classified in low or high grade according to their invasiveness. Surgery is the first treatment, followed by adjuvant radio and chemotherapy. However, high grade gliomas are characterized by a poor prognosis, because of fatal relapses. Indeed, despite the recent advances in surgery (neuronavigation, use of 5-aminolevulinic acid, and intra-operative magnetic resonance imaging), recurrences can derive either from incomplete resection of the primary mass or from tumour cells migrating into the health tissues, the so called brain adjacent-to-tumour (BAT) zone[1]. Within this concern, current chemotherapy, based upon oral temozolomide, is only a palliative care. Its efficacy is limited by chemo-resistance, while the brain-blood barrier (BBB) prevents the brain access of nearly 98% of alternative potential drug candidates. Nonetheless, despite intact BBB overcoming is needed to target cells in the BAT zone, tumour mass growth promotes the formation of an altered BBB, the so called blood-to-brain tumour barrier (BBTB), with a leaky vascularization[2]. Therefore, passive, active and homotypic targeting mechanisms can be exploited for brain delivery of multiple chemotherapeutic agents to the brain, acting on glioma proliferation, vascularization and differentiation.

Among available nanocarriers suitable for drug targeting to the brain, lipid-based ones (nanoemulsions and solid lipid nanoparticles – SLN) show several advantages in terms of biocompatibility and versatility. Indeed, lipids are either physiological compounds or substances endowed with an approved status, such as GRAS (Generally Recognized As Safe) substances. Moreover, they are either liquid or low melting, allowing an easy processing on a large scale. Finally, they can be surface functionalized owing to different strategies[3,4]. Nonetheless, several hurdles still limit the clinical translation of such nanocarriers for glioma chemotherapy. Among them the preclinical efficacy assessment in cell and animal models, suitable to truly recapitulate the human condition. In this presentation the main evidences obtained at the University of Turin in the last years about the usage of lipid-based nanocarriers for drug delivery against glioma in preclinical models are shown.

References:

[1] Ferraris C, Cavalli R, Panciani PP, Battaglia L. Int J Nanomedicine. 2020;15:2999-3022.
[2] Gastaldi L, Battaglia L, Peira E, Chirio D, Muntoni E, Solazzi I, Gallarate M, Dosio F. Eur J Pharm Biopharm. 2014;87(3):433-44.
[3] Battaglia L, Gallarate M. Expert Opin Drug Deliv. 2012;9(5):497-508.
[4] Battaglia LS, Dorati R, Maestrelli F, Conti B, Gabriele M, Di Cesare Mannelli L, Selmin F, Cosco D. Drug Discov Today. 2022;27(10):103321.

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Production of personalized pharmaceutical dosage forms by Direct powder extrusion 3D printing

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Three-dimensional printing (3DP) has now been widely used to produce customizable dosage forms useful for adherence to personalized medical therapies[1]. With this easily obtainable geometric variation and dosing flexibility, 3D-printed formulations could closely meet patient needs. This enables the development and growth of precision medicine, which involves optimizing drug doses based on a patient's age, sex, weight, disease severity, and genetic profile[2]. Out of the several 3D printing techniques explored for drug delivery applications, direct powder extrusion (DPE) represents one of the most innovative 3DP techniques for personalized pharmaceutical forms production[3]. It enables the production of finished solid pharmaceutical forms in a single step, directly from mixtures of excipients and active pharmaceutical ingredients (API), extending the possibility of printing even mixtures with high dosages of API, reducing their risk of degradation when exposed to double thermal stress, and accelerating the development of the formulation by lowering costs and waste production[4].

The novel 3DForMe® printer, based on DPE, was developed by our workgroup in collaboration with Farmalabor Srl to improve the preparation processes of highly personalized 3D-printed solid pharmaceutical forms. The 3DForMe® printer and the DPE 3DP technique have been effectively employed in scientific research operated by our workgroup to develop new solid pharmaceutical forms presenting improved chemical-physical characteristics. This technology was employed in different case studies on drugs belonging to classes II and IV according to the Biopharmaceutical Classification System. In the reported studies, the 3DP DPE technique was combined with the use of polymer blends containing cyclodextrin, selected for its ability to enhance the aqueous solubility, stability, and bioavailability of the printed investigated drugs.

Specifically, the different possibilities given by this technology were investigated in the creation of customized drug delivery systems for paediatric patients, with the production of mini-tablets for the immediate release of Captopril or sustained release of Budesonide, in the development of buccal delivery systems such as mucoadhesive orodispersible films for the release of Clobetasol or Lidocaine, or for drug repurposing with the development of Niclosamide-based tablets.

References:

[1] Cui M., Pan H., Su Y., Fang D., Qiao S., Ding P., Pan W., Acta Pharm Sin B., 2021, 2488-2504.
[2] Aguilar-de-Leyva Á., Linares V., Casas M., Caraballo I., Pharmaceutics, 2020, 12(7):620.
[3] Goyanes A., Allahham N., Trenfield S.J., Stoyanov E., Gaisford S., Basit A.W., Int J Pharm., 2019, 567:118471.
[4] Annaji M., Ramesh S., Poudel I., J Pharm Sci., 2020, 109(12):3551-3568.

TEF-OR-007

Importance of dissolution testing for IVIVC in drug product development

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IVIVC (*In vivo in vitro correlation*) is an essential tool for predicting the *in vivo* performance of a drug based on *in vitro* drug release profiles. Physicochemical and biopharmaceutical properties of the drug as well as the physiological conditions in the body must be considered to develop a reliable correlation. Key parameters for this include solubility and permeability of the drug, LogP and pKa values as well as ambient conditions in the area of the body the drug is distributed in like pH and presence of enzymes. The aim of IVIVC is therefore to establish a correlation between either the full dissolution profile and *in vivo* absorption curve or between any parameter derived from *in vitro* data and *in vivo* data. Based on these definitions, three main levels of correlation are defined, according to their ability to reflect the entire plasma drug concentration vs. the time profile. Level A is the highest level of correlation and represents a point to point relationship between *in vitro* dissolution and cumulative *in vivo* absorption. Level B is based on the principle of statistical moment analysis where the mean *in vitro* dissolution time is compared either to the mean *in vivo* residence time, to the mean *in vivo* absorption or mean *in vivo* dissolution time. Level C relates one dissolution result, such as the time to achieve a certain percent dissolved or percent dissolved at a certain time point to one pharmacokinetic parameter (AUC, tmax, cmax…). IVIVC enables to pre-optimize the drug product on base of these (dissolution) *in vitro* results without the need of animal/clinical studies and saves both time and money. The importance of IVIVC for drug product development is therefore undeniable. Dissolution testing is a widely used *in vitro* testing tool in both Academia and Pharmaceutical industry as it provides an indication of how well a dosage form will dissolve in the patient and thus be available for absorption in the small intestine. Depending on the drug product and site of action in the body, various methods for dissolution testing are possible.

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Formulation strategies for pulmonary delivery of biopharmaceuticals

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Biopharmaceuticals represent a significant and growing share of new drugs entering the market, but their administration is somewhat limited to parenteral injection, due to their instability when administered orally. Protein inhalation could represent an interesting alternative especially for the treatment of lung diseases or for the prevention of pulmonary infections. In any case, the successful development of inhalable protein therapeutics, in the form of nebulized solutions or dry powders, must take into consideration the risk of degradation of these products during formulation and administration. Both processes can damage proteins, so a thorough characterization of the respirable fraction, as well as of the preservation of biological activity and aggregation of the protein, is mandatory to correctly estimate the therapeutic potential of the preparation.

Alpha-1 antitrypsin (AAT) is administered intravenously to treat genetic AAT-deficiency. Only a small part of the injected dose reaches the lungs, which are the main organ affected by the deficiency. To achieve a higher local concentration and improve patient compliance, an inhalable formulation of AAT, as a nebulized solution or as a dry powder, would be highly desirable. Starting from the injectable solution of human AAT, we compared the effect of a jet nebulization system with an electronic active vibrating membrane nebulizer on nebulization efficiency, protein activity and aggregation. Protein activity and aerosolization performances were comparable between the two nebulizers, but dose delivery efficiency was higher with the mesh nebulizer[1]. A recombinant version of AAT, overcoming the limitations due to the availability of blood donors, was formulated as a dry powder in the presence of different excipients with the aim of prolonging its stability during storage. The combination of mannitol and leucine proved to be the most effective in preserving rAAT activity after storage in oxygen-free conditions and after aerosolization[2].

Dry powders for nasal inhalation have also been prepared from a hyperimmune serum against COVID-19 to be administered as a pre-exposure or early post-exposure prophylaxis in case of contact with the virus. Drying serum with trehalose did not alter the ability of immunoglobulins to bind the Spike protein and to neutralize pseudoviral preparations of different variants of concern of SARS-CoV-2. In vitro aerodynamic evaluation suggested the possibility of targeting both the upper and lower airways via nasal inhalation, providing broad coverage against viral spread in the airways.

References:

[1] A. Bianchera, V. Vilardo et al. Nebulizers effectiveness on pulmonary delivery of alpha-1 antitrypsin. *Drug delivery and translational research* (2023) https://doi.org/10.1007/s13346-023-01346-3

[2] A. Bianchera, E. Alomari; et al. Recombinant Alpha-1 Antitrypsin as Dry Powder for Pulmonary Administration: A Formulative Proof of Concept. *Pharmaceutics (*2022) *14*, 2754. https://doi.org/10.3390/ pharmaceutics14122754

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A heat-generated polymeric matrix technology transferred to drug delivery and cell culture systems

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Our research group have developed and patented[1] a matrix system, suitable for drug delivery and 3D cell culture, based on the application of a technology consisting in performing a thermal treatment on compact units including as excipients a specific type of cross-linked, water-insoluble polyacrylic polymers; the thermal treatment, under appropriate conditions, generates a monolithic hydrophilic matrix able to swell in aqueous medium at neutral or alkaline pH, forming a hydrogel very resistant to erosion.

This versatile matrix may be employed in systems for drug delivery. Indeed, the inclusion of a hydrophobic component, such as ethylcellulose, in the composition makes the matrix able to control the release rate of active substances in the intestinal medium. Moreover, when including in the composition a pH regulator, the polymer forming the matrix manages to swell even in the stomach's acidic environment. Tablets with this composition manage to float immediately in the gastric fluid owing to their low density, to absorb water and to enlarge, creating the conditions for gastroretention, associated to drug controlled release for up to several hours[2].

