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GESTIONE SOSTENIBILE DELLE RISORSE AGRARIE, FORESTALI E ALIMENTARI

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Influence of psychological traits and PROP status
on the acceptability of healthy foods

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Abstract

Food behaviour is affected by many interacting factors in humans, and the acceptability of a food depends on the interaction between its intrinsic and extrinsic characteristics and person-related dimensions that are biological, physiological, psychological, and socio-cultural.

The present thesis aimed to select, adapt and validate psychological traits questionnaires used in food science for the Italian population and to explore the role of psychological traits and taste responsiveness (PROP status) in the acceptability of phenol-rich and functionalised foods, also characterised by health benefits and warning sensations, such as bitterness and astringency. This was done by using multidisciplinary and multidimensional approaches and by considering simultaneously taste sensitivity, psychological traits, food attitudes, familiarity with and choice for phenol-rich foods and sensory and hedonic ratings to a real food added with different concentrations of phenol extracts from Olive Mill Waste Water (OMWW). Developing a phenol-enriched food can be a challenging task since consumers are not willing to compromise on sensory quality when it comes to functional foods and for this reason sensory and chemical properties of phenols derived from OMWW in plant-based foods varied in their macro-composition (proteins/neutral pH: bean purée (BP), starch/neutral pH: potato purée (PP), and fibre/low pH: tomato juice (TJ)) were evaluated. Findings suggested that BP contained the most appropriate matrix to counteract the impact of added phenol on negative sensory properties, thus enabling the optimization of the balance between health and sensory properties.

Psychological traits significantly affected self-reported food preferences and behaviours, in fact subjects with high food neophobia, sensitivity to punishment, or sensitivity to disgust reported a significantly low preference for phenol-rich foods characterised by warning sensations. Familiarity with vegetables was low in individuals with high sensitivity to punishment, high food neophobia, and high alexithymia, irrespective of their sensory properties. Familiarity with coffee/tea characterised by higher bitterness and astringency was low in individuals with high food neophobia, sensitivity to disgust, and alexithymia.

Psychological traits, and taste responsiveness, significantly affected also the perception and the evaluation of real foods. In fact, subjects with high food neophobia, sensitivity to disgust, sensitivity to punishment, alexithymia, state and trait anxiety, and PROP status significantly evaluated the intensity of warning sensations of BP samples added with phenols as more intense. Contrarily, subjects with high sensation seeking and sensitivity to reward perceived the critical sensations as weaker than subjects low in these traits. Few psychological traits affected liking. High sensation-seeking subjects and subjects with high alexithymia preferred the samples more than subjects who had low levels of these traits.

Our results confirmed that many factors interact to shape our perception and liking of phenol-rich and functionalised foods, highlighting that the acceptability of healthy foods characterized by warning sensations is inevitably mediated by the meaning attributed to the stimulus.

Taken into account these differences help to obtain a more complete picture of the complex relationships that determine the acceptability of a certain food category and enables the identification of the barriers to and the facilitators of healthy eating.

List of original publications

The present PhD project contributed to the following original scientific publications (published in international journals available on Scopus and WoS database):

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- Laureati, M., Spinelli, S., Monteleone, E., Dinnella, C., Prescott, J., Cattaneo, C., **De Toffoli, A.** ... & Torri, L. (2018). Associations between food neophobia and responsiveness to "warning" chemosensory sensations in food products in a large population sample. *Food quality and preference*, *68*, 113-124.
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- **De Toffoli, A.**, Monteleone, E., Bucalossi, G., Veneziani, G., Fia, G., Servili, M., ... & Dinnella, C. (2019). Sensory and chemical profile of a phenolic extract from olive mill waste waters in plant-base food with varied macro-composition. *Food research international*, *119*, 236-243 – chapter 6

1. Introduction

1.1 The importance of eating phenol-rich foods

In the last decades, food consumption has changed considerably and has shifted towards a more health-conscious behaviour, characterized by healthier lifestyle and greater attention to environmental sustainability and quality ingredients (Siró, Kápolna, Kápolna, & Lugasi, 2008).

