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Tailor-made innovation for children with different levels of food neophobia: Co-creating legume-based dishes for the school canteen☆

Nicole Cattarin [a,b], Sofia Trentanove [a,*], Lapo Pierguidi [a], Sara Spinelli [a], Erminio Monteleone [a], Caterina Dinnella [a]

[a] SensoryLab, Department of Agriculture, Food, Environment & Forestry, (DAGRI), University of Florence, Italy
[b] Qualità & Servizi S.p.A., Via del Colle 78, Calenzano, 50041 Florence, Italy

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ABSTRACT

Promoting the acceptability of healthy and sustainable dishes in school canteens is crucial to improve the quality of children's diets, which are often hindered by the low acceptance of plant-based foods and individual variables such as food neophobia. The study employed an approach which integrates co-creation and "Jobs-To-Be-Done" (JTBD) framework to design innovative legume-based dishes, as primary sources of plant-based protein, suitable for school service menus tailored to the needs and tastes of children with different levels of food neophobia. Both the final users (children, $n = 319$, 8–11 y.o.) and the service provider (catering company) were involved in the co-creation process. Hedonic, emotional and sensory responses by children were collected to guide the selection of the most promising solutions. The co-created prototypes were potentially accepted although high neophobic children rated liking lower and used more negative emoji than low neophobic children. One of the prototypes was implemented in the school canteen menu and accepted even by high neophobic children. Results indicated that the adopted co-creation strategy could help mitigate the negative effect of food neophobia on the acceptance of an innovative plant-based dish and to enable the identification of innovative solutions suitable for direct implementation within the regular school menu.

1. Introduction

The dietary quality of school-aged children is generally suboptimal, with insufficient consumption of health-promoting foods, such as vegetables and legumes (Amaral et al., 2022; Cox et al., 2023; Lynch et al., 2014; Mahmood et al., 2025; McCarthy et al., 2020). The rising prevalence of childhood obesity and related conditions linked to excessive intake of added sugars and fats has raised major public health concerns, given the substantial social and economic costs of these trends (Jebeile et al., 2022; World Health Organization, 2020). Diet quality is also closely connected to environmental sustainability (Laine et al., 2021; Schebesta et al., 2020). In this context, increasing attention has been directed toward promoting protein sources with lower environmental impact as alternatives to animal-based products (Ferrari et al., 2022).

Legumes represent a nutrient-dense food group, and are associated with multiple health benefits (Hughes et al., 2022). Their introduction is recommended from weaning, and positive health effects are documented such as improved glycaemic control in children with diabetes, favourable gut microbiota modulation, and support for weight management (Vieira et al., 2021). They are also considered a strategic component of sustainable food systems (Strid et al., 2021), and the Eat-Lancet Commission Planetary Health Diet recommends a daily intake of 75 g to achieve healthy and sustainable dietary patterns (Rockström et al., 2025).

Median daily consumption across European countries is generally below recommendations, ranging from 44.8 g to 1.2 g/day, with Italy reporting 14.9 g/day (Hughes et al., 2022). Regular legume consumption is hindered by several factors, including the lack of enjoyment and dislike of their sensory properties, such as bitterness and a generic "beany" flavour (Chigwedere et al., 2022). Additional barriers include low familiarity, perceived gastrointestinal discomfort, and limited knowledge of their nutritional properties (Appleton, 2024). Most research promoting healthy and sustainable diets focused on vegetables, while studies on legumes remain limited (Kokkorou et al., 2024).

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* Corresponding author.
E-mail address: sofia.trentanove@unifi.it (S. Trentanove).

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Moreover, product innovation targeting the development of plant-based protein solutions has mainly used legumes as protein isolates or concentrates in ultra-processed foods (Tso et al., 2020), while less attention was given to the use of legumes in their traditional form (Appleton, 2024). Overall, these factors highlight the need for further research and innovation focusing on legumes in their traditional form, particularly in child-targeted foods, to improve acceptability and support healthier and more sustainable dietary patterns from early life.

Interindividual variation in food neophobia (FN) has received considerable attention as a key psychological construct influencing the acceptance of new foods and dietary quality in both adults and children, including plant food consumption (Karaağaç & Bellikci-Koyu, 2023). Food neophobia is defined as the reluctance to try or consume novel foods (Pliner & Hobden, 1992) and is considered an adaptive developmental mechanism that limits the ingestion of unfamiliar, and potentially harmful substances. While “novelty” is central to the expression of FN, the construct reflects broader food preferences rather than only responses to new foods. Individuals high in food neophobia are also less inclined to consume even foods that are widely present in their familiar and cultural context but fall outside their habitual dietary repertoire, and to re-taste novel foods they have previously sampled (Mustonen et al., 2012).

In children, this behaviour appears to be mediated by the expectation that unfamiliar foods will taste unpleasant. Refusal among highly neophobic children may reflect a risk-avoidant strategy: when choosing between a potentially positive experience (e.g., tasting a novel, palatable, and nutritious food) or a negative one (e.g., an unpleasant food), they tend to avoid the latter and to minimize the risk of distaste (Hendriks-Hartensveld et al., 2023). Food neophobia in children is associated with limited dietary variety and poorer diet quality, including lower adherence to healthy eating patterns (Di Nucci et al., 2023; Maiz & Balluerka, 2016), and reduced vegetable preference (Laureati, Bergamaschi, & Pagliarini, 2015; Proserpio et al., 2020). Moreover, a lower proportion of energy from protein and a higher proportion from carbohydrates have been reported in children aged 6–12 years (Kutbi et al., 2022). In younger children (4–6 years), lower protein intake has been associated with reduced energy intake (Cooke et al., 2006), while a higher energy intake from discretionary foods, with no clear association with BMI, has been observed at 24 months (Perry et al., 2015).

Although FN has a genetic component (Knaapila et al., 2007), its expression is modulated by sociodemographic and socioeconomic factors and by gradual exposure to a broad and diverse range of foods (Estay et al., 2025; Meiselman et al., 2010). Foods characterized by warning sensory properties such as bitterness and astringency (Laureati et al., 2018) or with very intense flavours, those belonging to other cultures, perceived as dangerous, or simply new, may elicit such a high level of arousal that it becomes unpleasant, leading to rejection among highly neophobic individuals (Jaeger et al., 2021). This may reflect heightened stimulus responsiveness among those with higher levels of neophobia (Jaeger et al., 2021; Laureati et al., 2018). This theoretical framework reinforces the relevance of FN in the acceptability of innovative foods, such as legume-based dishes, considering that novelty and stimulus complexity, determines the level of arousal and its hedonic valence according to Berlyne's inverse U-shaped model (Berlyne, 1970; Köster & Mojet, 2007). Limited effort has been devoted to developing foods acceptable to high neophobic children. Tailor-made innovations targeting this group, together with the adoption of appropriate exposure strategies to new plant-based food solutions are needed.

School-provided meals (SPM) are a critical intervention point to advance both healthy and sustainable diets (Gallegos et al., 2025). They reach the vast majority of children aged 5 to 12–16 years in countries with compulsory education (Gallegos et al., 2025), offering a unique platform to influence dietary intake during key developmental periods. By improving nutritional quality, SPMs may reduce the early onset of diet-related non-communicable diseases (NCDs). In addition, eating habits established in childhood tend to persist into adulthood, increasing the long-term impact of early dietary interventions. For SPMs that incorporate plant-based dishes, success also depends on addressing barriers to children's preference and consumption of such foods. The Vegetable Intake Strategic Alliance (VISA) position statement (Cox et al., 2023) explicitly calls for moving beyond health- and nutrition-based messaging toward strategies that prioritize children's liking and enjoyment of vegetables.

Children should be actively engaged as food designers in tailor-made innovation of healthy and sustainable food products, particularly for two reasons: i) health-related messages are generally less appealing to children, who usually prioritize short-term sensory gratification over long-term health benefits; and ii) children's food preferences differ substantially from adults', showing a strong liking for sweet tastes, aversion to bitterness, and sensitivity to certain textures (Galler et al., 2020).

Participatory and iterative approaches, such as co-creation, represent promising strategies for child-centered food product development (Galler et al., 2020). Co-creation is one of the methodological approaches adopted within Open Innovation models for New Food Product Development (NFPD), enabling the active involvement of stakeholders, including consumers, in the design process. These frameworks support the development of products better aligned with users' needs and preferences, thereby increasing their likelihood of acceptance and market success (Prahalad & Ramaswamy, 2004).

In NFPD, several co-creation applications have focused on the development of healthier products, reflecting the recognized importance of involving end-users to promote healthy eating and food choice (see Durco et al., 2025; Pinesso Ribeiro et al., 2025 for review). However, studies involving children and adolescents remain relatively scarce, although the available evidence suggests promising outcomes. Galler et al. (2020, 2022) employed a multi-step co-creation approach consisting of: i) Show and Tell – photovoice activities (methods from participatory action research that enable children and youth to document and reflect on their realities: children take photographs, which are then used to elicit their perspectives and meanings regarding a given experience or topic); ii) Reflect – sorting tasks using photovoices to stimulate reflection on personal eating habits; and iii) Create – gamified brainstorming. This approach generated novel ideas for healthy snacks and provided insights into children's and preadolescents' food habits. A similar multi-step approach was applied in the development of innovative dairy products with children (Velázquez et al., 2022) and adolescents (Pinesso Ribeiro et al., 2025) including: i) Exploring – ingredient selection; ii) Prototyping – product tasting and qualitative assessment; iii) Refining; iv) Validation – evaluation of final products. This led to well-accepted healthy dairy products and insights into users' needs, preferences and perceptions.

More recently, Kokkorou et al. (2025), involved students and culinary instructors from a hospitality school in co-creating legume-based dishes for school canteens using an approach that integrates co-creation with the “Jobs-To-Be-Done” (JTBD) framework (Ulwick, 2017). JTBD is a customer-centric innovation and product development theory that shifts attention away from classic segmentation (e.g., demographics) toward understanding the underlying “jobs” people aim to accomplish in specific contexts (Christensen et al., 2003). People “hire” products or services not just for features, but to make progress in their lives (functional, emotional, social outcomes). A job encapsulates the situational context, desired outcome, and constraints that shape a consumer's decision-making. From a methodological point of view the “Jobs-To-Be-Done” approach is based on observation or indirect measures and does not consider asking consumers directly (Ulwick, 2017). The original approach proposed by Kokkorou et al. (2025) combines direct stakeholder involvement via participatory techniques with indirect methods (such as JTBD) to develop new legume-based dishes for school canteen and for new product development (Domenici et al., 2025).