The technology has also been employed and patented for the preparation of matrices for 3D cell cultures[3]: in this case, compacts including the polyacrylic polymer, sodium bicarbonate and sodium chloride, subjected to thermal treatment and subsequent leaching of the water-soluble components, create a porous hydrophilic scaffold, moist heat sterilizable, transparent and biocompatible, which has been successfully employed for 3D culturing of different cell types, and suitable for drug testing.

Our technology can be manufactured with easily available, low-cost components, and the heating process, fundamental for matrix formation, may be carried out using the common industrial heating systems. The temperature to which the compacts are heated and the duration of the thermal treatment may be set to modulate the features of the matrix, achieving either the appropriate drug release rate or the mechanical properties most suitable for the cultured cells, depending on its application.

References:

[1] G. Caviglioli, B. Parodi, E. Russo, S. Cafaggi, G. Bignardi, P. Cirrincione, 2010, Granted patent WO2010028826A2.
[2] G. Caviglioli, S. Baldassari, G. Zuccari, G. Ailuno, 2022, International patent application n. PCT/IB2022/052522.
[3] G. Caviglioli, S. Baldassari, G. Zuccari, A.M. Bassi, M. Yan, 2022, Granted patent EP3662054.

TEF-OR-010

Probiotic Microencapsulation: Exploring with Spray Drying and Prilling/Vibration Techniques to Enhance Performance Through Precision Polymeric Mixtures

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The human gut microbiota plays a crucial role in maintaining overall health and well-being, with oral probiotics recognized for their ability to promote a healthier gut microbiota. Probiotics, live microorganisms consumed in sufficient quantities, offer various health benefits, and contribute to the balance of the gut microbiota [1]. These microorganisms compete with pathogens, regulate inflammatory responses, produce beneficial metabolites, and support microbiota balance. Ensuring a minimum viable count of approximately log 6 CFU/mL is crucial for their optimal colonization at the intended site [2].

However, research on the viability of commercial probiotic products has revealed lower concentrations and deficiencies in probiotic strains' viability during passage through the gastrointestinal tract (GIT). This raises significant concerns about the effectiveness of many products currently available on the market, as they may not survive processing, GIT transit stress and storage processes [3].

To address these challenges, two approaches have been explored. Firstly, microparticles were developed using the prilling/vibration technique to encapsulate the probiotic strain Lactiplantibacillus plantarum 4S6R [4]. A specific polymeric mixture, selected for its responsiveness to colonic stimuli, was identified as an effective carrier for these microparticles. Secondly, a microencapsulation formulation was developed for the probiotic Bifidobacterium longum (strain 22348) to protect it from environmental and physiological factors (e.g., pH, oxygen, and temperature). The probiotic cells were encapsulated via spray drying using a polymer mixture consisting of Eudraguard® biotic, inulin, and alginate with or without maltodextrin as wall materials.

Both strategies yielded microparticles with high yield and encapsulation efficiency. The first approach suggests that the selected triggered dependent polymer mixture holds promise for enhancing probiotic survival and efficacy in the gastrointestinal tract, paving the way for advanced probiotic product development. The second study concluded that the characteristics of the powders were suitable for protecting probiotic viability during production and under gastrointestinal conditions, thereby extending their shelf life without compromising their health benefits. Spray drying of probiotic microcapsules shows significant potential in functional food, benefiting both industry and consumers alike.

References:

[1] A. Khalighi, R. Behdani, S. Kouhestani in Human Nutrition. Probiotics and Prebiotics 2016, 1-11.
[2] A. Terpou et al. Nutrients 2019, 11, 1591
[3] Naissinger da Silva et al. N. Surname, N. Surname, Curr Res Food Sci 2021,4, 320-325.
[4] V. D'Amico et al International Journal of Pharmaceutics 2024 Under review

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Challenges in microfluidic production of nanomedicine

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The production and development of the Covid-19 vaccines by Pfizer and Moderna have brought the microfluidic (MF) technique in the spotlight for the production of nanomedicines, thanks to the possibility of having high reproducibility and automation while also reaching large scale production.[1] This technique is based on the fine mixing of different solutions in microchannels with precise geometry, creating a controlled microenvironment that can be finely tuned in order to produce nanomedicines with the desired hydrodynamic diameter, high homogeneity, high drug loading, and good storage stability.

Since 2020, the use of MF has been widely and deeply investigated for nanomedicine production, improving the results of research projects and leading to products with a higher TRL; however, not only is the translatability of previously optimized products towards a MF device not linear, but also the MF technology itself is now facing some challenges that need to be addressed.

In this talk, an overview will be given about the use of the MF technique for NMed production, the main types of devices available, and protocol development. Moreover, highlights will be given about the difficulties in protocol translatability from benchtop to MF, and the future steps towards the development of this promising technology.[2,3]

References:

[1] S. Gimondi, H. Ferreira, R. L. Reis, N. M. Neves, ACS Nano 2023, 17 (15), 14205-14228
[2] I. Ottonelli, J.T. Duskey, A. Rinaldi, M.V. Grazioli, I. Parmeggiani, M.A. Vandelli, L.Z. Wang, R.K. Proud'homme, G.Tosi, B.Ruozi, Pharmaceutics 2021, 13(9), 1495
[3] R.K. Thapa, J.O. Kim, J. Pharm. Investig 2023, 53, 19–33

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Prolamin-Based Formulations for Drug Delivery Applications

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The proline- and glutamine-rich proteins (*prolamins*) contained in cereal grains have emerged as promising biomaterials with a wide range of applications. Among them, corn zein and wheat gliadin were the natural polymers employed for wound healing and oral delivery purposes, respectively. In detail, a green and biocompatible zein gel (20% w/v of protein) containing rutin (0.5-5% w/w with respect to the polymer) was characterized by means of passive and dynamic rheology, demonstrating the formation of samples with a marked solid-like character and a pseudoplastic behaviour. *In vitro* scratch assay performed on human keratinocytes and *in vivo* wound-healing studies performed on rats, respectively, showed that the entrapment of the drug within the zein gels promoted a faster wound closure as compared to the free form of the compound. Moreover, empty and rutin-loaded zein gels showed healing properties similar to the commercial formulation DuoDERM®; this was followed by a significant decrease of various pro-inflammatory cytokines in the serum of the animals due to the peculiar, intrinsic anti-inflammatory properties of the protein, suggesting a plausible application of the gel formulation as innovative wound dressing.

In another investigation, zein nanoparticles stabilized by sodium-deoxycholate were used as carriers of ovalbumin (OVA), used as a model of antigen, and then embedded within a thermosensitive hydrogel matrix made up of poloxamine-908 (P908), with the aim of obtaining an injectable formulation for the nanovaccination. The addition of OVA (0.2-0.8 mg/mL) did not significantly compromise the physico-chemical features of the carriers, obtaining an almost quantitative retention of the molecule (≥90%) and a sustained release over time. Successively, the nanoformulation prepared with 0.8 mg/mL of OVA was embedded within the hydrogels; the multistage formulation was characterized by a shear-thinning behaviour able to enhance the immune response after injection.

Additional experiments were focused on the characterization of gliadin nanoparticles and on the evaluation of their *in vivo* fate after oral administration. In this regard, the incubation of the nanosystems with *ex vivo* porcine intestinal mucus evidenced their ability to interact with the intestinal mucosa, while the biodistribution performed on rats evidenced that 4h-post oral administration the samples were able to reach the small intestine. Intake studies with *Caenorhabditis elegans*, used as an additional *in vivo* model, confirmed the ingestion of the particles through the oral route and evidenced the decrease of the age-related lipofuscin pigment in the nematodes in a dose-dependent manner. The obtained results provide the rationale of the conceivable use of gliadin nanoparticles as oral drug delivery systems.

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Dual function surfactants for pharmaceutical applications: the case of alkyl biguanides

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Biguanide is an interesting molecule whose chemical moiety can be found in the structure of several compounds with different therapeutic activities such as antidiabetic, antiviral, antimalarial, antibacterial, antimycotic, and anti-HIV. Biguanide derivatives are currently employed in clinics as orally administered hypoglycemic agents and they have been also proposed for the treatment of several other conditions (e.g. polycystic ovary syndrome, cancer, tuberculosis)[1]. Regarding antimicrobial activity, several biguanide derivatives are known to be active against a wide range of gram-positive and gram-negative bacteria as well as fungi, yeasts, and viruses. Indeed, a cationic bisbiguanide as chlorhexidine (and its salt form chlorhexidine digluconate) is one of the most used topical disinfectants and antiseptic agents for skin and mucosa[2]. Despite the large interest in biguanides derivatives, no detailed studies have been conducted for the development of novel surface-active molecules bearing this chemical moiety. Indeed, only one study can be found in the literature, in which a biguanide was linked to alkyl chains of a different length to produce amphiphilic molecules[3]. According to these premises, the biguanide moiety can be exploited to design new surfactants with a dual function as surface-active molecules and antimicrobial/disinfectant agents. As such, a new series of amphiphilic compounds derived from the alkylation (C3, C6- and C10-) of 1-(orto-tolyl)biguanide was synthesized and characterized in terms of surface tension, aggregation properties, and antibacterial activity.

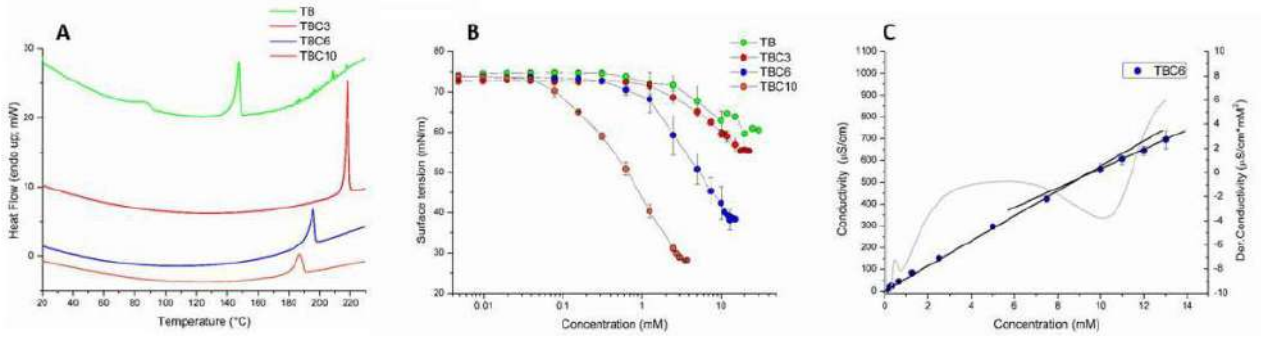

Figure 1: DSC traces (A), surface tension (mN/m) *vs* concentration (mN) (B), and conductivity (µS/cm) *vs* concentration (mM) (C) plots for the synthesized biguanide derivatives (TBC3, TBC6, and TBC10) in comparison to the commercial compounds 1-(o-tolyl)biguanide (TB).