Consumers have become increasingly aware of the fact that food choices may directly affect their health, and for this reason, nowadays, foods are not only intended to satisfy hunger and provide necessary nutrients but also to prevent nutrition-related diseases and improve physical and mental well-being (Menrad, 2003; Roberfroid, 2000).

Several dietary guidelines (Dietary Guidelines Advisory Committee, 2005) encourage the consumption of fruits and vegetables. Diets rich in fruits and vegetables can protect against the risk of cancer, cardiovascular disease, osteoporosis, inflammation, type II diabetes, and other chronic degenerative diseases (Boeing et al., 2012, He, Nowson, & MacGregor, 2006, Aune et al., 2017).

These beneficial effects have been ascribed, in part to the antioxidants, vitamin C, polyphenols, vitamin E, and carotenoids in plant-based foods. Crude extracts of fruits, herbs, vegetables, cereals, and other plant-based foods rich in antioxidant molecules have received increasing attention because they delay oxidative degradation of lipids and thereby improve the nutritional value of food (Nicolle et al., 2004).

In plants, phenolic compounds are synthetized through the pentose phosphate, shikimate, and phenylpropanoid pathways. Based on their carbon skeleton, different phenolics can be categorised into the following groups: phenolic acids, flavonoids, stilbenes, tannins, lignans, coumarins, curcuminoids, and quinones. Plant phenolics are powerful antioxidants and free radical scavengers. They contribute to the healthy functional properties of plant-based foods and beverages (Abuajah, Ogbonna, & Osuji, 2015; Halliwell, Rafter, & Jenner, 2005; Liu, 2013; Shahidi & Ambigaipalan, 2015).

Apart from natural food sources, phenolic compounds are available from plant extracts and chemical synthesis for usage as supplements and food preservatives. The term 'functional food' was first used in Japan in the 1980s for food products fortified with special constituents that possess advantageous physiological properties (Hardy, 2000).

Phenols from plant by-products (Nirmala, Bisht, Bajwa, & Santosh, 2018; Świeca, Gawlik-Dziki, Sęczyk, Dziki, & Sikora, 2018; Torri et al., 2016), including Olive Mill Waste Water (OMWW) (Araújo, Pimentel, Alves, & Oliveira, 2015; Esposto et al., 2015; Servili et al., 2011), have been proposed as functional ingredients that are able to enhance food and beverage antioxidant activity and its potential pro-health effects. Plant by-products may also have beneficial effects on the economic and environmental sustainability of the agro-industry (Kowalska, Czajkowska, Cichowska, & Lenart, 2017).

Meta-analyses of the effects of such foods indicated that phenolic-enriched diets can help prevent a wide-range of diseases, such as cancers, diabetes, heart disease, neurodegenerative and cardiovascular diseases, and aging (Balasundram, Sundram, & Samman, 2006).

The increasing demand on these foods can be explained by the increasing cost of healthcare, the steady increase in life expectancy, and the desire of older people to improve the quality of their latter years (Menrad, 2003; Roberfroid, 2000). Nevertheless, the acceptance of plant-based and functional foods by consumers is far from being unconditional.

1.2 Determinants of acceptability of phenol-rich foods

Food behaviour is affected by interacting factors and this multicomplex process appears particularly relevant in the choice of phenol-rich foods that are characterised at the same time by health benefits and warning sensory properties.

Taste is particularly relevant in this context as past research has revealed that consumers believe healthy foods are less tasty and desirable than unhealthy foods (Raghunathan, Naylor, & Hoyer, 2006). This type of effect has also been observed in children, who believe that foods that are considered as being instrumental for their health, such as fruits and vegetables, are less tasty (Maimaran & Fishbach, 2014). Taste is also particularly relevant in functional food consumption (Urala & Liisa, 2003), as the addition of functional ingredients to food products has frequently resulted in changes in the sensory properties of the product which could lead to a decrease in its acceptability among consumers. Cardello (2007) reported that the cornerstone of acceptance is the perceived sensory quality, consisting of appearance, texture, and chemosensory attributes and that familiarization with a product consolidates expectations about sensory quality.