Emotions are increasingly considered alongside traditional affective measures to describe consumers' food experiences (Spinelli, 2021) and

more recently have proved to be a valid measure of children's experience of SPMs (Piochi et al., 2025). Evidence from studies with children has also shown that emotions complement liking measures in predicting product performance and understanding drivers of food choice (Schouteten et al., 2018), particularly for novel foods (Appiani et al., 2025). Within NFPD, emotion measurement is considered crucial for assessing the potential success of new products (Köster & Mojet, 2007), as innovative products typically elicit surprise upon first exposure, which may evolve into other positive (e.g., relaxing, cheerful) or even negative (e.g., boredom) emotions, influencing their success or failure in the medium to long term. Recently, child-friendly emotion measurement tools based on emojis, have been developed and successfully applied to describe food experiences (Deubler et al., 2020; Gallo et al., 2017; Schouteten et al., 2018; Schouteten et al., 2019; Sick et al., 2020; Sick et al., 2022). Similarly, Kokkorou et al. (2025, 2026) applied an emotion-based questionnaire to describe legume-based dishes co-created by adolescents and to assess their performance over time. These approaches highlight the growing relevance of emotion-based methodologies in understanding children's interactions with food, offering valuable insights for product design, communication, and the development of healthier and more appealing food options.

Earlier co-creation studies on children (Galler et al., 2020, 2022; Pinesso Ribeiro et al., 2025; Velázquez et al., 2022) often included the end-users only. Prototype validation typically relied on a single measure (overall liking), without considering sensory or emotional responses, or individual differences such as food neophobia. Furthermore, testing was frequently conducted in controlled settings rather than real contexts for example through small portions tastings in a dedicated school area (Velázquez et al., 2022) or during a lunch offered in the school dining room (Kokkorou et al., 2026).

The present study addresses these critical issues by extending an iterative co-creation/JTBD framework to develop legume-based foods (Kokkorou et al., 2025) within the real-world context of primary school canteen, involving both end-users (children) and the service provider (canteen catering company). The aim was to develop co-created tailor-made legume-based dishes to implement in the school canteen menu, suitable for children with different levels of food neophobia. An integrated approach combining liking, emotional and sensory responses was used to evaluate and select the most promising concepts and prototypes. Finally, the acceptance of one co-created legume-based dish was assessed within the school canteen menu and compared with the regular legume-based offerings.

2. Materials and methods

2.1. Participants

This study was conducted in two primary schools in the municipality of Campi Bisenzio, in the Florence area (Italy), in collaboration with the school Catering Company (CC). Both schools are located in peri-urban areas, characterized by socio-economic indicators below the metropolitan average. The municipality of Campi Bisenzio hosts a highly diverse student body, with approximately 30% of students having a migrant background (mainly from Asia, Central-Eastern Europe, and North Africa) compared to 13.3% at the national level (Ministero dell'Istruzione e del Merito, 2024). This allowed the research to be conducted in a mixed cultural and socio-economic background. The data collection took place between February and May 2024 (phases 1–6: prototype development) and between March and April 2025 (phase 7: co-created dish testing in the canteen service) and involved children, school catering staff (chefs, dieticians, purchasing manager) and the research and nutrition team from SensoryLab UniFi (Table 1). In total, 319 children (aged 8–11 years) were involved in the various phases of co-creation, with a partial overlap of participants across phases. Students were recruited from the third, fourth, and fifth grades of the primary schools. The absence of food allergies and intolerances was the only inclusion criterion; other

Table 1
Phases of the experimental plan of the co-creation process and demographic characteristics of each panel. n/a = not applicable, CC = Catering Company.

		Participants					
Project phases	Aim	Panel	Size	Mean age (SD)	Boys (%)	Methods and Measures	No. of concepts/dishes (*)
Phase 1	Identification of opportunities and concept development	Children (P1)	25	8.29 (0.46)	63%	Focus Group Jobs-To-Be-Done Free-association-task SCAMPER	9
		CC staff	5	n/a	n/a	Focus Group Jobs-To-Be-Done SCAMPER	10
Phase 2	Concept refinement	Children (P1)	25	8.29 (0.46)	63%	Focus Group SCAMPER	30
Phase 3	Concept validation	Children (P2)	133	8,77 (0.70)	53%	Familiarity with legumes Willingness to try the concepts Food Neophobia (ICFNS) Emotional profile (CATA Emoji Pair Questionnaire)	30
Phase 4	Concept selection & recipe development	SensoryLab UniFI team	4	n/a	n/a	Nutritional & sustainability assessment	11
		CC staff	5	n/a	n/a	Assessment of cost & feasibility (including preparation and serving)	10*
Phase 5	Generation of dish specific sensory vocabulary	Children (P3)	25	8.65 (0.59)	55%	Modified Repertory Grid Method (EmoSemio)	7*
Phase 6	Prototype validation in the classroom	Children (P4)	125	8.92 (0.69)	50%	Food Neophobia (ICFNS) Familiarity with legumes Appetite Liking Emotional profile (CATA Emoji Pair Questionnaire) Sensory profile	7*
Phase 7	Prototype validation in the school canteen	Children (P5)	126	9.67 (0.63)	53%	Food Neophobia (ICFNS) Appetite Liking	1* prototype and 3* regular dishes

reasons for not participating in the study were the lack of child or parental consent and the absence on test days. Children who were unable to complete the test independently or who provided inconsistent responses (e.g., indiscriminate selection of all emojis) were excluded from the data analysis (~10%).

Written informed consent was obtained from all children and parents in line with the General Data Protection Regulation (GDPR) 2016/679. Confidentiality and anonymity were maintained through secure data storage and pseudonymisation of participant information. Participants' identifying information was replaced with a numeric code; the correspondence between the code and personal data was stored in a protected file with access restricted only to the principal investigator. The study was approved by the Commission for Ethic in research of University of Florence (prot. N. 0316027 2024).

All activities with children were coordinated by the expert staff of the SensoryLab UniFi, experienced in conducting activities involving children as well as vulnerable populations. The experimental protocol also includes alternative recreational activities (e.g., food-themed crossword puzzles, word and logic games) to ensure comfortable and inclusive conditions also for pupils unable to participate (e.g., lack of consent from parents or from the minor, or the presence of food allergies/intolerances).

2.2. Co-creation procedure

The study followed a six-step procedure specifically developed and applied for the co-creation of plant-based dishes for the school canteen with adolescents (Kokkorou et al., 2025) with an additional phase aimed at prototype validation in the school canteen (Table 1). Consistent with Kokkorou et al. (2025), smaller panels (classes of 25 children) were used for the qualitative phases (phases 1–2 and 5) to facilitate effective session management. In contrast, larger samples were employed for the quantitative phases (phase 3 and phases 6–7). Specifically, 133, 125, and 126 children participated in phases 3, 6, and 7, respectively, ensuring adequate statistical power to detect effects in the ANOVA models while accounting for potential dropouts.

2.2.1. Phase 1 - Identification of opportunities and concept development with children and Catering Company technical staff

The first phase of the co-creation process included two focus groups, one conducted with children and one with the chefs of the Catering Company (CC). Twenty-five children (panel P1) participated in a 1-h focus group, divided into four groups of 6–7 participants, each guided by a moderator and an assistant from the SensoryLab UniFi team. Children involved in the focus groups in this phase and in phase 2 (concept refinement) were not included in the subsequent co-creation stages. First, the "Jobs-To-Be-Done" (Ulwick, 2017) framework was employed through a series of specifically designed questions using the evoked context technique (*Think about when you are in the school canteen, in general, not about specific dishes. What do you like? What don't you like? / What would you change? How do you think the school canteen dishes should be?*) to explore the various dimensions of children's needs and expectations regarding the canteen and the dishes served, and particularly the "jobs" that dishes should fulfil to satisfy their initial needs.

Next, the free-association task (FAT, Koll et al., 2010) was performed to obtain information on children's knowledge and attitudes toward legumes. Children were shown nine cards, each representing a legume commonly present in the Italian culinary tradition (brown lentils, chickpeas, fava beans, peas, borlotti (brown) beans, and cannellini (white) beans) or in ethnic cuisine (red lentils, soybeans, soybean sprouts) following the procedure described in Kokkorou et al. (2025). They were asked whether they recognized the legume and were invited to freely elicit three words for each legume. Results from FAT were represented as word clouds (Fig. 1).

Subsequently, the SCAMPER (Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Rearrange/Reverse) technique

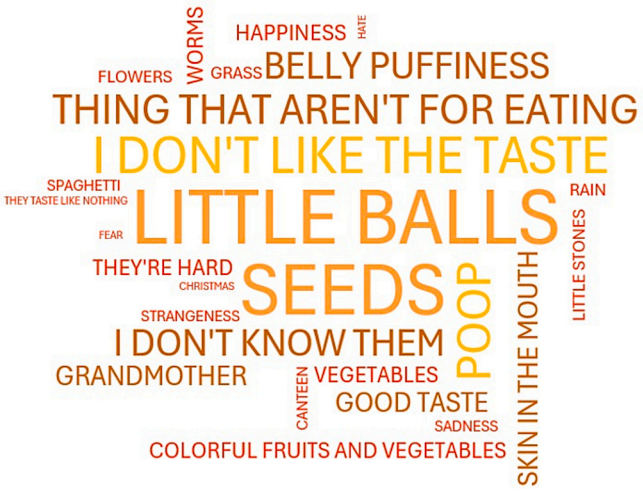

Fig. 1. Word cloud of the most frequently cited words related to legumes during the free-association task (FAT); word size is proportional to the frequency of mention.

(Boonpracha, 2023; Eberle, 1972; Serrat, 2017) was used to develop new legume-based (LB) dish ideas. Children were asked to imagine themselves as head chefs of the school canteen and to develop second courses, alternatives to meat dishes, that would appeal to their peers. They were asked to choose one or more legumes from those shown with the cards and guided to the development of a legume-based dish through a series of questions designed to stimulate creativity and encourage exploration of different aspects of dish creation, such as ingredient selection and combination (Supplementary materials, Table S1). The selection of pasta and rice as the main ingredient in the new dish was not allowed to avoid the development of a first course where legumes represent only a secondary ingredient, while dairy products and eggs were discouraged to facilitate the development of new dishes mainly containing protein from plant sources. This procedure continued until at least three dish ideas were generated per group.

Five CC chefs participated in a separate focus group to increase the variety of concepts, ingredients, and cooking methods. Chefs underwent the JTBD and SCAMPER tasks to provide opinion on how dishes should or should not be prepared to be highly accepted by children, and to generate further LB dish concepts, respectively. Chefs were shown children's JTBD and FAT results to aid the development of LB dishes well accepted by the target group.