References:

[1] D. Kuthuria et al., Eur. J. Med. Chem., 2021, 219, 113378.
[2] I.A. Jones and L.T. Joshi. Molecules, 2021, 26, 2276.
[3] S. Fortun et al., ACS Omega, 2018, 3, 1889–1896.

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TEF-PO-001

Hyaluronan-based graft copolymers for the development of novel biocompatible materials with high potentiality in biomedical applications

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Hyaluronic acid (**HA**), a natural polysaccharide belonging to the glycosaminoglycans, represents the main component of the extracellular matrix (ECM). Thanks to its molecular properties, **HA** plays an important role in tissue engineering, wound healing, cancer treatment, ophthalmology, and cosmetics.[1] Ferulic acid (**FA**, 4-hydroxy-3-methoxycinnamic acid), a natural compound largely distributed in the plant cellular wall, possesses many health benefits[2] and represents an interesting biocompatible fluorophore.[3] In this context, aggregation-induced emission (AIE) fluorogenic **FA** residues bearing propargyl (**Pg**) groups were used in the grafting reaction of **HA** macromolecules to afford the resulting hyaluronan derivative **HA-FA-Pg** graft copolymers that could be exploited in Cu(I)-Catalyzed Azide-Alkyne 1,3-dipolar Cycloaddition (CuAAC) conjugation.[4] This synthetic strategy was employed in a biocompatible and biomimetic hyaluronic coating (BBHC) of surfaces of different nanostructures[3-7] to obtain novel materials. Based on the encouraging obtained results, we also evaluated the effects of the covalent coating of **HA**, by using **HA-FA-Pg** graft copolymers, around the spheroidal geometry of poly(propylene imine) (PPI) dendrimers of first, second, and third generation on the architecture and aggregation features of hybrid resulting dendrimeric materials, which represent biocompatible drug carriers endowed with encouraging features in transporting anticancer doxorubicin to tumor cells.[8] Additionally, we further extend the application of **HA-FA-Pg** grafted derivatives, by developing a new crosslinking procedure in which the propargyl groups of **HA-FA-Pg** graft copolymers were exploited in the CuAAC coupling with different oligo(ethylene glycol)-based spacers terminated with azide groups to obtain novel biocompatible crosslinked **HA** materials potentially useful in different biomedical applications.[9-10]

References:

[1] K.T. Dicker, et al., Acta Biomater. 2014, 10, 1558-1570.
[2] M. M. Buanafina, Mol. Plant 2009, 2, 861.
[3] A. Cappelli, et al., RSC Adv. 2018, 8, 5864.
[4] A. Cappelli, et al., Polym. Chem. 2016, 7, 6529.
[5] M. Licciardi, et al., J. Nanopart. Res. 2017, 19, 197.
[6] A. Atrei, et al., Mater. Sci. Eng. C 2020, 107, 110271.
[7] M. Paolino, et al., Pharmaceutics 2019, 11, 675.
[8] M. Paolino, et al., J. Appl. Polym. Sci. 2023, 140, e53300.
[9] M. Saletti, et al., Pharmaceutics 2022, 14, 1041.
[10] F. Terracina, et al., Gels 2024, 10, 91.

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TEF-PO-002

Scaffolds enriched with magnetite for the mechanotransduction stimulation in tendon tissue regeneration

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Introduction: Tendon pathologies are medical conditions that include ruptures and overuse injuries accompanied by inflammatory and degenerative alterations, such as tendinopathies and tendinitis. The aim of the present work was the development of fibrous scaffolds based on polyhydroxybutyrate (PHB) doped with magnetic iron oxide nanoparticles (Fe_3O_4 NPs) and coated with gelatin (Gel), able to mimic the hierarchical structure of the tendon and to improve the tissue healing potential [1,2].

Experimental methods: The blends were spun using a centrifugal spinning apparatus obtaining PHB, PHB-Fe_3O_4, and PHB-Fe_3O_4-Gel fibers. The systems morphology and the surface wettability were evaluated. The scaffolds' superparamagnetic behavior, mechanical properties and weight loss in physiological medium were evaluated. Finally, cell adhesion and proliferation in vitro were evaluated with and without the application of static magnetic fields of different extent for 21 days of culture.

Results: The systems were characterized by an aligned structure and Fe_3O_4 NPs were successfully incorporated into the fibrous structure, increasing the scaffolds' rigidity. Moreover, the presence of Gel increased the surface wettability. PHB-Fe_3O_4 and PHB-Fe_3O_4-Gel were characterized by a superparamagnetic behavior, while the PHB scaffold was characterized by a spectrum typical of not-magnetic samples. The scaffolds showed a progressive weight loss in physiological medium, while maintaining the fibers' morphology and alignment for 3 months. Finally, the application of the magnetic fields led to a significant increase in cell proliferation, and alignment onto the systems loaded with magnetite, mimicking the tendon fascicles.

Conclusion: Fibrous scaffolds based on PHB and Gel and doped with magnetite were successfully manufactured, representing an interesting tool to enhance the wound regeneration when combined with the application of external magnetic fields.

References:

[1] R. Urie, D. Ghosh, I. Ridha, K. Rege, Annu Rev Biomed Eng. 2018, 353-374
[2] R. Sheng, Y. Jiang, L.J. Backman, W. Zhang, J. Chen, Stem Cells Int. 2020, 8824783.

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TEF-PO-003

Chitosan/Hydrolysed Collagen-based spray-dried microparticles endowed with antimicrobial properties for the treatment of respiratory tract infections

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Pulmonary administration route has been extensively exploited for the treatment of local lung diseases such as asthma, chronic obstructive pulmonary diseases and respiratory infections and it is one of the most preferred routes for drug delivery, providing a high surface area for a quicker and effective drug absorption[1,2].

The aim of the present work was the development of microparticles (Mps) via spray-drying technique. Insoluble Mps, resulting from the interaction between chitosan (Cs; medium MW, Sigma Chimica, I) and hydrolysed collagen (HC; Kelisema, I), were prepared for the treatment of respiratory tract bacterial infections.

HC aqueous solutions were prepared at different concentrations (1, 2, 4 % w/w) and mixed at 1:1 weight ratio with 2% w/w Cs solution in 0.5M acid acetic. Cs/HC0.5, Cs/HC1 and Cs/HC2 mixtures were spray-dried setting different inlet temperature values ranging from 120 to 200°C (100% aspirator, 0.6 L/h flux). Mps collected were characterized for: i) morphology and size by Scanning Electron Microscope (SEM), ii) physicochemical properties by Fourier-Transform Infrared Spectroscopy (FT-IR) and Thermal Gravimetric Analysis/Differential Scanning Calorimetry (TGA/DSC); iii) aerodynamic performance and particle size distribution by Next Generation Impactor (NGI); iv) in vitro cytotoxicity assay on adenocarcinomic human alveolar basal epithelial cells (A549); v) antibacterial properties and capability to inhibit bacterial adhesion to A549 (*S. aureus BH1CC strain and P. aeruginosa PAO1 strain*).

The main results pointed out that Mps were characterized by a spherical shape and a particle size between 1-10 µm depending on the inlet temperature set and the polymer concentration; in the case of Mps Cs/HC0.5 obtained at 120°C, 95% of Mps had a mean diameter lower than 5 µm, suitable for pulmonary drug delivery. FT-IR and TGA/DSC analysis confirmed the formation of an interaction product (IP) between Cs and HC, responsible for the formation of insoluble and biodegradable Mps. In vitro assay on A549 cells demonstrated the Mps optimal biocompatibility. Mps displayed antimicrobial properties against both Gram + and Gram – bacteria higher than those of the raw materials and their physical mixture. Finally, Mps were also able to inhibit bacterial adhesion to A549.

In conclusion, water insoluble Mps based on CS and HC IP have been successfully achieved by means of spray drying. They were characterized by a size functional to pulmonary administration. The IP was characterized by improved antimicrobial properties and capability to inhibit bacterial adhesion to cells.

References:

[1] B. Mishra, J. Singh, Academic Press, 2020, 57-95
[2] H. Jain, A. Bairagi, S. Srivastava, S.B. Singh, N.K. Mehra, Drug Discovery Today, 202, 25 (10), 1865-1872.

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Circadian and dopaminergic influence on chlorogenic acid intestinal permeability

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Chlorogenic acid (CGA) is a natural polyphenol potentially health promoting along the gut-brain axis, even if limited by poor oral bioavailability[1]. As components of therapeutic drugs or functional food, polyphenols can influence each other their absorption from the gut according to circadian rhythms[2].

Therefore, we have evaluated, via HPLC-UV analysis, how the permeability of CGA across IEC-6 cell monolayers, as a model of intestinal barrier, is influenced by the presence of arbutin, gallic, caffeic and ferulic acids and by circadian cycles entrainment by horse serum shock. Moreover, dopaminergic neuronal influence on CGA intestinal permeability was investigated by co-culture with rat pheochromocytoma PC12 cell line mimicking dopaminergic component of enteric nervous system (ENS).

Our results indicate the presence of a circadian-dependent active efflux for CGA permeation across IEC-6 monolayers, suggesting its higher bioavailability in the evening rather than in the morning. Among the natural polyphenols tested, only gallic acid was able to influence the CGA permeation, causing its reduction. Finally, (60 mM KCl)-evoked dopamine release from PC12 cells[3] induced a significant CGA permeation increase across IEC-6 monolayers, probably by downregulation of efflux transporters expression/activity. Dopamine ENS-evoked may therefore enhance the CGA oral bioavailability dependence on circadian rhythms.