However, some consumers like and habitually consume phenol-rich foods despite the taste. One of the reasons is that other factors are involved, such as taste sensitivity and psychological traits. Individual differences exist in bitter taste sensitivity as well as in astringency perception and there is also clear evidence that these differences reflect different perceived intensities, liking, preferences, and food intake (Dinnella, Recchia, Tuorila, & Monteleone, 2011; Mennella & Bobowski, 2015). Variations in perception and liking are also affected and modulated by differences in psychological traits and food attitudes levels Individual differences are often treated as nuisance variables but can also be considered to 'provide useful evidence on the nature of mechanisms underlying sensory phenomena and thus are important in the generation of research hypotheses' (Stevens, 1996). For example, psychological traits may affect taste perception and acceptability of healthy foods; some people may detect the finer nuances of different sensory properties and praise a product in every way while others may detect only the most prominent sensory properties present in that product.

Therefore, developing a phenol-enriched functional food appears particularly challenging since consumers are not willing to compromise on sensory quality when it comes to functional foods (Jaeger, Axten, Wohlers, & Sun-Waterhouse, 2009; Verbeke, 2006) and individual differences need to be considered.

1.2.1 Sensory impact on the acceptability of phenol-rich foods

Sensory properties drive liking for vegetables (Dinnella et al., 2016), and it is well-known that bitterness and other unpalatable sensory properties may act as a barrier to vegetable acceptance (Appleton et al., 2019; Drewnowski, 1997; Drewnowski & Gomez-Carneros, 2000; Shimada, 2006).

Additionally, phenol compounds from vegetable sources are characterised by warning sensations such as bitterness, astringency, and pungency (Lesschaeve & Noble, 2005; Monteleone, Condelli, Dinnella, & Bertuccioli, 2004), sensations that may limit food acceptability (Köster, 2009; Tuorila & Cardello, 2002). Humans, who have been sensitised to the bitter taste of plant toxins over a long period of time, consider excessive bitterness the principal reason for food rejection (Drewnowski & Gomez-Carneros, 2000). The tactile sensation of astringency discourages animals from ingesting foods high in tannins. This protects them from tannin's potential harmful anti-nutritional effects (Shimada, 2006). A high level of perceived astringency negatively impacts the acceptance of high phenol-containing foods (Lesschaeve & Noble, 2005). The high number of phenol-binding proteins secreted by the parotid glands protect against dietary phenols, and astringency arises from phenol interactions with the adsorbed glycoprotein layer, leading to oral cavity delubrication (Dinnella, Recchia, Fia, Bertuccioli, & Monteleone, 2009; Nayak & Carpenter, 2008).

Usually, consumers are not prepared to accept functional foods that taste worse than conventional foods (Tuorila & Cardello, 2002; Verbeke, 2006). For this reason, one of the first steps of functional food development is studying changes in the sensory characteristics of the product as a consequence of the addition of a novel ingredient, and the reactions of consumers to these changes.

Developing a phenol-enriched functional food can be a challenging task since consumers are not willing to compromise on sensory quality when it comes to functional foods (Jaeger, Axten, Wohlers, & Sun-Waterhouse, 2009; Krystallis, Maglaras, & Mamalis, 2008; Verbeke, 2006). Hence, strategies to control the intensity of warning sensations need to be considered when developing phenol-enriched functional foods. Three main strategies can be envisaged to reduce the intensity of the unacceptable sensory properties of phenols (Ares, Barreiro, Deliza, & Gámbaro, 2009; Gaudette & Pickering, 2013; Keast, 2008).