2.2.2. Phase 2 - Concept refinement with children

The four groups of children from panel P1 participated in a second focus group to review, modify, refine, and improve the LB concepts developed in the previous phase. Each group revised the concepts developed by a different group and by chefs. Children addressed the last two SCAMPER questions, i.e. *What do you think are the strong points of the dish?; What could you change in this recipe if you were to think of a variant?* (e.g., *you could change an ingredient, the preparation and assembly,* i.e. *chickpeas could be puréed,* etc.). This phase generated further variants and allowed a larger number of children to contribute to the improvement of the developed ideas. This phase led to the development of 30 concepts of LB-dishes.

2.2.3. Phase 3 - Concept validation with children

The concept validation phase is the first quantitative phase of this co-creation process, aimed at selecting the concepts with the highest acceptability potential by groups of children higher in food neophobia level and then less well-disposed toward LB innovative dishes. To validate the concepts, 133 children (panel P2) completed a questionnaire on a tablet. The test was conducted over two days with sessions of one class

at a time and was organized in the morning, in sessions of approximately one hour. The questionnaire included a first section to collect demographic characteristics (age and gender) and familiarity with the same nine legumes depicted in the FAT cards, using a 5-point categorical scale (Tuorila et al., 2001): 1 = I do not recognize it; 2 = I recognize it, but I have never tasted it; 3 = I have tasted it, but I don't eat it; 4 = I occasionally eat it; 5 = I regularly eat it. For each of the 30 concepts, presented as written descriptions (Table 2), Willingness To Try (WTT) was assessed using a 9-point-categorical scale (1 = I really don't want to taste it; 5 = Neither yes nor no; 9 = I would very much like to taste it) and the emotional profile was evaluated using the CATA Emoji Pair Questionnaire (Sick et al., 2022). The latter is a questionnaire specifically validated for food products with school-aged children, who are asked to indicate one or more emoji pairs, out of 17 possible pairs, that they consider appropriate to describe the item. The concept descriptions appeared in a randomized and balanced order to control for the presentation order effect.

2.2.4. *Phase 4 - Concept selection, recipe development and prototyping*

In this step, the SensoryLab UniFi team selected the most promising concepts based on WTT scores and emotional profile for both high and low neophobic children. Concepts were selected also to cover different dish types (e.g., salads, soups, patties).

Selected concepts were then evaluated by the CC technical staff who assessed their feasibility for inclusion in school canteens in terms of cost and logistic (i.e. time needed for preparation, suitability to be transported from the company's central kitchen to school, easiness to be served according to canteen organization).

CC chefs developed recipes and prepared dish prototypes, producing at least two versions per concept. Recipes were verified for compliance with national nutritional guidelines for school canteens (Ministero della Salute, 2010, 2021).

Prototypes were evaluated in a collective session by SensoryLab UniFi and CC teams considering: i) compliance with child expectations (JTBD); ii) consistency with the original concepts; iii) suitability to be part of the menu as second course or as single dish ("piatto unico"). As a secondary aspect, prototypes were selected to cover different dish types. This process led to the selection of six savoury (multicolour muffin, savoury pancakes, rice croquettes, multilayer cake, colourful rice cake and multilayer flatbread) and one sweet (sweet pancakes) legume-based prototype dishes (Table 2; Fig. 2). Their ingredients are listed in Table S2.

2.2.5. *Phase 5 – Generation of dish specific sensory vocabulary*

A modified version of the Repertory Grid Method-RGM (Spinelli et al., 2014; Spinelli & Jaeger, 2019) was adopted to identify the sensory descriptors of the seven prototypes. Twenty-five children (Table 1, panel P3) took part in one-on-one interviews moderated by SensoryLab team personnel in a quiet room suitably equipped for the purpose.

Samples (around 50 g) of the six savoury prototypes were presented to the children in randomized order and served each in a small container identified by a three-digit code. All dishes were served warm, except for the multilayer flatbread and the sweet pancakes, which were served at room temperature. Children tasted and ranked the samples according to their preferences. Then, the samples were divided into two triads from the most (1st to 3rd rank) to the least (4th to 6th rank) preferred. Starting with the first triad the respondent was asked how each sample was in terms of appearance, smell, flavour and texture compared to the other two (*In which aspects is it different/similar to the other two samples?)*. The same procedure was applied to the 2nd triad. Then, a new triad was formed, including the sweet pancakes, the sample the child ranked first and the savoury pancakes (if the savoury pancakes were ranked first, then the triad included the sample ranked second). This was done because the sweet pancake was the only sweet dish presented. Responses were analysed using a semiotic approach, generating a participant-led lexicon used to measure children's sensory responses in the validation

Table 2
Concepts of the co-created dishes and their characteristics: the main legume ingredient and the dish category. In bold, the concepts selected to be used in phase 4. Letters in the first column indicate the prototypes developed from the concept: a = multilayer flatbread, b = rice croquettes c = colourful rice cake, d = savoury pancakes, e = multicolour muffin, f = multilayer cake, and g = sweet pancakes.

	Concepts	Legume used	Category
1	Sandwich with lentil cream and melted cheese, soft zucchini and cooked onion	Lentils	Sandwich
2	Sandwich with lentil cream and melted cheese, salad, tomatoes and diced carrots	Lentils	Sandwich
3a	**Burdigato with layers of beans, lentils and chickpeas, tomato sauce, onion, salad, boiled egg slices, with sauces on the side (e.g. cocktail sauce, mayonnaise, ketchup, barbecue)**	**Beans, lentils and chickpeas**	**Sandwich (multi-layered sandwich inspired by a cartoon food)**
4a	**Burdigato with layers of lentils and chickpeas, yellow and orange carrots, potatoes, salad, boiled egg slices, with sauces on the side (e.g. cocktail sauce, mayonnaise, ketchup, barbecue)**	**Lentils and chickpeas**	**Sandwich (multi-layered sandwich inspired by a cartoon food)**
5	Red lentil, bean and chickpea balls with sauces on the side (e.g. cocktail sauce, mayonnaise, ketchup, soy sauce)	Red lentils, beans and chickpeas	Patties
6	Red lentil, beetroot, fava bean, pea and green bean balls with salad, with sauces on the side (e.g. cocktail sauce, mayonnaise, ketchup, soy sauce)	Red lentils, fava beans and peas	Patties
7bc	**Rice and bean croquettes with a colourful red lentil filling, served with melted cheese cream**	**Beans and red lentils**	**Patties**
8	Salad wrap stuffed with fava beans, black olives and cherry tomatoes, with sauces on the side (e.g. cocktail sauce, mayonnaise, ketchup, barbecue)	Fava beans	Wraps
9	Salad wrap stuffed with beans, baby carrots, black olives, soy sprouts, with sauces on the side (e.g. cocktail sauce, mayonnaise, ketchup, barbecue)	Beans and soy sprouts	Wraps
10	**Salad wraps stuffed with peas, baby carrots and tomatoes, with sauces on the side (e.g. cocktail sauce, mayonnaise, ketchup, barbecue)**	**Peas**	**Wraps**
11	Legume-stuffed wrap with fava beans and pecorino cheese	Chickpeas, lentils and fava beans	Wraps
12	Necci (chestnut flour crêpes) stuffed with lentils and pumpkin	Lentils	Wraps (inspired by regional cuisine)
13	**Spring roll stuffed with chickpeas and peas, diced tomatoes and carrots, with sauces on the side (e.g. cocktail sauce, mayonnaise, ketchup, barbecue)**	**Chickpeas and peas**	**Wraps (inspired by ethnic cuisine)**

(*continued on next page*)

Table 2 (*continued*)

	Concepts	Legume used	Category
14	Colourful salad with fresh fava beans, olives, cherry tomatoes and corn, with sauces on the side (e.g. cocktail sauce, mayonnaise, ketchup, barbecue)	Fava beans	Salads
15	Warm rainbow mix of chickpeas and carrots	Chickpeas	Salads
16	Warm and crunchy rainbow mix of chickpeas, carrots and tomatoes	Chickpeas	Salads
17	**Rainbow salad with chickpeas, peas, sweet corn, with popcorn served on the side**	**Chickpeas and peas**	**Salads**
18	Rainbow salad with chickpeas, crunchy carrots, celery and tomatoes	Chickpeas	Salads
19	Rice salad with peas, potatoes, boiled egg, with mayonnaise on the side	Peas	Salads
20	Rice salad with peas, potatoes, boiled egg, pickled gherkins, with mayonnaise on the side	Peas	Salads
21	Vegetable sticks with hummus (chickpea cream)	Chickpeas	Salads
22	Panzanella with crunchy bread croutons, peas, beans and lentils, cherry tomatoes, salad, and diced cheese	Peas, beans and lentils	Salads (inspired by regional cuisine)
23	Panzanella with crunchy bread croutons, peas and beans, cherry tomatoes, salad, pickled gherkins, topped with a whole creamy mozzarella	Peas and beans	Salads (inspired by regional cuisine)
24d	**Colourful legume pancakes with pea or carrot cream of choice**	**Chickpeas and peas**	**Savoury pies**
25	Stuffed pastry cupcake with red lentils, peas, potatoes and seasonal vegetables	Red lentils and peas	Savoury pies
26ef	**Tricolour multilayer cake with lentil tomato cream, melted cheese filling and pea cream**	**Lentils and peas**	**Savoury pies**
27 g	**Colourful legume pancakes with yoghurt, bananas and strawberries**	**Chickpeas**	**Sweet pies**
28	**Warm soup with rice, lentils, tomato sauce and potatoes**	**Lentils**	**Soups**
29	Warm soup with peas, rice and potatoes (without onion)	Peas	Soups
30	**Ramen (oriental-style broth) with red lentils, soy sprouts, rice and narutomaki, with croutons on the side**	**Red lentils and soy sprouts**	**Soups (inspired by ethnic cuisine)**

phase (Table 3).

2.2.6. Phase 6 – Prototype validation in classroom

The seven prototypes were evaluated for sensory, liking and emotions by 125 children (panel P4) who completed a questionnaire on a tablet. The test was organized in each class in the morning and lasted approximately one hour. Children received small portions (around 50 g) of each prototype identified by a three-digit code. The savoury samples were presented in a randomized order, while the sweet one was always presented as the last to avoid the contrast and convergence effect in sensory description (Lawless & Heymann, 2010). Children were asked to rate their appetite on a 100-point visual analogue scale (VAS), anchored from "not at all" to "extremely", which has been successfully used to assess this variable in children within the age range considered in this study (Kral et al., 2011; Lee et al., 2020; Roemmich et al., 2002). Then, they took a bite of the sample and rated their liking on a 9-point hedonic scale (1 = dislike extremely; 5 = neither like nor dislike; 9 = like extremely) (Peryam & Pilgrim, 1957). Emotional responses were assessed using the CATA emoji questionnaire (Sick et al., 2022), and sensory attributes were evaluated using a CATA questionnaire with attributes derived from the RGM interview. Children were encouraged to rinse their mouths with water between samples. Participants who refused to taste the prototypes served were excluded from the analyses of liking as well as emotional and sensory characterization. Data on familiarity with legumes (Tuorila et al., 2001) and on food neophobia (Laureati, Bertoli, et al., 2015) were also collected.