Although this is a preliminary study in this field, the results obtained allow us to suggest that the absorption of CGA from an oral administration of a food supplement is not influenced by arbutin, caffeic acid and ferulic acid, whereas it can be enhanced in the absence of gallic acid and by evening intake.

References:

[1] L. Zeng, R. Xiang, C. Fu, Z. Qu, C. Liu, Biomedicine & Pharmacotherapy 2022, 149, 112831.
[2] J. Pácha, K. Balounová, M. Soták, Expert Opinion on Drug Metabolism & Toxicology 2021, 17, 425-439.
[3] B. Pavan, A. Bianchi, G. Botti, L. Ferraro, M.C. Valerii, E. Spisni, A. Dalpiaz, International Journal of Molecular Sciences 2023, 24, 1800.

TEF-PO-006

Curcumin-loaded O/W nanoemulsions: combining pH-sensitivity with potential effect of natural active compounds

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The incidence of melanoma is rapidly increasing worldwide; improvement of both target and immune therapies against melanoma is counterbalanced by a high percentage of severe drug-related toxicity. In fact, tumour microenvironment represents a key obstacle for drug efficacy, being characterized by hypoxia, low blood pressure and acidic pH [1]. To enhance the effectiveness of cancer chemotherapy it is necessary to develop nanocarriers that can be triggered to release the anticancer drug in response to extracellular or intracellular chemical stimuli (e.g., pH, temperature) [2]. Therefore, the use of nanocarriers composed of pH-sensitive substances, like Oleic Acid [3] could exploit the physiological differences between tumour cells and normal cells.

The aim of this study was to develop oil-in-water nanoemulsions (NEs), composed of Oleic Acid, Hepes buffer (pH 7.4 – 10^{-2}M), and Tween 80. NEs were loaded with curcumin, a natural compound useful for enhancing the existing chemotherapy treatments against melanoma [4].

A deep physical chemical characterization of NEs was carried out evaluating size, PDI, ζ-potential, fluidity, microviscosity and polarity. The pH-sensitivity of formulated nanocarrier was demonstrated through fluorometric assays employing different probes, like DPH and Pyrene and by morphological studies utilizing TEM.

Looking to pulmonary administration, NEs were coated by Chitosan, a mucoadhesive agent, to enhance the nanocarrier lung residence time and the selected formulations remained stable even during the nebulization process.

In order to confirm NEs stability and curcumin stability in terms of decomposition/degradation, all samples were analysed by DLS and UV analysis for 90 days at room temperature and 4°C.

Finally, cytotoxicity, cellular uptake and *in vitro* activity were investigated in order to assure the safety and the activity of characterized NEs against B16F10 melanoma cell line.

References:

[1]: Pascale, R.M. et al. Cancers. 2020, 12,2819.
[2]: Karimi, M. et al. Reviews: Nanomedicine and Nanobiotechnology 2016, 8(5), 696-716.
[3]: Rinaldi, F. et al. Inter. J. of Pharmaceutics 2022, 613, 121391.
[4]: Adeluola, A et al. European J. of Pharmacology 2021, 906, 174266.

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TEF-PO-008

Bile acid-based nanosystems for the delivery of budesonide

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In this study ursodeoxycholic acid (U), sodium cholate (C) and sodium taurocholate (T) were selected to prepare bile acids-based vesicles and nanoparticles (i.e. bilosomes and biloparticles) to improve the solubility, the absorption and to preserve the activity of budesonide, used as a model lipophilic drug. It is well known that bile salts are physiologically involved in the digestion of lipids therefore they can affect the absorption of poorly soluble drugs in different ways[1].

Bilosomes and biloparticles were prepared following standard protocols with minor changes[2]. The obtained systems showed good encapsulation efficiency and dimensional stability. Particularly, biloparticles showed an increase in encapsulation efficiency following the order U < C < T.

The in vitro release of budesonide from both bilosystems was performed by means of dialysis using either a nylon membrane or a portion of a Wistar rat small intestine and two receiving solutions simulating gastric or intestinal fluid (i.e. FASSGF and FASSIF). Both in gastric and intestinal fluid, budesonide is released from bilosystems more slowly than the reference solution, while biloparticles showed a significant improvement of budesonide passage into aqueous solution. On the other hand immunofluorescence experiments indicated that budesonide-containing U-bilosomes are able to decrease the inflammatory response induced by glucose oxidase stimuli and to counteract the ox-inflammatory damage within intestinal cells.

In conclusion the obtained bilosystems can efficiently encapsulate budesonide while preserving its properties. However, the influence of different bile acids (i.e. U, C, T) on the performance of the bilosystem needs to be studied in depth to understand their contribution to the specific drug release properties. Future studies will be carried out to delve deeper into the reasons for the different behaviours expressed by the different bile acids used. The encouraging results showing the efficient antioxidant effect by a complete restoring of IL-1β basal level after U-bilosomes treatment, suggest the possibility to further investigate the use of bilosystems to counteract the ox-inflammatory damage within intestinal cells especially for those intestinal pathologies correlated to the development of an oxidative stress status.

References:

[1] C.J.H. Porter, et al. Advanced Drug Delivery Reviews 2008, 60, 673 – 691.
[2] M. Sguizzato, et al. Antioxidants 2023, 12, 2025 – 2044.

TEF-PO-009

Chitosan-associated SLNs promoting mucin binding for ocular drug delivery

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Solid lipid nanoparticles (SLNs) made of biodegradable physiological lipids have been widely suggested as carriers in ophthalmic drug delivery. The synergic combination of natural polymers, such as chitosan, and SLNs could be an effective strategy for increasing nanoparticles retention. This mainly occurs due to the electrostatic interaction between the positively charged chitosan and the negatively charged mucin. At this purpose, in the present study, SLNs were manufactured by means of high shear homogenization and ultrasound method [1]. Three different systems were prepared: naked SLNs, chitosan-associated SLNs (CH-SLN), and SLNs coated with chitosan (CH-c-SLNs). As for naked SLNs, the lipid phase (Compritol 888 ATO and cyclosporin A) was melted and the aqueous phase (water with surfactants – Tween 80 and Pluronic F68) was added to the lipid phase under homogenization (T25, IKA-Werke GmbH, Germany). CH-SLNs were prepared by mixing the lipid to a chitosan hydrochloride solution and then diluted in water, while CH-c-SLNs were produced by adding chitosan solution after hot emulsification of SLNs. All samples were submitted to ultrasound treatment (Elmasonic S80 H) for 10 min to avoid aggregation during particles stabilization.

The morphology and the particle size of SLNs were investigated by means of cryo transmission electron microscope Glacios (Thermo Fisher Scientific) and dynamic light scattering (Litesizer 500), respectively. Overall, the results highlighted circular dark structures related to spherical nanodroplets, and a mean particle size of about 180 nm. In particular, the presence of chitosan led to the production of particles with a higher particle size characterized by a rigid core enclosed by a jelly coating, and to the presence of some free polymer chains without nanoparticles. Moreover, the thermodynamic interaction between SLNs and mucin was investigated by isothermal titration calorimetry at 37°C (MicroCaL PEAQ-ITC, Malvern). After the addition of trehalose as cryoprotectant (solid lipid: cryoprotectant 1:4), SLNs were freeze-dried and dispersed in acetate buffer 20 mM at pH 4.5. The nanoparticle dispersion with a concentration of 1 mg/ml was placed in the syringe and was added into the thermostated cell containing a suspension of mucins in acetate buffer (0.1 mg/ml). A plateau, corresponding to the equilibrium of the system, was reached for CH-SLNs and CH-c-SLNs, meaning that saturation of mucin by the SLNs occurs. In fact, the dissociation constant (Kd) of naked SLNs was higher compared to that obtained for SLNs containing chitosan, indicating a lower binding affinity.

Further studies are ongoing to assess the permeation and penetration of SLNs across the corneal cells, and the cellular uptake.

References:

[1] G. Sandri et al. European Journal of Pharmaceutics and Biopharmaceutics 2017, 110, 13–18.

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TEF-PO-010

Polycaprolactone and zein-based fibrous scaffolds for skin tissue engineering

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Tissue engineering is a branch of regenerative medicine that focuses on the design and the development of biological substitutes able to repair or replace a damaged tissue[1]. The most promising adavances in this field are the three-dimensional biocompatible scaffolds[2]. In this scenario, centrifugal spinning became a promising method to produce fibrous scaffolds[3].

Given these premises, the aim of the present work was the design and the development of polycaprolactone (PCL) and zein (Z) fibers via centrifugal spinning, for skin tissue engineering.

PCL blends (18%-30% w/w) were prepared in acetic acid 96% v/v and subjected to centrifugal spinning. Z was added to PCL in a concentration ranging from 2% w/w to 10% w/w and the formulations were spun.

The obtained fibers were subjected to physicochemical characterizations. The morphological and dimensional analyses were carried out on both dry and hydrated samples by scanning electron microscopy. The formulation based on PCL 30 % w/w and Z 5 % w/w was the most promising to obtain regular and homogenous fibers with a mean diameter of 5µm. The hydration process, in distilled water overnight, do not show a variation of mean fiber diameter and the overall structure is maintained, indicating that fibers preserved their structural integrity. Since an ideal scaffold for wound healing should be elastic and maintain its shape after mechanical stresses, mechanical properties were evaluated on both dry and hydrated samples. The hydration process does not affect the scaffolds resistance. The degradation of fibers was investigated by keeping each sample in PBS at 37 °C in a water bath for 28 days. Preliminarily results showed that no degradation has occurred. Contact angle was evaluated to assess wettability of the scaffolds. The results reveal that the scaffolds are characterized by a hydrophilic surface that should support cell attachment. Moreover, scaffolds cytotoxicity was evaluated, and the preliminary results demonstrate that the fibers are biocompatible.

In conclusion, PCL-Z fibers have been successfully developed and have shown promising features for tissue engineering application. Further investigations are ongoing in order to deeply assess the biocompatibility and cell adhesion on the scaffolds.

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References:

[1] S, Enoch and D.J. Leaper, Surgery (Oxford), 2008, 26, 31-37.