The first of these is to take advantage of common perceptual interaction, which involves the suppression of the target sensation through the addition of a counteracting tastant. Sweeteners, fats, and salt can lead to perceptual interactions that reduce the impact of phenols on sensory properties of functional food. However, these sensory stimuli may also negatively impact the pro-health properties of functional food due to the energy and salt intake. Secondly, tasteless ingredients, such as cyclodextrin derivatives, that compete to bind to the phenol receptor can be employed (Gaudette & Pickering, 2013). Finally, the chemical interactions between phenols and biopolymers naturally occurring in vegetable foods (Zhang et al., 2014) can be used to lower the bitter and astringent potential of functional phenols. Plant biopolymers can act as a physical barrier for the phenol stimuli utilised, thus, hindering their interactions with sensory receptors and saliva.

1.2.3 Taste responsiveness to PROP

Healthy individuals differ significantly in their chemosensory perception, and this variability has been extensively studied in recent years. Most notably, the inherited capacity to perceive the bitterness of propylthiouracil (PROP) is considered a reliable broad marker for individual differences in taste responsiveness, defined as the perceived intensity of oral sensations, that may influence food preference and eating behaviour (Tepper, Banni, Melis, Crnjar, & Barbarossa, 2014). According to Hayes et al. (2010) and Fischer et al. (2013), three PROP status can be identified based on PROP bitterness ratings on the generalised Labeled Magnitude Scale (gLMS) ≤17, non-taster (NT); 18–52, medium-taster (MT); and ≥53, super-taster (ST). A certain variability has been highlighted in the proportions of non-tasters and super-tasters among different races and populations worldwide (NT from 7% to 40%) (Guo & Reed, 2001).

In humans, differences in bitter taste perception are controlled by the family of TAS2R genes (Drayna 2005; Kim et al. 2003). The TAS2R gene family consists of 25 functional genes and 11 pseudogenes (Chandrashekar et al., 2000; Go et al., 2005) that bind structurally to different molecules that elicit bitterness. Among these genes, one of the most widely studied is the TAS2R38 gene. TAS2R38 encodes a seven transmembrane G protein-coupled receptor (Drayna, 2005). It binds to the N-C=S group contained in synthetic compounds such as phenylthiocarbamide (PTC) and 6-n-propylthiouracil (PROP) (Kim & Drayna, 2005).

While several allelic forms have been observed, the two most common are Proline-Alanine-Valine (PAV) and Alanine-Valine-Isoleucine (AVI). PAV is the taster allele while AVI is the non-taster allele. Individuals carrying the dominant diplotype (PAV/PAV and PAV/AVI) report higher bitterness intensity for PROP than individuals carrying the homozygous recessive diplotype (AVI/AVI) (Garneau et al., 2014). The two allelic forms of TAS2R38 have been suggested to influence dietary habits. Individuals carrying the AVI/AVI diplotype reported that they consumed more vegetables than individuals carrying PAV/AVI and PAV/PAV diplotype (Duffy et al., 2010). Further, Sacerdote et al. (2007) reported that AVI/AVI genotypes consumed significantly more brassica vegetables. When presented on the circumvallate papillae, PAV homozygotes considered ethanol and capsaicin to be more bitter than their heterozygote and AVI homozygote counterparts (Nolden, McGeary, & Hayes, 2016). PAV homozygotes exhibit greater sensitivity to PTC/PROP bitterness, while AVI homozygotes are less sensitive to the bitterness of PTC/PROP (Bufe et al., 2005; Duffy et al., 2004). Heterozygotes (PAV/AVI) show intermediate bitter taste sensitivity (Calò et al., 2011; Hayes, Bartoshuk, Kidd, & Duffy, 2008).

Those who consider PROP as very bitter consider a wide range of compounds such as quinine hydrochloride (Hayes et al., 2008), grapefruit juice and coffee (Lanier, Hayes, & Duffy, 2005), alcoholic beverages (Intranuovo & Powers, 1998; Lanier et al., 2005), green tea and soy products (Akella, Henderson, & Drewnowski, 1997), and brassicaceous vegetables (Drewnowski & Gomez-Carneros, 2000; Gorovic et al., 2011) to be very bitter and less acceptable (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006).