2.2.7. Phase 7: Prototype validation in the school canteen

Prototype validation in the school canteen involved a panel of 126 children (panel P5) and was conducted over four separate days, in which a different LB dish was evaluated each time. Three options were part of

Table 3
Dish-specific sensory lexicon developed using the Repertory Grid Method procedure.

Sensory Modality	Descriptors
Appearance	It is multicoloured
	It is green
Taste/Flavour	It is sweet
	It is spicy
	It is sour
	It is bitter
	It is salty
	It has a taste I don't recognize
	It tastes like chickpeas
	It tastes like tomato
	It tastes like cheese
	It has many flavours
	It tastes like cooked vegetables
	It tastes like salad
	It tastes like lentils
	It tastes like fruit
	It tastes like peas
Texture	It is mushy
	It is fluffy
	It is chewy
	It melts in the mouth
	It is crunchy
	It is soft
	It is hard

Fig. 2. The seven co-created prototypes: sweet pancakes, multicolour muffin, savoury pancakes, rice croquettes, multilayer cake, colourful rice cake and multilayer flatbread.

the regular school menu (bean soup with pasta, chickpea flatbread, and white beans), while one was a co-created dish (rice cake). The dish was selected based on phase 6 results, considering the concept that was more well accepted by children with a different level of food neophobia and feasibility restrictions of the Catering Company. In the school canteen considered, meals are fixed and no alternative options are routinely available. Food is served by catering staff and neither children nor parents select menu items. A standard meal consists of two courses served sequentially: a carbohydrate-based first course (e.g., pasta or rice), followed by a protein-based second course (meat, fish, eggs, dairy, or legumes, rotated weekly) with a side of vegetables. Alternatively, a single-course dish combining carbohydrates and protein (e.g., pasta with beans) may be provided, followed by vegetables, bread, and fruit. Sweet dishes are occasionally offered in place of fruit. Parents may request a plain diet for children who are temporarily unwell.

The LB dishes were included within a standard menu, where they represented either the second course, corresponding to the main protein source according to the Italian menu structure, or a single-dish option. When served as a second course, the dish was combined with a first course, whereas all meal options, including the single-dish alternatives, were accompanied by a vegetable side dish, bread, and fruit. To avoid potential effects of satiety resulting from the consumption of the first course or side dishes, as well as possible influences of other menu components on liking for the target dish, all LB dishes were always served alone before the other courses.

Before starting lunch, children reported their level of appetite using a 100-point visual analogue scale (VAS), anchored from “not at all” to “extremely”. After consuming the target dish, they rated their liking using a 9-point hedonic scale (1 = dislike extremely; 5 = neither like nor dislike; 9 = like extremely) (Peryam & Pilgrim, 1957).

Activities were managed by the technical staff of the catering company and the SensoryLab UniFi staff under typical school meal conditions.

In each phase, children who had not participated previously completed the Italian Child Food Neophobia Scale (ICFNS) (Laureati, Pagliarini, et al., 2015) to measure food neophobia level, using only verbal labels (1 = Very false, 2 = False, 3 = So-so, 4 = True, 5 = Very true) instead of verbal labels and emoji.

For Phases 3, 6, and 7, questionnaires were completed individually by the children. Personnel from SensoryLab UniFi supervised the sessions, provided clarification when needed, and ensured the absence of interactions between participants. Data were collected using Compusense software (ver. 25.0.33398) and, for the school canteen test in Phase 7, via paper questionnaires to optimize time and logistics.

Fig. 9 summarizes the flow of selection from concept development to co-created dish introduction in the school canteen.

2.3. Data analysis

2.3.1. Qualitative data

Results from focus groups were recorded and a qualitative analysis was first independently performed by three operators and then collectively discussed. Information from the “Jobs-To-Be-Done” framework and SCAMPER grids were respectively analysed to identify the JTBD of food served in school canteens (social, sensory, functional and emotional aspects) and to develop legume-based dish concepts. Data from Free Association Task with legume pictures were reported as frequency of citations and graphically represented as word clouds.

Qualitative data collected through individual interviews using the modified Repertory Grid Method were submitted to a semiotic analysis (Spinelli et al., 2014) to identify the sensory dimensions relevant to children in describing new dishes. The descriptors were grouped into construct classes. The construct classes referred to dimensions concerning texture, taste and appearance. The set of construct classes generated the descriptive lexicon (Table 3), which was then used in the prototype validation phases.

2.3.2. Quantitative data

Cronbach-α was computed on the individual ratings assigned to the FN questionnaire items, after reversing the neophilic items, to check for questionnaire reliability (0.76 for panel P2, 0.77 for panel P4 and 0.93 for panel P5). FN score was computed for each subject by summing the ratings assigned to each item (FN score range 8–40, higher scores indicating higher FN). The FN score normal distribution was checked by Shapiro-Wilk test and subjects divided around the median into High Food Neophobic (HFN) and Low Food Neophobic (LFN) children. A two-way ANOVA model with interactions was used to assess the effect of gender and age class on FN score.

A legume familiarity score (LF) was computed for each subject by summing up the ratings assigned to each legume. The LF score normal distribution was checked by Shapiro-Wilk test. A linear regression was applied to assess the relationship between LF and FN scores. The Kruskall-Wallis test was used to assess the effect of the type of legume on familiarity followed by Steel–Dwass post-hoc test when significant differences ($p \leq 0.05$) were found.

Characteristics of Panel P2, P4 and P5 were compared. Gender and age distribution between panels was tested by χ^2-test. One-way ANOVA models were applied to test for differences in FN and LF scores between panels.

In phase 6 (prototype validation in the classroom) the effect of the class on appetite was tested using a one-way ANOVA model. In order to explore the effects of FN and concepts or prototypes on WTT and liking, respectively, Repeated Measure Mixed ANOVA models were computed. Interactions were tested using Satterthwaite's approximation and subjects included as a random effect. To identify the most promising concepts, a one-sample *t*-test was applied to the concept mean WTT ratings assigned by HFN children in order to determine whether they were significantly lower ($p \leq 0.05$) from the scale's neutral point (5 = neither yes nor no). The same test was applied on mean liking ratings of prototypes to assess their significant difference from the scale neutral point (5 = neither like nor dislike).

In phase 7 (prototype validation in the school canteen), the effect of the dishes on liking was independently assessed in HFN and LFN groups using independent Repeated Measure Mixed ANOVA models with Satterthwaite's approximation with interactions. Subjects were treated as a random factor, products as a repeated factor, and appetite was included as a covariate. Tukey's HSD test (honestly significant difference) was used as a post-hoc test when significant differences ($p \leq 0.05$) were detected.

Data from sensory and emotion CATA questionnaires were subjected to Cochran's Q test to assess the significance of the differences in citation frequencies for each descriptor/emoji pair, followed by post-hoc pairwise McNemar tests with Bonferroni correction. Correspondence Analysis was performed on significant attributes to map emotion and sensory space of the concept or prototypes. RV coefficient was computed to compare sample configuration based on sensory descriptors according to HFN and LFN children. To explore the relationships among concept emotion descriptions by HFN and LFN children Multiple Factor Analysis (MFA) (Escofier & Pages, 1994) was conducted. The frequency of selection of emoji pairs per each concept by the two children's groups were considered as data blocks, and only emoji pairs showing significant discrimination between samples ($p < 0.05$) were included in the analysis. Statistical analyses were performed with the software XLSTAT version 2025.2.0 (Addinsoft, Paris, France).

3. Results

3.1. Participants' characteristics: Food neophobia and familiarity with legumes

A total of 193 children took part in the co-creation phases 1–6 (53% boys, mean age = 8.89 (0.68)). Food neophobia (FN) scores were normally distributed within the whole population ($W = 0.987$; $p = 0.080$)

with a mean value of 21.30 and a median value of 21. The two-factor ANOVA model did not reveal any significant effects of "gender" ($F = 0.077$; $p = 0.781$), "age" ($F = 1.878$; $p = 0.156$) and "gender*age" ($F = 0.928$; $p = 0.397$) interaction on FN on the aggregate panel.

Panels P2 and P4 showed similar FN results, with mean and median values of 21.37 and 21.00 for P2, and 21.65 and 21.00 for P4, respectively. Thus children were split on the median value and two groups of high (H) and low (L) FN were obtained (P2: HFN, $n = 60$, 52% boys, mean age = 8.75 SD = 0.70; LFN, $n = 65$, 54% boys, mean age = 8.85 SD = 0.71); P4: HFN, $n = 62$, 45% boys, mean age = 8.86 SD = 0.62; LFN, $n = 54$, 56% boys, mean age = 9.02 SD = 0.74). Eight participants from panel P2 and nine participants from panel P4 were excluded from the analyses, as their FN scores were equal to the median value. Familiarity scores with legumes followed a normal distribution ($W = 0.989$; $p = 0.136$) with a mean value of 23.24 and a median value of 23.00. Analogous results were obtained for panels P2 and P4, with mean and median values of 22.47 and 22.00 for P2, and 23.75 and 23.00 for P4, respectively. Results indicated that the type of legume significantly influenced familiarity ($p < 0.0001$). Specifically, legumes more commonly present in Italian culinary tradition, such as peas, chickpeas, brown lentils, and cannellini beans, received significantly higher familiarity scores compared to red lentils, soybeans, or soybean sprouts. Linear regression between FN and familiarity with legume scores revealed a significant negative association ($\beta = -0.432$, $p < 0.0001$), although the correlation was weak, as the model explained the 18.7% of the variance. No significant differences were found among P2 and P4 in terms of mean age, gender distribution, FN and familiarity with legume scores thus the two panels were considered fully comparable.

A total of 126 children (panel P5, 9–11 y.o.) took part in the co-creation phase 7 to validate the prototype in the school canteen. Food neophobia (FN) scores of panel P5 were normally distributed ($W = 0.982$; $p = 0.087$) with a mean value of 21.05 and a median value of 21.00. Three participants were excluded from the analyses, as their FN scores were equal to the median value. The two-factor ANOVA model did not reveal any significant effects of "gender" ($F = 1.327$; $p = 0.252$), "age" ($F = 1.065$; $p = 0.348$) and "gender*age" ($F = 1.552$; $p = 0.216$) interaction on FN.

The FN mean values did not differ significantly among P2, P4 and P5 ($F = 0.279$, $p = 0.757$), and no significant differences in gender distribution were found ($\chi^2 = 0.218$, $p = 0.897$).