[2] B.P. Chan, K.W. Leong, European Spine Journal, 2008, 17, 467–479.

[3] N. E. Zander, Journal of Applied Polymer Science, 2015, 132, 41269.

TEF-PO-011

Ozonized oil-based NLCs for wound healing and infection control

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Chronic wounds, characterized by impaired healing processes and prolonged inflammation, pose a significant healthcare challenge. Persistent open wounds can also provide a favourable environment for bacterial colonization and proliferation, which can lead to localized or systemic infections (1). Antimicrobials-based nanomedicine can prevent infection and wound chronicity, promoting and accelerating the healing process. In this context, ozonized oils are characterized by considerable antibacterial properties without developing bacterial resistance, due to their capability to disrupt cell membrane and interact with DNA (2). In addition, they can improve the oxygenation of the site and stimulate the release of growth factors (3). At this purpose, the aim of this work was the development of nanostructured lipid carriers (NLC), loaded with ozonized oils, as medical devices, to enhance healing and prevent infections of chronic wounds.
Cocoa Butter (Aboca S.p.A., Sansepolcro, Italy) was used as solid lipid and sunflower ozonized oil (Innovares srl, Sant'Ilario d'Enza (RE), Italy) as liquid lipid. In the aqueous phase Tween80 was added as surfactant. NLC were manufactured using microfluidics (ANP Automated nanoparticle system) at 40°C. Several processes parameters (total flow rate and ratios) were tested, and their impact on size and PDI was evaluated. NLC were characterized using a multidisciplinary approach including morphology, particle size, zeta potential and *in vitro* cytotoxicity towards Normal Human Dermal Fibroblast (NHDF)
Pre-formulative studies on NLCs production show that the processes parameters variation had a significant impact on the particles size and smaller particles were obtained increasing the ratio aqueous/organic phase. In particular, the ratio 8:1 between aqueous and organic phase was the best ratio to obtain nanoparticles with a dimension around 165 nm and a polydispersity index lower than 0.25. In addition, nanoparticles were characterized by negative zeta potentials (-30 mV) at all aqueous to organic ratio. Subsequently, to study the influence of the total flow rate (TFR) on the physical-chemical properties of the nanoparticles, the ratio aqueous/organic was kept constant and nanoparticles were produced at different TFR (5000 ul/min – 10000 ul/min). Hence, nanoparticles dimensions were assessed, and results showed that dimensions and zeta potential were slightly affected by the variation of the total flow rate. Moreover, in vitro assays towards NHDF showed that NLCs were biocompatible and enhance cell proliferations.
NLCs were successfully manufactured using microfluidics and characterized in terms of physical chemical properties. Moreover, they showed good biocompatibility and proliferation properties towards normal human fibroblasts. Further studies are ongoing to assess the antimicrobial properties of the nanoparticles.
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References

1) Mihai M.M. et al, Materials, 2019.
2) Anzolin A.P. et al, Medical Gas Research, 2020
3) Brito J.A.A et al, Rev Gaúch Odontol, 2022

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Electrospun nanofibers coated with a pH-responsive film to be used as vaginal delivery systems for the prevention of sexually transmitted infections.

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The present work aims to develop electrospun nanofibers coated with a pH-responsive film to be used as vaginal delivery systems for the prevention of sexually transmitted infections. The film coating should remain intact at vaginal pH, protecting the inner nanofibers. The increase in the environmental pH due to the presence of the seminal fluid should cause film solubilization, resulting in nanofibers exposure, and their subsequent hydration and adhesion to the vaginal mucosa. For the fibers preparation, polyvinyl alcohol (PVA; Sigma-Aldrich, I) and carrageenans (κ-CAR and ι-CAR; Sigma-Aldrich, I) were prepared in MilliQ water (2h at 85°C). Different concentrations of PVA (10-20 % w/v) and CARs (1-2% w/v) were considered. PVA and CARs solutions were mixed at 9:1 weight ratio at 95°C for 1 h^{1}. Mixtures viscosity (shear rates 10-1000 s^{-1}, 30°C) was assessed by means of a rotational rheometer (MCR 102, Anton Paar, I). Polymer solutions were electrospun (STIKIT-40; Linari Engineering, I) at a constant temperature (28-30°C) and relative humidity (30%-40%). The nanofibers obtained were characterized for morphology (SEM; PhenomTM Pure Desktop, Thermoscientific, I) and mucoadhesive properties (TA.XT plus; Stable Micro Systems, UK), using commercial mucin suspensions in simulated vaginal fluid[2] (SVF) as biological substrate. An *in vitro* degradation assay was performed in SVF and simulated seminal fluid (SSF)[3] at 37°C. 8% w/v Eudragit L100 (EL100, Evonik, I) solution in absolute ethanol and glycerol (Gly, Sigma-Aldrich, UK) at 8% and 16% w/v were used for film preparation by casting[3]. Films mechanical properties (tensile strength and elongation at break %) were investigated by means of TA.XT plus. Films were subjected to *in vitro* degradation assays in both SVF and SSF at 37°C. Viscosity values in a range of 2-3 Pa.s at 1,000 s^{-1} were evaluated as ideal to obtain bead-free homogeneous PVA/CAR nanofibers with a mean diameter of about 500 nm. They are characterized by good mucoadhesive properties and a small weight loss after 24 h of immersion in SVF/SSF. EL100/Gly films possess adequate mechanical properties, able to allow their administration avoiding ruptures, a proper stability in SVF and a quick dissolution in SFF, to permit the exposure of PVA/CAR nanofibers after the contact with a potentially infected seminal fluid. In conclusion, promising nanofibers characterized by suitable mucoadhesive and degradation properties, and polymeric films to be used as a protective coating were successfully developed. Ongoing studies are focused on nanofibers loading with a model drug.

References:

[1] S. Forghani, F. Zeynali, H. Almasi, H. Hamishehkar, Food Chem. 2022, 388, 133057.
[2] Sulistiawati, C.K. Enggi, H.T. Isa, S.Wijaya, K.A.R. Ardika, R.M. Asri, R.F. Donnelly, A.D. Permana Spectrochim Acta A Mol Biomol Spectrosc. 2022, 267 part 2, 120600.
[3] A. Martín-Illana, R. Cazorla-Luna, F. Notario-Pérez, J. Rubio, R. Ruiz-Caro, A. Tamayo, M.D. Veiga, Int. J. Pharm. 2022, 616, 121554.

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Inorganic Nanoparticles-doped nanofibrous scaffold for skin regeneration

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Introduction: Natural polymers are considered promising biomaterials in regenerative medicine since they can provide a suitable microenvironment for wound healing, mimicking the structural and biochemical cues of native tissues [1]. Scaffolds produced by animal proteins, such as gelatin, could sustain cell adhesion and proliferation due to the presence of tripeptide Arg-Gly-Asp (RGD) motifs, while scaffolds based on plant-based proteins, such as zein, have less immunogenic response than animal-derived proteins. In addition, inorganic nanoparticles, such as selenium nanoparticles (SeNPs), can improve the wound healing process, thank to their antimicrobial activity against *Pseudomonas aeruginosa*, a pathogen involved in life-threating wound infections [2]. In light of these considerations, gelatin or gliadin-based nanofibers doped SeNPs were designed and developed.

Materials and Methods: The polymeric blends were based on pullulan, an electrospinnable polymer, and proteins, gliadin or gelatine. Citric acid was added as crosslinking agent and SeNPs as antimicrobials. Nanofibrous scaffolds were obtained using horizontal electrospinning apparatus keeping the same variables for each formulation. the systems were made insoluble by heating and imaged using electron microscopy (SEM and TEM). Physico-chemical properties, including the mechanical ones, were also assessed.

Results: SEM images revealed smooth surface and uniform nano-dimension fibers independently of scaffold compositions. In addition, after crosslinking and subsequent hydration, each scaffold retained a nanofibrous structure. TEM images confirmed fiber doping with SeNPs. Moreover, the mechanical analysis showed that the presence SeNPs led to increased elastic properties and Young modulus in the case of gelatine-based nanofibers.

Conclusion: Nanofibers based on proteins, doped with SeNPs, have been successfully developed. Current studies are ongoing to evaluate the effect of SeNPs on the preclinical properties of the fibers, in particular biocompatibility and antioxidant properties in vitro on fibroblasts.

References:

[1] H. Zhang, et al. 2024, 33, 355-376.
[2] C. Meyli, et al., 2021, 7, 1– 25.

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Composite biomaterial-based microneedles for pathological scars treatment

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Abnormal scars, also known as pathological scars, refer to a variety of skin formations that deviate from the typical healing process after injury. These scars may include keloids, hypertrophic scars, or scars resulting from conditions like acne or burns[1]. Recent research has highlighted the potential of drug-free microneedles (MN) in reducing scar growth by inhibiting skin fibroblast proliferation[2]. This effect, known as the contact inhibition effect, is achieved by disrupting the mechanical communication between fibroblasts and the extracellular matrix[3]. The objectives of the present work are i) the development of a novel composite biomaterials consisting of whey protein isolate (WPI, Milei GmbH, DE), and chitosan (CS, Sigma Aldrich, I) or trimethyl chitosan (TMC, ChitoLytic, CAN) and ii) the design and production of composite biomaterial-based MN that employ a mechanotherapeutic approach to treat abnormal scars.

For the development of the composite biomaterials different complexes were prepared by mixing WPI 4% w/w aqueous solution with 4% w/w CS solution in 0.5M acetic acid or 4% w/w TMC aqueous solution at 1:1 weight ratio. The influence of WPI denaturation (70°C for 20 min) on complexes formation was investigated. Rheological, turbidimetric, dynamic and electrophoretic light scattering, SEM analyses were performed to characterize the complexes. Moreover, *in vitro* biocompatibility on NHDF cells and antioxidant activity were also evaluated.

MN patches consisting of the complexes were fabricated via a two-step centrifugation casting method, using two different polydimethylsiloxane molds containing pyramidal cavities. The MN patches were characterized for morphology and mechanical strength. Insertion studies were also performed on model membranes. For the *in vitro* performance studies, a fibroblast-populated collagen lattice system (FPCL) model was used to investigate if MN were able to reduce collagen matrix contraction, modifying its viscoelastic properties.

The formation of CS-TMC:WPI complexes was significantly affected by WPI denaturation. All complexes were characterized by *in vitro* biocompatibility and antioxidant properties. MN showed a well-defined structure with a pyramidal morphology, evidenced by SEM analysis. The fracture force for all the MN prepared exceeded 0.058 N, that is the minimum average penetration force for normal skin. Preliminary results pointed out that MN inhibited FPCL contraction with a significant change in its viscoelastic properties. *In vivo* studies are on-going to evaluate the biocompatibility of the obtained composite biomaterial-based MN.

References:

[1] Y. Chen, et al., Polymers 2022, 14, 4436.
[2] D. Yeo, et al., Eur. J. Med. 2017, 22, 28.
[3] Q. Zhang, et al., ACS Nano 2022, 16, 10163-10178.

TEF-PO-015

Development of a nasal spray based on cyclodextrin/hydrophobically-modified hydroxypropyl-methyl cellulose association for the prevention of viral infectious diseases

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The present work aims to develop a thermo-gelling and mucoadhesive system intended to be administered as nasal spray for the prevention of viral infectious diseases. The addition of cyclodextrins (CDs), hydroxypropyl-β-CD (HPβ-CD; Sigma-Aldrich, I) and randomly methylated-β-CD (rβ-CD; CycloLab, HU), to hydrophobically-modified hydroxypropyl-methyl cellulose (Sangelose (SG)) aqueous solutions is proposed to obtain thermo-gelling systems. At room temperature, SG/CDs aqueous solutions are characterized by a low viscosity due to SG/CDs complexation. As the temperature increases to physiological values, SG/CDs complex dissociates: SG hydrophobic chains interact with each other, causing the system sol-gel transition[1].

SG/CD solutions, based on 0.5% w/w SG and different HPβ-CD or rβ-CD concentrations (0.1-0.5% w/v and 0.025-0.2% w/v respectively), were characterized in terms of rheological behavior; viscosity and viscoelastic measurements were performed at room (25°C) and body temperature (37°C) and gelation temperature (T_{gel}) and time (t_{gel}) were determined. The mucoadhesive properties were tested by means of a Texture Analyzer using 8% w/v mucin suspension in simulated nasal fluid as biological substrate. Sprayability and spreadability were investigated for the most promising thermo-gelling and mucoadhesive systems. The spray coverage area using a conventional nasal device, tension surface and contact angle on gelatin/mucins substrates were investigated. Spray deposition in a nasal cast model will be also studied. SG/CD systems stability was evaluated in terms of viscosity at room temperature. Finally, *in vitro* experiments will be performed to assess system cytocompatibility on different cell lines (HeLa, MRC-5, A549, or HEp-2 cells).

The addition of both HPβ-CD and rβ-CD to SG solution was responsible for a sol-gel transition within a physiological temperature range (29-34°C) in about 1 minute. SG/CD systems were characterized by a prevalence of the elastic properties on the viscous ones at 37°C; this behavior is functional to the formation of a protective gel barrier on the mucosa. SG/CD systems were characterized by optimal mucoadhesive properties. The most promising formulations showed sprayability and spreadability suitable for nasal administration. *In vitro* test demonstrated that the systems do not alter the viability of any of the cell lines used.

The thermo-gelling and mucoadhesive systems obtained are proved to be easily sprayed through an appropriate device into the nasal cavity and to form a gel at physiological conditions that should act as a physical barrier to the entry of pathogens into the respiratory tract.

References:

[1] D.Iohara, et al, Mol. Pharmaceutics (2017); 14: 2740-2748.

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ZnAl layered double hydroxides as functional materials in wound healing treatment

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Skin chronic wounds are characterized by a disrupted healing process[1]. Therefore, 3D structures are used as scaffolds to stimulate skin reparation[2]. Layered double hydroxides (LDH) are anionic clay minerals which should contribute to boost the cellular processes thanks to their peculiar structure and chemical composition[3]. The aim of this work was the development of polymeric spray-dried microparticles doped with ZnAl LDH to enhance the skin tissue regeneration. The production method was designed in view of a continuous manufacturing process involving the LDH synthesis and the development of the microparticles.

LDH containing Zn^{2+} and Al^{3+} were synthesized via co-precipitation using ammonia as an alkaline agent. The LDH were then isolated and dispersed in water, without further washing. Alginate and chondroitin sulfate were added to the dispersion, which was then spray dried. The microparticles were then crosslinked using $CaCl_2$. Physico-chemical characterizations, together with *in vitro* proliferation assays on normal human dermal fibroblasts (NHDF), were carried out. The efficacy of the systems was assessed through preclinical *in vivo* testing on a murine model.

Microparticles with a spheroidal shape and a mean diameter of 10-15 μm were produced. The crosslinking step with $CaCl_2$ allowed to obtain water insoluble microparticles without changes in morphology. The presence of LDH in the microparticles was confirmed and corresponded to the theoretical value. The amount of Zn released from the microparticles was evaluated to assess its role in the regeneration process. Cell proliferation assays showed that the scaffolds improved cell growth up to 6 days and the presence of the LDH seemed to increase cell viability. *In vivo* testing confirmed the efficacy of the systems and proved the crucial support of LDH in the skin regeneration phases.

To conclude, microparticles made of alginate and chondroitin sulfate doped with synthetic LDH, based on Zn^{2+} and Al^{3+}, were successfully manufactured. These scaffolds proved to support cell proliferation over 6 days and confirmed their efficacy on the skin regeneration process on a murine model.

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References:
[1] R. Zhao, H. Liang, E. Clarke, C. Jackson, M. Xue, Int. J. Mol. Sci., 2016, 17, 2085
[2] T. Limongi, L. Tirinato, F. Pagliari, A. Giugni, M. Allione, G. Perozziello, P. Candeloro, E. Di Fabrizio, Nano Micro Lett. 2017, 9, 1-13
[3] A. Murali, G. Lokhande, K.A. Deo, A. Brokesh, A.K. Gaharwar, Mat. Today, 2021, 50, 276-302

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3D Bioprinting of an Oral Solid Probiotic Dosage Form

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Inflammatory bowel disease (IBD), including Crohn's disease and ulcerative colitis, affects over 6 million people globally[1]. The composition of gut microbiota in IBD patients has been reported to be significantly different from that of healthy individuals. Therefore, the treatment of dysbiosis could have a positive impact on IBD. This may be achieved by various approaches ranging from simple dietary changes to replenishment of the bacteria. Probiotics are commonly administered in the form of capsules or sachets. Their incorporation into tablets, more convenient from the industrial and treatment compliance perspectives, is challenging because of the compaction forces involved[2]. To overcome such limitations, bioprinting, which consists in 3D printing of biomaterials (bio-inks), was here proposed for the manufacturing of a solid probiotic dosage form for colon delivery[3,4]. Particularly, the aim of the present work was to set up an immediate-release core formulation, where the bacteria would be incorporated, intended for subsequent embedding in a functional polymer shell. For fabrication of the disintegrating core, extrudable pastes, including a large amount of solids, were prepared, and printing by a 3D Discovery™ Gen. 5 bioprinter (RegenHU, CH) was attempted. The pastes, also containing paracetamol as an analytical tracer, were based on either insoluble (Kollidon® SR) or soluble (Mannogem® XL) fillers, which were expected to impart the desired mass and density of the final product while maintaining proper viscosity of the formulations to be extruded. In the former case, a superdisintegrant was added to accelerate interaction with aqueous fluids. By adjusting the composition and the process parameters, it was possible to print selected pastes into monolithic units of desired shape and size. These were allowed to dry at room temperature before being characterized in terms of mass, dimensions, mechanical resistance, disintegration time and dissolution rate. Using a soluble filler led to faster disintegration than combining an insoluble one with a superdisintegrant. The best-performing pastes were then loaded with *Lacticaseibacillus paracasei* as a model probiotic, pointing out compatibility issues only in the case of that containing Kollidon® SR, as highlighted through viable cell count. Even though extensive studies need to be performed to assess the impact of formulation and printing as well as drying conditions on cell viability, the present work would pave the way for the use of bioprinting technique in manufacturing solid dosage forms intended for oral administration of probiotics.

References:

[1] S.C. Ng et al. Lancet 2017, 390 (10114), 2769–2778.
[2] B. Bosch et al. Eur J Pharm Biopharm 2023, 190, 73-80.
[3] A. Mallick et al. Food Hydrocoll Health 2022, 2, 100088.
[4] S. Moutaharrik et al. Drug Deliv Transl Res 2024, 14, 3, 826-838.

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TEF-PO-018

Design of microneedles for dermal delivery of cationic liposomes

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Skin delivery of drugs has been investigated for decades to achieve local or systemic effects. However, the strong barrier given by the tightly packed skin corneocytes prevents the passive diffusion of most compounds into the deepest strata. Among the approaches studied to breach the skin barrier, using microneedles (MNs) or very fluid and deformable liposomes seems to be the most effective; therefore, several studies recently proposed a combination of the two methods[1]. However, most of the research tracked the skin permeation of the drugs delivered with this approach, whereas the effect of MNs on the skin penetration of liposomes *per se* has been scantly investigated.

In this work we designed microneedle arrays (MNA) with different geometrical properties to verify how the MNA pre-treatment on the skin could affect the diffusion of cationic liposomes, either conventional rigid liposomes (RL) or fluid liposomes (FL). Squared arrays of 6.4 mm^2 composed of 7x7 pyramidal MNs were produced with a 3D printer at different base diameters (150 or 200 μm) and needle heights (600 or 1000 μm). After UV curing (60°C, λ=405 nm), MNA were characterized for their morphology, mechanical strength (tensile testing machine) and skin depth (Parafilm model[2]). RL and FL liposomes were prepared by thin film hydration method. RL composition was DPPC/DOTAP/Cholesterol/Rho-PE 45/45/9/1 mol/mol/mol/mol whereas FL bilayers were composed of DOPE/DOTAP/Rho-PE 24/75/1 mol/mol/mol and Tween 80 was added as edge activator in 85:15 w/w ratio with respect to the lipid component. The particle size distribution and ζ potential were measured by dynamic light scattering (DLS). Low density MNA of 200x1000 μm showed the best mechanical properties, thus were selected to evaluate the diffusion of RL and FL formulations into full-thickness porcine ear skin. Skin samples were poked with the MNA (30 N, 60 s), then treated with 50 μL liposomes dispersion on Franz diffusion cells under non-occlusive conditions for 15 min before tape-stripping, PFA fixation, cryosectioning, and observation under a fluorescence microscope.