3.2. Phase 1 & 2: Identification of opportunities, concept development and refinement

Children highlighted several JTBD when thinking about the canteen environment and the dishes served there (Table 4). For the canteen environment, comfort was a key dimension, cited in terms of space, noise, ambient odour and temperature, and scheduling/shift organization. Children also emphasized the importance of the social and autonomy spheres: the canteen should represent a moment of relaxation and social interaction with peers, but also a time when children feel responsible for the service and the choice of lunch. In addition, some children expressed expectations for the future in terms of canteen renewal, which should be more lively, interactive, and technological. Regarding food offerings, the most frequently cited dimension, by both children and chefs, concerned sensory properties, such as taste, texture, and appearance. Dishes should be tasty, flavourful and colourful, with pleasant texture and appealing appearance. Children clearly expressed a desire to personalise their dishes with condiments or sauces and to choose among several alternatives according to their preferences. Meals should also be appropriate to the context in terms of serving temperature and portion size. Chefs further stressed that dishes should be simple and familiar but not repetitive and should include at least one element of novelty. The FAT provided insights into children's perceptions of legumes (Fig. 1). They were often associated with negative words, both in terms of sensory properties ("they're hard," "skin in the mouth," "I do

Table 4
The school canteen Jobs-To-Be-Done related to the environment and the food offering expressed by children and chefs of the Catering Company team.

Questions	Dimension	School canteen Jobs-To-Be-Done
	Children Environment	
Think about when you are in the school canteen, in general, not about specific dishes. What do you like? What don't you like? / What would you change?	Comfort/ organization	The school canteen should be comfortable and spacious. The environment should be less chaotic, less noisy, and not cold. The service should be more hygienic: the school canteen and the tableware should be clean and not have a bad smell. Lunchtime should be scheduled appropriately, avoiding long waiting times before and after lunch.
	Autonomy	Children would like to be able to serve themselves, like in a sort of self-service. Children would like the possibility to choose what and how much to eat. Children would like to sit next to whoever they want.
	Renovation	The school canteen should be renovated in a livelier, more colourful way (e.g., changing the cafeteria style, modifying the dishware set). The school canteen should be more interactive and technological (e.g., the presence of a tablet to play or order).
	Social	The school canteen should be a break from lessons, a moment of leisure and social interaction with classmates and service staff.
	Food offering	
How do you think the school canteen dishes should be?	Sensory properties - taste	The food should be tasty and suitable for children; for instance, snacks and desserts should be part of the offer. The dishes should be seasoned in a way that makes them more flavourful.
	Sensory properties - appearance	The dishes should be more colourful, varied, and appealing in appearance.
	Sensory properties - texture	The dishes should possess a pleasant texture; for instance, they should be crisp without being excessively hard, and combine contrasting textures.
	Personalization and choice	It should be possible to choose variants of a dish according to individual preferences. The menu offering should be varied frequently to provide a broader range of choices. Condiments or sauces should be available so that the dishes can be seasoned as desired.
	Context appropriateness	The temperature of the dishes should be appropriate for the season (i.e., warm in the winter and cold in summer). The portion size should be adequate and satisfying.

(*continued on next page*)

Table 4 (*continued*)

Questions	Dimension	School canteen Jobs-To-Be-Done
	Children Environment	
	Catering Company Team	
	Food offering	
How do you think the school canteen dishes should be?	Familiarity/novelty	The dishes should be simple and familiar but not repetitive, and they should include elements of novelty, such as ingredients from different cultures.
	Sensory properties - appearance	The dishes should be more colourful, imaginative, and creative in their presentation.
	Sensory properties - taste	Dishes containing less liked foods should be prepared, cooked, and presented in a way that makes them attractive and tasty for children.
	Appropriateness of seasonings	The dishes should be more flavourful, also through the use of condiments and new spices.

not like the taste") and emotions ("sadness," "fear," "hate"). A limited knowledge of these foods also emerged ("I don't know them"), with some legumes even associated with objects or elements considered disgusting or inedible ("little balls," "seeds," "poop," etc.).

The first two focus groups of phase 1 led to the definition of 19 innovative legume-based dish concepts. Thanks to refinement and the definition of variants during the phase 2 focus group, the total number of concepts increased to 30 (Table 2). Five out 30 defined concepts were based on chickpeas, four on peas, four on lentils, and two on fava beans, while the remaining concepts were developed using two or more different legumes. The concepts covered various dish types (sandwich, wrap, patties, pie, salad, and soup), which differ not only in the selected ingredients but also in their modes of consumption (e.g., eaten by hand or with utensils) as well as in serving temperature, including both hot and cold dishes. Furthermore, some preparations were inspired by ethnic cuisine - such as ramen or spring roll - or by traditional Tuscan dishes (e.g., panzanella and necci, ie. chestnut pancakes) or cartoon-inspired food (Burdigato, a fictional sandwich combining many different ingredients - meat, cheese, vegetables, bread, and various toppings - resulting in multiple layers and a highly colourful appearance) reinterpreted with the addition of legumes according to the children and chef's creativity.

3.3. Phase 3: Concept validation

The 30 developed concepts were evaluated by the children, who indicated their Willingness to Try (WTT) them. WTT significantly differed across concepts ($F = 7.948$, $p < 0.0001$) ranging from 4.4 to 7.2. FN level significantly affected the WTT ($F = 41.272$, $p < 0.0001$), with HFN subjects expressing a significantly lower WTT compared to LFN (mean WTT = 4.7 vs. 6.2). The "concept × FN" interaction was largely non-significant ($F = 0.823$, $p = 0.735$). Mean WTT values expressed by LFN and HFN for each concept were compared with the central point of the scale (Neither yes nor no = 5), assumed as the theoretical acceptability threshold (Fig. 3). Results indicate that LFN subjects consistently expressed mean WTT above the scale central point for all the concepts, while HFN subjects considered acceptable (above "neither liked nor disliked") 25 out of the 30 developed concepts.

Results from the CATA Emoji Pair Questionnaire were analysed separately for HFN and LFN. The HFN group exhibited emoji elicitation frequencies ranging from 1.7% to 35% for negative emotions and up to 43.3% for positive emotions (Table S3a). In the case of LFN children, the frequency of selection of positive emojis was higher and ranged from 4.6% to 49.2%, whereas the percentages of selection for negative valenced emojis were considerably lower, ranging from 0% to 18.5% (Table S3b). Furthermore, children's neophobia groups differed for the number of emoji significantly discriminating among concepts (HFN: 8 out of 17 emoji pairs; LFN: 6 out of 17 emoji pairs). Emojis with positive valence at high (🤤 🥰 and 😍 🥰) and low (😀 😄 and 😇 😊) arousal were used to discriminate among concepts by both LFN and HFN. HFN used more emojis with negative valence (😕 😒, 😫 😠 and

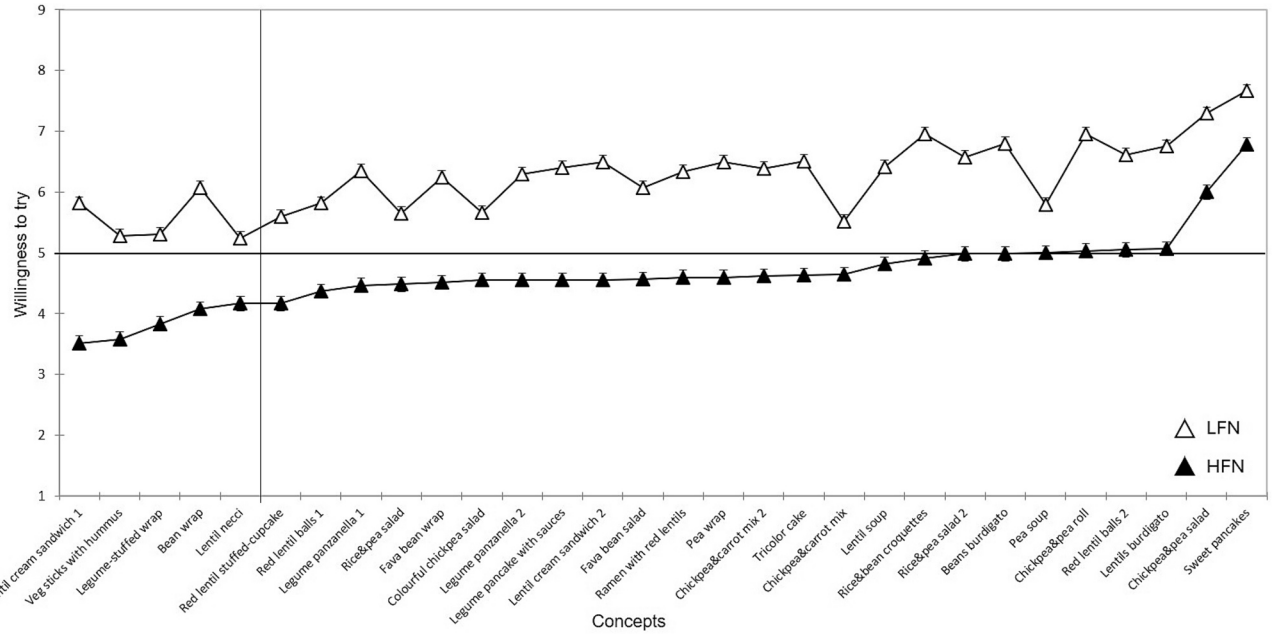

Fig. 3. Willingness To Try (WTT) mean scores in Low and High Neophobic subjects (LFN = Δ; HFN = ▲) for the 30 co-created concepts. The horizontal line represents the midpoint of the scale ("Neither yes nor no" = 5) taken as the theoretical threshold of acceptability. The vertical line separates the concepts that are potentially acceptable (on the right) from those not accepted (on the left) by HFN children.

🤢 🤮) than LFN (emoji 😕 😒) to discriminate among concepts (Tables S3a and S3b). The MFA provided a comprehensive overview of the emotional description of concepts among children with different FN levels (Fig. 4). The first two principal dimensions of the MFA explained a substantial portion of total variability, capturing 50.48% and 14.31%, respectively. The first dimension clearly separated concepts by emotional valence, with those positively valenced positioned on the left and those negatively valenced on the right of the map. The projection of the supplementary variable WTT showed a strong association with positive emoji along the first dimension and with concepts such as "sweet pancakes", "chickpea and pea salad", "chickpea and pea roll", "lentil soup", "bean burdigato" (revisited food cartoon)) and "lentil burdigato". Conversely, concepts such as "vegetable sticks with humus", "lentil necci," or "legume-stuffed wrap" were associated with negative emoji on the opposite side of the map. The emoji that significantly discriminated among the concepts for both the HFN and LFN groups (positive: 🤩 🥳, 😍 🥰, 😇 😊 and negative: 😕 😒) were associated with the concepts in a broadly similar manner; however, the two data blocks yielded relatively different configurations (RV coefficient = 0.394). These results indicate that HFN and LFN children share the main associations driven by emoji valence and willingness to try the concepts, while still exhibiting more subtle differences in the way emojis are used to describe concepts they are more or less willing to try.