All the MNA reached at least 2 Parafilm layers; MNA 200 μm base and 1000 μm height reached 5 parafilm layers (approx. 600 μm depth). A reduction in base diameter increased the fragility of 1.0 mm height MN and reduced the reached skin depth. Liposomes showed homogeneous nanometric size (121 ± 3 nm RL; 112 ± 2 nm FL) and positive ζ potential (49 ± 10 mV RL, 28 ± 4 mV FL). Fluorescence imaging indicated that after 15 min FL could efficiently reach the epidermis/dermis interface (EDI) either with or without MN skin pretreatment, while the 200x1000 MN improved the diffusion of RL to the EDI (ImageJ elaboration, $p<0.05$, Two-way ANOVA). Thus, MNs treatment may be required to enhance RL diffusion into the skin, albeit less impacting on FL diffusion.

References:

[1] N. Dragicevic, H. Maibach, Adv Drug Deliv Rev 2018, 127, 58 – 84.
[2] E. Larrañeta et al., Int J Pharm 2014, 472, 65 – 73.

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TEF-PO-019

Cytotoxicity of curcumin decorated silver nanoparticles on human fibroblasts

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Silver nanoparticles (AgNPs) have been long known for their antimicrobial activity and are currently commercialized in different consumer products, medicinal products and medical devices. However, their safety has been questioned and, even though many studies on teir toxicity have been performed, the results reported in literature are often unexhaustive and contradictory.[1]

Here we report the results of AgNP cytotoxicity on WS1 human fibroblasts taking advantage of ptychography, a label free, high-contrast imaging technique for live cells using quantitative phase information. Ptychographic quantitative phase imaging (QPI) technology gives consistent information on cell morphology (e.g., sphericity) proliferation and growth (e.g., dry mass content, cell number), cell motility (e.g., displacement, track speed) providing much more complete information on nanomaterial cytotoxicity than conventional assays.[2]

AgNPs were synthesized employing a safe-by-design approach and using hydroxyethyl cellulose as reducing/capping agent (AgHEC)[3] and curcumin (AgCUR) as natural occurring adjuvant, to take advantage of the potential synergistic antimicrobial and/or antiviral effect of Ag and curcumin.

The selected AgHEC and AgCUR formulations had selectivity index (SI) of 22 and 47, displaying effective antiviral concentration 50 (EC_{50}) at concentration of 12 and 8 ppm, respectively.

On human fibroblasts, AgCUR demonstrated a reduced cytotoxicity with respect to AgHEC, probably due to the intrinsic curcumin antioxidant properties resulting in a cell protective effect. AgCUR had no significant effects on cell morphology and at 49 ppm the dry mass content and the cell number were similar to the untreated control. Cell motility was affected significatively only at the highest concentrations (e.g., 195 ppm) with no effect at concentrations lower than 97 ppm.

Taken together, these results demonstrate the potential value of AgCUR as antiviral tool with a favourable cytotoxicity profile.

Fundings:
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References:

[1] A. Malysheva, A. Ivask, C.L. Doolette, et al., Nature Nanotechnology, 2021, 16, 926-932.
[2] J. Marrison, L. Räty, P. Marriott, et al. Scientific Reports, 2013, 3, article 2369, 1-7.
[3] A.L. Costa, M. Blosi, WO2016125070 - Process for the preparation of nanoparticles of noble metals in hydrogel and nanoparticles thus obtained.

TEF-PO-020

Lemon derived exosome-like nanovesicles as drug delivery system

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Exosomes are extracellular nanovesicles secreted by all cell types and they are involved in various physio-pathological processes, through intercellular communication and substance exchange. The simplicity of large-scale production, low toxicity, low immunogenicity, and high biocompatibility are just some of the aspects that make these nanovesicles attractive as drug delivery systems[1]. The goal is to extract and characterise exosome-like nanovesicles from lemon (ELNVs), load them with a promising drug against Multiple Sclerosis and evaluate the system's effect on an oligodendrocyte progenitor cell line (OPCs)[2]. We successfully extracted ELNVs sustainably without the use of solvents. These particles were characterised in terms of size and stability under different conditions. We were able to load ELNVs with 80% efficiency with an antihistamine drug, Clemastine, achieving a post-loading size of 342.0±107.0 nm in Milli-Q water. The pharmacological activity of the system was assessed in an OPCs model (Fig. 1). ELNVs appear to be a promising drug-loading platform. The outlook is to broaden this technique to more plant sources and include different classes of drugs.

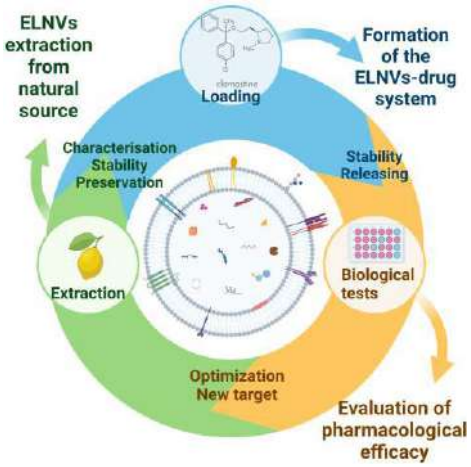

Figure 1: Schematic representation of ELNVs extraction, loading and biological assessment.

References:

[1] Suharta, S.; Barlian, A.; Hidajah, A. C.; Notobroto, H. B.; Ana, I. D.; Indariani, S.; Wungu, T. D. K.; Wijaya, C. H. Journal of Food Science 2021, 86 (7), 2838– 2850.

[2] Boltz, F.; Enders, M.; Feigenspan, A.; Kirchner, P.; Ekici, A.; Kuerten, S. Brain Sci. 2022, 12, 476.

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TEF-PO-021

Poloxamine-908-based hydrogels containing zein nanoparticles as hierarchical injectable formulations

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The excellent flexibility, biocompatibility and soft nature of hydrogels promoted their use in various pharmaceutical and biomedical applications. In particular, the design of thermo-sensitive formulations represent a feasible strategy for the sustained drug release in the required body compartment with reduced side effects. Among the molecules characterized by thermo-responsive features, poloxamines, pharmaceutical excipients belonging to the family of amphiphilic block copolymers, have attracted a certain degree of attention. In this context, this work aims at evaluating the feasibility of poloxamine 908 (P908), a hydrophilic, X-shaped tetrablock copolymer consisting of an ethylenediamine central moiety linked to four chains of poly(propylene) and poly(ethylene) oxide blocks, for the development of *in situ*-forming hydrogels[1]. Various amounts of P908 (15-35 % w/w) were solubilized in cold water under magnetic stirring until a clear solution was formed; then, the samples were characterized by means of passive and dynamic rheology with the aim of investigating the influence of the copolymer concentration and temperature against their mechanical properties. The obtained data showed that the use of concentrations ≥25% w/w P908 favored the formation of systems with a gelation within a suitable temperature range (27-33 °C) and a viscoelastic behavior at 37 °C. Moreover, it was shown that P908 hydrogels can be easily prepared in different physiological relevant media (0.9% saline solution, 5% w/v glucose solution or 0.01 M phosphate buffered saline) and can withstand the autoclave sterilization procedure without any variations of their rheological features[1]. The entrapment of rhodamine B (0.10 and 0.25% w/w) and ovalbumin (1% and 2% w/w), used as models of hydrophilic compound and protein, respectively, demonstrated the ability of the hydrogel matrix to ensure a prolonged and sustained leakage of the entrapped compounds. Additional investigations have been performed in order to develop a hierarchical injectable formulation; in detail, various colloidal carriers, such as zein nanoparticles, have been embedded within the P908 hydrogels with the aim of modulating the biological activity and leakage of the encapsulated compound(s) demonstrating the physico-chemical properties of the nanosystems influence the rheological features of P908-hydrogels.

These results confirm the potential use of P908-based thermo-sensitive hydrogels for the prolonged release of active compounds and the development of multistage systems.

References:

[1] E. Giuliano, M. Fresta, D. Cosco, Journal of Molecular Liquids 2021, 337, 116588.

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TEF-PO-022

Lipopolyplexes for DNA delivery: the effect of cationic polymer on cytotoxicity and transfection

Camilla Pozza, Viola Bertolotti, Giulia Anderluzzi, Silvia Franzè
Department of Pharmaceutical Science via Colombo 71 Milano

Lipopolyplexes (LPP), namely ternary complexes of biocompatible cationic polymers, nucleic acid and liposomes, represent an attractive though poorly investigated alternative to lipoplexes for gene delivery. Poly-L-lysine (PLL), polyethyleneimine (PEI), spermidine, spermine and protamine sulfate are the most used polymers for LPP preparation[1]. Nevertheless, a systematic study of the polymer nature on nucleic acid complexation and transfection efficiency is missing. Here, we prepared LPP using three cationic polymers (Chitosan, PLL and PEI) and 1,2-dipalmitoyl-sn-glycero-3-phosphocholine (DPPC) based liposomes to complex a pDNA encoding the green florescence protein (EGFP). Briefly, pDNA encoding EGFP was complexed with chitosan, PLL or PEI in PBS 50mM pH 4.5 at different polymer/DNA mass ratios. Selected polyplexes were further complexed with DPPC:DOPE:Chol liposomes (55:35:10 mol%, in PBS 50 mM pH 7.4) at at different molar ratios. All formulations were characterized in terms of hydrodynamic size, polydispersity index (PDI) and zeta potential by dynamic light scattering (Malvern, UK). Cytotoxicity, assessed by an MTT assay, and transfection efficiency were determined HeLa human epithelial cells by GFP detection. A pDNA/DOTAP based lipoplex was used as positive control.