Based on dish type diversity and MFA results, the concepts that were associated with positive emotions also for HFN (Fig. 4) were selected to pass to the next stage: "bean burdigato", "lentil burdigato", "rice and bean croquettes", "pea wrap", "chickpea and pea roll", "chickpea and pea salad", "legume pancakes with sauces", "tricolour cake", "lentil soup", "ramen with red lentils" and "sweet pancakes" (see Table 2, selected concepts are in bold).

3.4. Phase 4: Concepts selection and recipe development

CC staff considered ten of the eleven selected concepts suitable to be implemented as dishes for school canteen. Ramen was excluded due to logistic difficulties (transportation and serving). CC chefs developed several prototype variants for each of the selected concepts and during a tasting session together with the SensoryLab team, seven prototypes were selected for the next research stage: sweet and savoury pancakes with sauces, multilayer cake, multicolour muffin, colourful rice cake (category: sweet and savoury pies), multilayer flatbread (category: sandwiches), rice croquettes with sauces (category: patties) (Fig. 2).

3.5. Phase 5: Generation of dish specific sensory lexicon

This phase aimed to develop a set of specific sensory descriptors for LB dishes, elicited by children during the RGM interviews. The data analysis identified a vocabulary of 24 descriptors covering different sensory modalities (Table 3): appearance ($n = 2$), taste and flavour ($n = 15$), and texture ($n = 7$). The resulting lexicon reflects children's spontaneous sensory expressions and is therefore easily understood and used in the dish evaluation phase.

3.6. Phase 6: Prototype validation in classroom

The objective of this phase was to obtain overall feedback from children on the prototypes developed based on the selected concepts of innovative LB-dishes in terms of liking, emotional response, and sensory profile. The classes involved in the test were checked for possible differences in children's appetite, and no significant differences were found ($F = 1.201$, $p = 0.312$). Prototypes significantly differed for liking ($F = 10.328$, $p < 0.0001$), with a mean liking ranging from 4.9 (multicolour

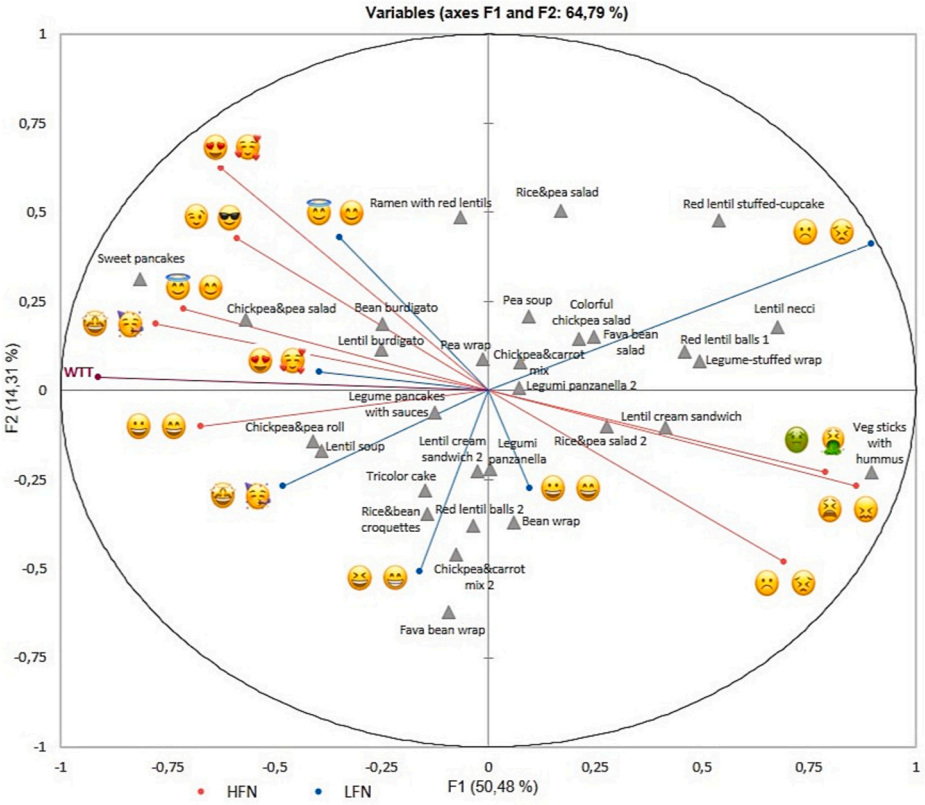

Fig. 4. Correlation circle from the Multiple Factor Analysis (MFA) showing emoji vectors and their relationship with products, comparing Low and High Neophobic children (LFN, in blue; HFN, in red). Willingness to try (WTT) was included as a supplementary variable. The ellipse represents the boundary corresponding to 100% of the explained variance. Only emoji that significantly discriminated among products in each group were considered. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

muffin) to 7.0 (multilayer flatbread). Food neophobia had a significant main effect on liking for prototypes ($F = 21.098$, $p < 0.0001$), with children in the LFN group giving higher ratings than those in the HFN group (liking mean 6.4 and 5.0, respectively). No significant effect of interactions "prototype x FN" was found ($F = 1.221$, $p = 0.293$). Mean liking values expressed by LFN and HFN children for each prototype are shown in Fig. 5. Results indicated that LFN children rated all prototypes higher than the scale midpoint with scores ranging from 7.8 for multilayer flatbread to 5.7 for the multicolour muffin. Three prototypes were well accepted by HFN children (multilayer flatbread, sweet pancakes, rice croquettes with sauce) with mean rating ranging from 6.3 to 5.5; the multilayer flatbread was the most liked prototype also within this child group. Rice colourful cake and savoury pancakes were neither rejected nor particularly liked by this group, with ratings not significantly lower than the scale midpoint. Multicolour muffin ($p = 0.016$) and multilayer cake ($p = 0.031$) were rated lower than the acceptance level by the HFN children.

The sensory description of the prototypes highlighted a marked difference between the sweet option, which was characterized by a high citation frequency of the attributes sweet and fruity flavour, and the savoury prototypes, for which these attributes were never used. Therefore, only savoury samples were compared to improve sensory discrimination.

Results from the CATA sensory questionnaire on savoury dishes revealed that 18 out of 24 attributes significantly discriminated among the prototypes, indicating a wide sensory variability across the samples. The first two dimensions of the correspondence analysis explained the 82.57% of the total variance (Fig. 6). Prototypes differ along the first dimension according to texture: samples on the right of the map (colourful rice cake and rice croquettes) are characterized by hard and crunchy textures, opposed to fluffy, soft and melty attributes describing the prototypes on the left (savoury pancakes, multicolour muffin, multilayer cake and multilayer flatbread). Along the second dimensions multilayer flatbread is positioned in the upper part according to familiar (chickpeas, lentils, tomato) and mild (salad) flavours in opposition to multilayer cake and multicolour muffin associated with generally disliked sensations (bitterness) and objectionable flavour and colour (boiled vegetables, green colour, etc.). Sample configuration based on sensory descriptors were compared between HFN and LFN children, showing no differences in sensory profiling (RV coefficient = 0.975).

Results of the CATA emoji questionnaire were analysed separately for the HFN and LFN groups. Emoji selection frequency was generally high in both groups. HFN children showed a high selection for both positive- and negative-valence emojis (positive: 1.8%–36.4%; negative: 3.6%–40%) (Table S4a). In the LFN group, positive emojis selection remained high, (from 5.8% to 48.1%), whereas the selection frequency of negative emojis was lower (from 0% to 23.1%) (Table S4b). As observed for concepts, the LFN group showed a lower discrimination among prototypes compared to the HFN group. Indeed, only four emojis – three with positive valence (both high 😍 🥰, 🤩 😘 and low 😇 😊 arousal) and one with negative valence (🤢 🤮) – significantly discriminated among prototypes in the LFN group, compared to eight in the HFN group, including five positive-valence emojis (both high 🤩 😘, 😍 🥰, 😆 😁, 😀 😄 and low 😇 😊 arousal) and two negative-valence emojis (low 🤢 🤮 and high 🤬 😤 arousal). For exploratory purposes, the emotional profile map was computed for the HFN group by selecting emojis showing significance levels of $p \leq 0.1$ in Cochran's Q test (Fig. 7). Overall, positive emotions were associated with the most liked prototypes (multilayer flatbread, rice croquettes, and colourful rice cake), whereas negative emotions were linked to the least appreciated ones (savoury pancakes, multilayer cake, and multicolour muffin). The second dimension separates the colourful rice cake, more associated with the emoji expressing surprise (😯 😮), from the multilayer flatbread and savoury pancakes.

Overall, these results indicate that more neophobic children rely more strongly on emotional cues to differentiate among prototypes, whereas less neophobic children show a more homogeneous emotional response, particularly toward positively evaluated options.

3.7. Phase 7: Prototype validation in school canteen setting

The objective of this phase was to introduce one of the new legume-based dishes in school canteens and to evaluate its acceptance compared with the legume-based dishes already included in the regular menu. The rice cake was selected for this purpose because it was neither rejected nor strongly accepted, and associated with positive emotions and surprise among HFN children. Its selection was also consistent with the

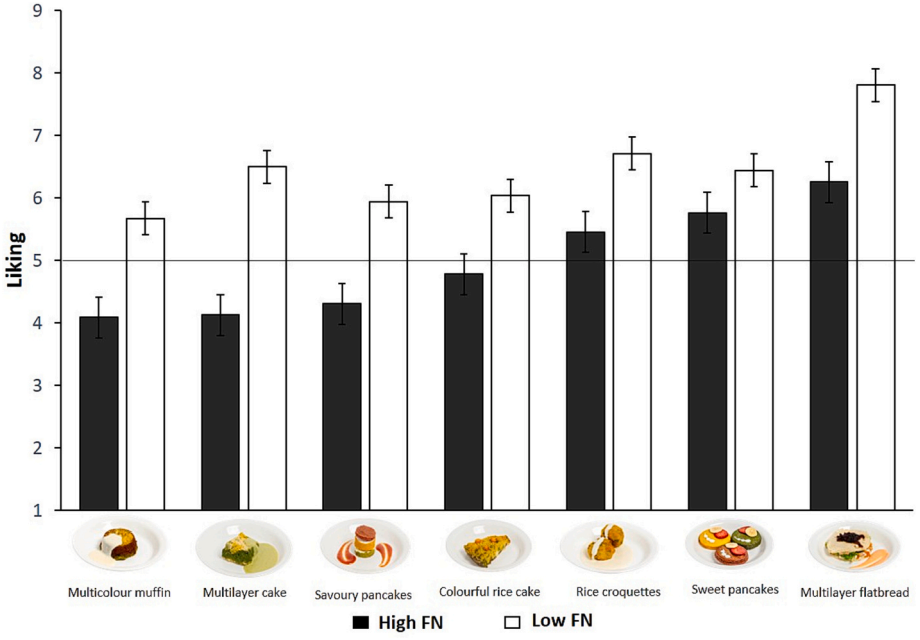

Fig. 5. Mean liking scores in children Low (in white) and High (in black) in food neophobia (FN) for the seven co-created prototypes. The horizontal line represents the midpoint of the scale ("Neither like nor dislike" = 5) taken as the theoretical threshold of acceptability.

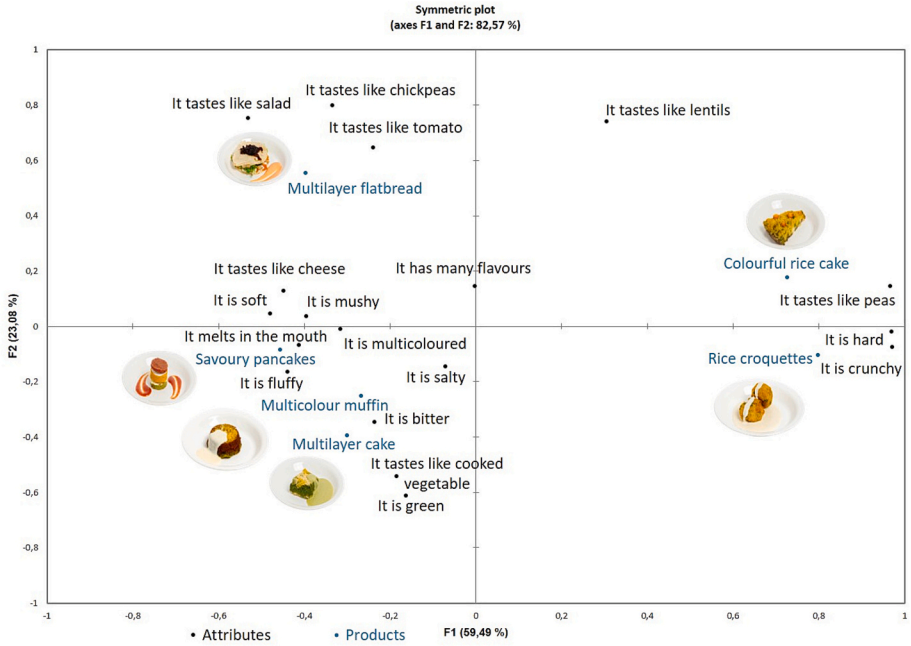

Fig. 6. Correspondence analysis showing the sensory attributes (in black) and the six savoury prototypes (in blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

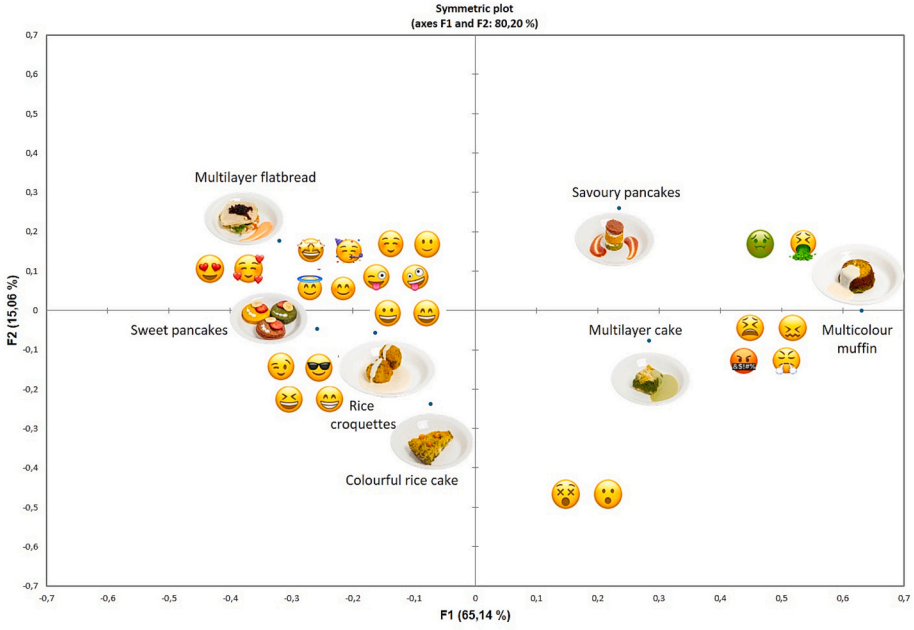

Fig. 7. Representation of the first and second dimension from the correspondence analysis of emoji-based CATA responses of High Food Neophobic children (HFN) for the seven prototypes. Emojis showing significance at $p < 0.1$ in Cochran's Q test were retained.

previously identified JTBD, particularly regarding sensory appeal (colourful appearance and texture) and the customisation potential through sauce choice. In addition, it was selected because, according to the CC technical staff, it could be readily implemented in the spring menu based on logistical and supply constraints and was suitable for inclusion as a "single-dish" option.

Liking ratings for the 4 dishes were tested separately for the HFN and LFN groups and a significant effect of the dish was revealed in both groups ($p < 0.01$) (Fig. 8). Results showed that all legume-based dishes were well accepted by the LFN group, with liking scores ranging from 6.1 to 7.7. Specifically, the rice cake received a high rating among these children (mean = 7.6), which was not significantly different from the most appreciated regular legume-based options (bean soup and chickpea flatbread), while it was significantly higher than the least liked option (white beans). Among HFN children, liking ratings covered a wider range (5.0–7.2). The innovative dish received a mean score of 6.1, indicating that it was accepted, and its liking did not differ from the most accepted regular options (bean soup and chickpea flatbread). It also did not differ significantly from the least accepted option, although the mean rating for this latter showed a neutral mean rating (5.0).

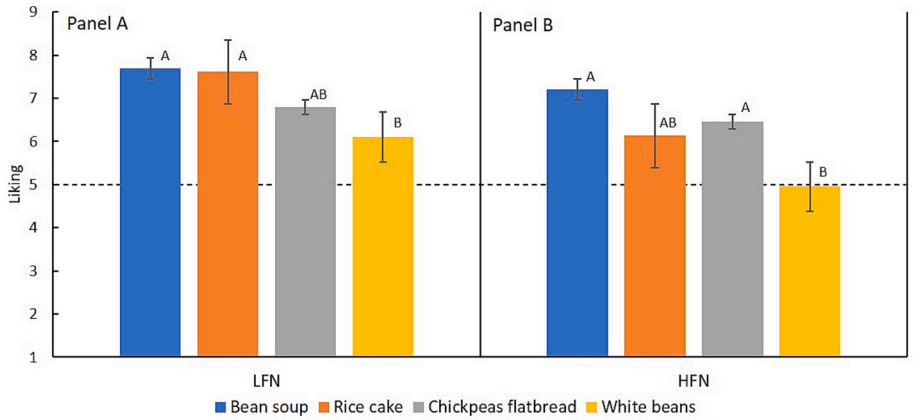

Fig. 8. Mean liking scores among children with Low (LFN, panel A) and High (HFN, panel B) food neophobia for the three regular (bean soup, blue; chickpeas flatbread, grey; white beans, yellow) and the co-created (rice cake, orange) legume-based dishes served in the school canteen. The horizontal line represents the scale midpoint ("Neither like nor dislike" = 5) taken as the theoretical threshold of acceptability. Different letters indicate statistically significant differences ($p < 0.05$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

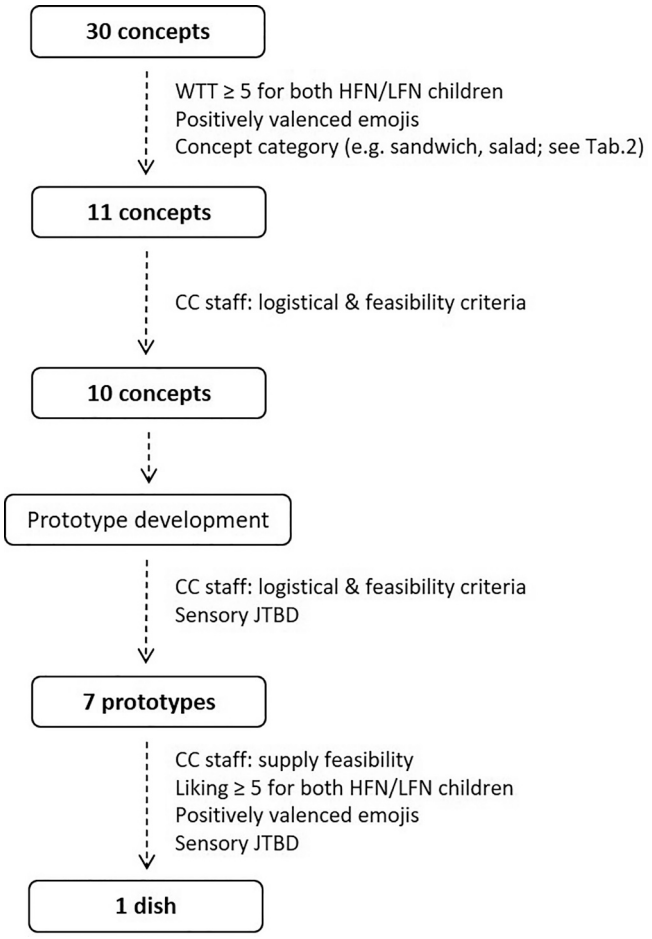

Fig. 9. Overview of the selection process from the initial 30 concepts to the final dish implemented in the school canteen menu, highlighting the criteria jointly guiding product selection at each stage, including willingness to try (WTT), emotional profiling, product category, sensory characterization and Jobs-To-Be-Done (JTBD), liking, and Catering Company (CC) feasibility considerations.

4. Discussion

The study extends to children the integrated co-creation and JTBD approach previously applied to adolescents confirming its effectiveness in supporting the development of school canteen offerings tailored to children with different levels of food neophobia. By explicitly accounting for individual variability in food neophobia, the proposed framework addresses a key barrier to both the acceptance of novel foods and the adoption of more diverse and balanced dietary patterns in childhood (Karaağaç & Bellikci-Koyu, 2023).

When introduced into the school canteen menu, the co-created innovative dish was accepted by both LFN and HFN children, even if liking remained lower among children with higher levels of food neophobia. Comparison with regular menu offerings is encouraging. The quite high liking of some traditional options likely reflects children's familiarity with dishes long included in the school menu. In contrast, the innovative proposal was presented as a first-time exposure. Prior evidence indicates that repeated exposure to novel foods can enhance acceptability and promote consumption in children (Karaağaç & Bellikci-Koyu, 2023). Thus, it can be hypothesized that repeated exposure may increase the acceptability of the co-created proposal, warranting further investigation.