We found that optimal polymer/DNA mass ratios were 10 for chitosan and PLL polyplexes and 6 for PEI polyplexes. These polyplexes were around 100 nm in size, PDI<0.2 and positively charged, while final LPP had a mean diameter of about 180 nm, PDI<0.2 and they were slightly positive/neutral. The formation of the ternary complexes were confirmed by Fluorescence resonance energy transfer (FRET) and crioEM. In vitro, generally LPP were significantly less toxic than corresponding PP, with chitosan LPP being the most biocompatible. LPP showed higher transfection efficiency than corresponding PP and control lipofectamine like formulations. In particular, PEI LPP induced the highest GFP expression, both as percentage of positive cells and mean fluorescence intensity also in comparison with the lipoplex. In conclusion, that the choice of polymer influenced the mode of gene expression mediated by these LPP in vitro; generally, PEI is the most promising polymer for the design of LPP, offering a valid alternative for the delivery of pDNA platform.

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IUPAC

IUPAC CrystEng 2024
4th IUPAC Workshop on Crystal Engineering

Lunedì, 26.08.2024: 10:00 - 12:00
Sala: Red2 (level +1)

Chair di sessione: Pierangelo Metrangolo, Politecnico di Milano; pierangelo.metrangolo@polimi.it
Chair di sessione: Gabriella Cavallo, Politecnico di Milano; gabriella.cavallo@polimi.it
Chair di sessione: Giancarlo Terraneo, Politecnico di Milano; giancarlo.terraneo@polimi.it

Satellite meeting to SCI2024 and ECM34 - Padova, in relation with the IUPAC Project 2012-044-1-100 "Basic Terminology of Crystal Engineering"[1]

Abstract della sessione

Crystal engineering is a highly interdisciplinary field, dealing with the design of predictable and controllable solid-state materials by exploiting different intermolecular interactions. Crystal engineering has expanded rapidly in the last decades producing many structurally precise functional materials with advanced properties. The subject goes beyond the traditional division of organic, inorganic, and physical chemistry. It has strong overlap with supramolecular chemistry, X-ray crystallography, material science, and solid-state chemistry and this makes for a very eclectic blend of ideas, techniques and strategies.

This SCI2024-ECM34 satellite meeting aims to provide a forum to discuss the current state of the art of this rapidly evolving field. Through invited talks by leading scientists from institutions and organizations worldwide, we intend to create open relaxed discussions between researchers focused on the latest developments in the field.

We are pleased to invite you to be a part of this exceptional event. It will offer networking opportunities among peers, recognized leaders, young scientists and students and permit the exchange of the latest scientific knowledge regarding the field of crystal engineering.

We look forward to meeting you at the IUPAC CrystEng 2024 workshop in Milan!

Gabriella Cavallo
Pierangelo Metrangolo
Giancarlo Terraneo

[1] https://iupac.org/project/2012-044-1-100/

Programma dettagliato dell'evento satellite

IUPAC CrystEng 2024: 4th IUPAC Workshop on Crystal Engineering

Lunedì, 26 agosto 2024 - Luogo, sala: **Red2 (level +1)**

Satellite meeting to SCI2024 and ECM34 - Padova, in relation with the IUPAC Project 2012-044-1-100 "Basic Terminology of Crystal Engineering" https://iupac.org/project/2012-044-1-100/

Chair di sessione: **Pierangelo Metrangolo**, Politecnico di Milano; pierangelo.metrangolo@polimi.it
Chair di sessione: **Gabriella Cavallo**, Politecnico di Milano; gabriella.cavallo@polimi.it
Chair di sessione: **Giancarlo Terraneo**, Politecnico di Milano; giancarlo.terraneo@polimi.it

10:00 - 10:30

Basic Terminology of Crystal Engineering

Metrangolo, Pierangelo
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Crystal engineering is the design and synthesis of functional crystalline structures, based on a bottom-up approach from smaller building blocks. Crystal engineering is a fascinating and relatively young subject that has expanded rapidly the last 20 years, and is also attracting the interest of the chemical and pharmaceutical industry. It has strong overlap with supramolecular chemistry, X-ray crystallography, materials science, and solid-state chemistry, and, yet, it is a distinct discipline in itself. The subject goes beyond the traditional divisions of organic, inorganic, and physical chemistry, and this makes for a very eclectic blend of ideas, techniques and strategies.

The diversity in both focus and scientific basis of the researchers involved in the field has led to numerous terminology practices that are not consistent among research groups, causing much confusion and unnecessary conflicts.

The purpose and scope of this IUPAC project (no. 2012-044-1-100, https://iupac.org/project/2012-044-1-100) is to provide a basic glossary of terms for this rapidly evolving, highly interdisciplinary field of crystal engineering, to identify and debate open questions, and to point out new directions.

This project brings together a task force of eminent scientists in the field with the objectives to:

• Document, analyze, and evaluate existing practices.

• Make preliminary suggestions for a limited number of terms (basic glossary of terms).

• Organize discussions of these recommendations with a large group of researchers in the area.

• Adjust and optimize preliminary findings in order to have highest possible acceptance from the research community.

• Publish the final recommendations in PAC.

• Approach journal editors and publishers to have the recommendations included, or cited, in their guidelines for authors.

Acknowledgements: The International Union of Pure and Applied Chemistry (IUPAC) is gratefully acknowledged for funding the project no. 2012-044-1-100.

CV dell'autore: Pierangelo Metrangolo is Full Professor of Chemistry Fundamentals of Technologies at Politecnico di Milano, Department of Chemistry, Materials, and Chemical Engineering "Giulio Natta" and Task Group Chairman of the IUPAC project no. 2012-044-1-100 "Basic Terminology of Crystal Engineering" (https://iupac.org/project/2012-044-1-100)

10:30 - 11:00

Crystals that Can Self-Heal

Naumov, Pance
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Self-healing is an intrinsically exciting concept as it applies to the process of recovery, an almost commonplace effect found in living organisms, and extends to inanimate objects. Self-healing of artificial materials is as beneficial as it is to living creatures, as the effect significantly prolongs the lifetime of both. Self-healing polymers, cementitious materials, and coatings have already found commercial applications. Self-healing of crystals was first discovered in sodium chloride in 1980. However, the field has recently entered a renaissance when it was observed for the first time in the emerging material class of molecular crystals in 2016. The reinvigoration of interest in self-healing molecular crystals stems from their prospects as durable, lightweight, and flexible emissive or electronic materials. As ideally defectless and ordered media, organic crystals have unique optical, mechanical, and electrical properties, and the possibility of self-healing substantially increases their viability for durable, lightweight smart devices.

CV dell'autore: Tenured professor at New York University Abu Dhabi, with a cross-appointment at NYU's Molecular Design Institute, and a director of the Center for Smart Engineering Materials. He is a native of Macedonia, where he

got a BSc degree from Ss. Cyril and Methodius University. After acquiring his PhD in chemistry and materials science from the Tokyo Institute of Technology in 2004, Dr. Naumov continued his research at the National Institute for Material Science, Osaka University and Kyoto University. The research in his group is related to materials science, focusing on smart materials, crystallography, bioluminescence, and petrolomics

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11:00 - 11:30

Experimental Data Mining of C/N-I···O-N Halogen Bonds

Rissanen, Kari

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Data mining is the process in which certain specific information is extracted from existing large data sets to discover systematic patterns or parameter modulations. In crystallography data mining1 normally means the use of large crystallographic databases, such as the Cambridge Structural Database2 (CSD) and Inorganic Crystal Structure Database3 (ICSD) for extraction of geometrical parameters, viz. bond distances, angles, interaction distances (e.g. hydrogen and halogen bonds) etc. Our research interest has been focused on the studies of weak non-covalent intermolecular, viz. supramolecular interactions as the driving force in complex formation, self-assembly and molecular recognition, especially in the solid state by single crystal X-ray diffraction. The lecture will highlight some of our recent studies on N-I···O-N and C-I···O-N halogen-bonded systems, using unusually large set of in-house single crystal X-ray structures.4-7

CV dell'autore: Professor of Chemistry at the University of Jyväskylä, Finland. The research of Rissanen group focuses on the design, synthesis and structures of supramolecular and nano-sized assemblies and the weak intermolecular interaction they manifest. Single crystal X-ray crystallography is an integral part and is heavily involved in all areas of the research group. Projects lie at the interface between synthetic chemistry, structural chemistry and nano-related materials science and aim to the understanding of the weak intermolecular interactions. One major area is the synthesis of receptors for cations, anions and ion-pairs and their recognition properties, e.g. for early detection of cancer

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11:30 - 12:00

Crystal Engineering: Then, Now and Next

Zaworotko, Michael J.

University of Limerick, Irlanda; xtal@ul.ie

That composition and structure can so profoundly impact the properties of crystalline solids has provided impetus for exponential growth in the field of crystal engineering1 over the past 30 years. This contribution will address how crystal engineering has evolved from its initial focus upon design (form) to its current emphasis on properties (function) was exemplified by three classes of sorbent materials:

• Ultramicroporous materials offer exceptional control over pore chemistry, pore size and pore shape. New benchmarks for CO2 (see Figure), C2H2 and C6H6 have been observed2 thanks to tight binding sites and strong electrostatics associated with these coordination networks, which remain underexplored when compared to materials such as large pore MOFs. Studies that address water harvesting will be presented.

• Flexible metal-organic materials, FMOMs, were once seen as a curiosity but it is now recognized that they can offer solutions to important gas storage and separation applications, especially when they reversibly switch from closed (non-porous) to open (porous) phases.3 New examples of switching FMOMs will be discussed.

• Non-porous solids. Non-porous solids that undergo pressure-induced switching between closed and open phases are of interest for storage and separations applications.4 New examples of such “switching adsorbent materials” covering 0D, 1D and 2D materials will be covered.5

The overall goal of this presentation is to convey how and why crystal engineering can teach us to custom design the right crystalline material for the right application, including what this means for global challenges such as carbon capture and water purification.

CV dell'autore: Bernal Chair of Crystal Engineering, Science Foundation of Ireland Research Professor and codirector of the Synthesis and Solid-State Pharmaceutical Centre, www.sspc.ie. His research activities have focused upon fundamental and applied aspects of crystal engineering since 1990. Currently, metal-organic materials (MOMs), especially microporous and ultramicroporous sorbents, and multicomponent pharmaceutical materials (MPMs) such as cocrystals, hydrates and ionic cocrystals are of particular interest. These new materials are aimed at addressing global challenges such as carbon capture, water purification and better medicines. He is a Fellow of the Royal Society of Chemistry, the Learned Society of Wales and the Institute of Chemistry of Ireland. He is also a Member of the Royal Irish Academy.

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