While acceptability differed by food neophobia level, with the HFN group consistently giving lower hedonic ratings than LFN, five prototypes (out of seven) did not differ from the hedonic scale midpoint for the HFN group, indicating neither clear rejection nor strong liking. Three prototypes (rice croquettes, sweet pancakes, and multilayer flatbread) received even higher mean liking scores than the selected one among HFN children. This suggests that non-selected prototypes, excluded for logistical or supply reasons, could be considered for future implementation in school canteens with potential for success. These results support the potential of co-creation for developing healthy and child-acceptable food products (Kokkorou et al., 2025; Pinesso Ribeiro et al., 2025; Velázquez et al., 2022).

Overall, these findings confirm the negative impact of food neophobia on the acceptance of innovative plant-based dishes, while also suggesting that co-creation may help mitigate this barrier by identifying options that are acceptable even among more neophobic children consistently with previous findings in adolescents (Kokkorou et al., 2025).

The concept validation phase revealed a clear gap in mean Willingness To Try between children with high and low levels of FN, underscoring the importance of a tailored innovation approach focused on neophobic children's needs. While all concepts were well accepted by the LFN group, with WTT scores well above the scale midpoint, five concepts were not accepted by the HFN group, whereas 25 concepts received ratings above or not significantly different from 5. In this context, the integration of WTT responses with emotional

characterization enabled a more precise differentiation and selection of concepts that HFN children were willing to try.

Emojis were widely and consistently used to describe both concepts and prototypes, and those expressing positive emotions were positively associated with WTT and liking. Moreover, the frequency of elicited positive emotions was generally higher than negative ones. These results are in line with the positive association between liking and positive emotions observed in adults (Cardello et al., 2012; Gutjar et al., 2015) and children (Sick et al., 2023; Zanoni et al., 2025), as well as with evidence showing that high-arousal positive emotions are a key driver of food acceptance in children (Sick et al., 2019). They also support the broader association found between positive emotions and both food (Panagiotou & Gkatzionis, 2022) and meal experience (Piochi et al., 2025).

The data nonetheless highlighted clear differences between children with different levels of food neophobia in their use of emotions. Specifically, HFN children reported positive emotions less frequently and negative emotions more often than LFN children. More neophobic children also used emotions more extensively to discriminate between products. This may be due to the fact that LFN children expressed high acceptability for most of the innovative solutions, which were generally associated with positive emotions. In HFN children, liking scores were less homogeneous even for preferred options, and these were accompanied by emotional profiles still characterized by different types of positive emotions. Furthermore, HFN children more frequently elicited high-arousal emojis, both positive and negative, than LFN children. This pattern is consistent with evidence indicating that individuals with high food neophobia are more hyper-reactive to food stimuli, which may induce unpleasant levels of arousal and reduce hedonic evaluations (Jaeger et al., 2021). This response may be particularly evident when stimuli are complex and unfamiliar (Giacalone et al., 2014).

In this context, it is useful to refer to the role of arousal in shaping responses to novel stimuli and their potential success over the medium to long term. According to Berlyne's model optimal hedonic responses occur at intermediate arousal levels, whereas stimuli that are either insufficiently stimulating or overly arousing may lead to boredom or aversion, respectively (Berlyne, 1960; Berlyne, 1970). Building on this framework, Köster has emphasized the dynamic nature of food liking, highlighting how repeated exposure and familiarization can progressively modulate arousal and, in turn, acceptance (Köster, 2009; Köster & Mojet, 2015). Specifically, familiarization with a novel stimulus initially associated with low arousal may lead to boredom, which can negatively affect product acceptability. Conversely, repeated exposure to a stimulus initially characterized by high arousal may reduce excessive activation over time, thereby promoting more positive hedonic evaluations in the medium to long term.

In this context, it may be hypothesized that regular inclusion of co-created products in school menus could help modulate arousal levels and enhance acceptance among children with higher food neophobia. The initial co-creation phase within the “Jobs-To-Be-Done” (JTBD) framework, enabled the identification of key aspects that school food services should address to meet children's needs and expectations. These aspects concern mealtime organization, which should foster socialization and relaxation while ensuring a certain degree of autonomy (Piochi et al., 2025). These data confirm that the value of the meal extends beyond food quality alone (Nyberg, 2019) and encompasses an important social function, allowing children to interact outside the classroom setting, exchange opinions, relax, and enjoy themselves (Fossgard et al., 2021; Gallegos et al., 2025).

Another relevant aspect emerging from the JTBD analysis concerns expectations related to the sensory attributes of the dishes, including flavour, appearance, and texture (Nguyen et al., 2015; Sick et al., 2019). Visual cues play a crucial anticipatory role in food perception, with bright and vivid colours being instinctively preferred (Tan et al., 2024). Children are generally more sensitive to texture than adults, making it a key driver of food acceptability (Chow et al., 2024). Overall, these findings underline the central role of sensory expectations in shaping children's acceptance of school meals, highlighting the need to carefully consider food sensory properties when developing plant-based dishes for this target group.

The results obtained in this phase indicate that the tools used for idea generation were effective with children, further expanding previous knowledge related to their application in adolescents. The idea-generation phase for legume-based dishes resulted in highly creative and diverse proposals in terms of ingredients and dish categories (e.g., sandwiches, wraps, patties, soups, pies, and salads). This variety can be attributed to the multicultural community in which the study was conducted, where regional food culture coexists with influences from multiple ethnic groups. The combination of multi-ethnic ingredients (e.g., soybean sprouts, soy, etc.) with elements of traditional Italian gastronomy resulted in recipes with a high novelty and originality, while maintaining a sense of familiarity, a combination known as crucial for promoting the acceptance and consumption of new foods (Berlyne, 1970; Köster & Mojet, 2007). In particular, the SCAMPER technique, through its systematic exploration of alternative ideas and its capacity to foster structured divergent thinking (Serrat, 2017), highlights its potential for product innovation even among non-expert populations such as children and adolescents (Kokkorou et al., 2025). A further element contributing to the generation of a wide range of ideas was the iterative approach adopted in this phase. Specifically, the information provided by children on their perceptions of legumes in the FAT activity was shared with chefs, guiding them toward solutions that addressed the children's concerns through creative uses of legumes. Subsequently, children were asked to revisit and reflect on both peer-generated and chef-developed proposals.

The sensory data obtained from the prototypes showed that the innovative solutions covered a broad sensory space and addressed the sensory “Jobs-To-Be-Done” (JTBDs) identified in early co-creation phases, confirming the effectiveness of the adopted methodology.

Children with different levels of food neophobia described the prototypes similarly; however, sensory properties influenced liking differently across neophobia groups. While children with low food neophobia generally accepted all developed options, those with higher neophobia showed greater appreciation for prototypes characterized by light and bright colours, complex textures (e.g., hard and crunchy), and based on more familiar legumes, such as peas, lentils, and chickpeas. Conversely, they exhibited lower liking scores (<5) for prototypes characterized by undesirable sensory attributes, including bitterness, cooked-vegetable notes, green colour, and mushy texture. These attributes can be interpreted as warning cues that, particularly in more neophobic individuals, reduce liking (Cooke & Wardle, 2005; Köster, 2009; Laureati, Bergamaschi, & Pagliarini, 2015; Rozin & Fallon, 1987). Overall, the results suggest that balancing sensory complexity and familiarity is key to developing innovative food solutions, especially when targeting populations with higher food neophobia.

The sample of children involved in the study can be considered appropriate in terms of target end-users for the intended school canteen context. Indeed, the sample was balanced in terms of sex and age, both of which are known to influence familiarity with and preference for different foods (Sick et al., 2019). The mean food neophobia scores observed were comparable to those reported in previous studies using the same scale (ICFNS) among European children aged 9–12 years (Laureati, Bertoli, et al., 2015; Proserpio et al., 2020).

5. Strengths and limitations

Conducting the study within the school canteen environment represents a major strength of the work. Sensory and hedonic evaluations were conducted in the classroom, a familiar and comfortable setting that likely enhanced engagement and response reliability. Moreover, one of the developed solutions was tested in a real-life consumption context, allowing evaluation of the innovative dish under actual consumption

conditions and a realistic comparison with plant-based options already available in the school menu.

A limitation related to data collection in the canteen concerns the lack of uniformity in menu structure across testing days in phase 7. It is well established that liking for a food item may vary depending on other items presented within the same meal (Eindhoven & Peryam, 1959; Jimenez et al., 2015; Lahne et al., 2017; Lahne & Zellner, 2015; Moskowitz & Klarman, 1977). To mitigate this limitation, legume-based dishes were always served first and presented as a standalone item. Nevertheless, it cannot be excluded that children's awareness of subsequent courses may have influenced evaluations of the target dish.

6. Conclusions

This study demonstrates that an integrated co-creation and "Jobs-To-Be-Done" (JTBD) approach provides an effective framework for tailor-made innovation in school canteen settings, enabling the development of plant-based dishes that account for individual differences in children's food neophobia. Considering food neophobia as a guiding factor in the co-creation process proved crucial for understanding and mitigating barriers to the acceptance of innovative dishes. Results obtained under real consumption conditions showed that the proposed approach can lead to the development of prototypes that are well-received by all the children, although they remained less liked among the more reluctant. By engaging key stakeholders in an iterative development process and collecting hedonic, emotional, and sensory responses throughout all stages, from ideation to real-context validation, this study provides a rigorous and comprehensive experimental framework. Taken together, these findings highlight the potential of co-creation, when combined with attention to individual differences, to facilitate the successful introduction of innovative plant-based dishes within school catering systems.

Ethical statement for food quality and preference

Hereby, I Sofia Trentanove consciously assure that for this manuscript the following is fulfilled:

1) This material is the authors' own original work, which has not been previously published elsewhere.
2) The paper is not currently being considered for publication elsewhere.
3) The paper reflects the authors' own research and analysis in a truthful and complete manner.
4) The paper properly credits the meaningful contributions of co-authors and co-researchers.
5) The results are appropriately placed in the context of prior and existing research.
6) All sources used are properly disclosed.
7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.
8) This study was conducted according to the guidelines established in the Declaration of Helsinki.
9) Written informed consent was obtained from all participants according to the GDPR (General Data Protection Regulation) 2016/679.

CRediT authorship contribution statement

Nicole Cattarin: Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Sofia Trentanove:** Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Lapo Pierguidi:** Writing – review & editing, Visualization, Investigation. **Sara Spinelli:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Erminio Monteleone:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization. **Caterina Dinnella:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization.

Author statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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During the preparation of this work, the authors used ChatGPT in order to improve readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2026.105963.

Data availability

Data will be made available on request.

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