Several studies have reported mixed results on the effect of PROP status on the intake and preference for bitter foods and beverages, mainly because demographics, genetics, and other environmental factors may influence both phenotypic responses to oral stimulation and affective response to food (Piochi, Dinnella, Prescott, & Monteleone, 2018; Tepper et al., 2017). On the other hand, no differences between PROP phenotypes were found in the preference for plant-based bitter foods (Catanzaro, Chesbro, & Velkey, 2013) or for actual vegetable intake in children (Baranowski et al., 2011; Keller & Tepper, 2004; Lumeng, Cardinal, Sitto, & Kannan, 2008a). Super-tasters assigned higher bitterness, sourness, and astringency ratings to coffee, but these ratings did not significantly affect liking (Masi, Dinnella, Monteleone, & Prescott, 2015) or consumption of coffee (Ly & Drewnowski, 2001). In general, these results are inconsistent and causal models that indicate direct associations between variations in taste abilities and food perception and choice have a weak predictive power.

1.2.4 Psychological traits

Personality is the set of psychological traits and mechanisms within an individual that is organised and relatively persistent and that influences his or her interactions with, and adaptations to, the intrapsychic, physical, and social environments (Larsen & Buss, 2005). Psychological traits distinguish one person from another, helping to define each person's individuality. Psychological traits directly influence behaviours (Matthews, Deary, & Whiteman, 2009).

The identification of psychological traits as sources of individual differences in sensory and hedonic responses is not new (Stevens, 1996; Stone & Pangborn, 1990) and has been increasingly gaining attention following recent findings suggesting a link between specific psychological traits and sensory thresholds (Croy, Springborn, Lötsch, Johnston, & Hummel, 2011). However, only through a multidisciplinary approach will it be possible to explore the complex interplay of factors that contribute to food choices.

One key psychological variable is the trait of **food neophobia** (FN), originally defined as the reluctance to try or eat unfamiliar foods (Pliner & Hobden, 1992). Food neophobia is nowadays considered a maladaptive tendency (Birch, 1999) as it decreases diet variety, thus having potentially important nutritional consequences. An important aspect for novel food refusal is the expectation that the sensory properties of the food may be unpleasant (Pliner, Pelchat, & Grabski, 1993). Differences in this trait may play an essential role in modulating the acceptability of phenol-rich foods and recent studies have suggested that the high product failure rate of new food products entering the market could be partially due to negative attitudes towards food and food neophobia (Barrena & Sánchez, 2013; Henriques, King, & Meiselman, 2009).

Thus, across all fruit, vegetable, protein, condiment, beverage, and dairy product categories, high FN individuals were restricted relative to low FN individuals in both frequency of intake and range of foods preferred. In other words, a high level of food neophobia was associated with reduced preference for and intake of many food products belonging to different categories (Jaeger, Rasmussen, & Prescott, 2017; Knaapila et al., 2015; Törnwall et al., 2014), suggesting that the effect of food neophobia extends beyond rejection of unfamiliar/unusual foods to encompass many commonplace foods making up the diet (Jaeger, Rasmussen, & Prescott, 2017). Few differences between food neophobia groups were found for the liking of bland vegetables and beverages, or for sweets and desserts (Törnwall et al., 2014).

Children who exhibit higher food neophobia consume lesser amounts of vegetables (Galloway, Lee, & Birch, 2003) and, compared to neophilic individuals, have significantly less variety in their diets (Carruth et al., 1998; Falciglia, Couch, Gribble, Pabst, & Frank, 2000). Food neophobia appears to have differential effects on diet, affecting some food groups more than others. Russell and Worsley (2008) found that food neophobia for vegetables is the strongest, followed by food neophobia for meats and fruits.

Disgust is defined as a broad adaptive functional behaviour that protects against pathogen infections (Curtis, Barra, & Aunger, 2011) and is therefore also called the behavioural immune system (Terrizzi, Shook, & McDaniel, 2013). Even though disgust is seemingly elicited by many different vectors like rotten foods, vermin, and bodily liquids (Curtis et al., 2011; Herz, 2011, 2014), it is assumed that disgust prevents the oral ingestion of toxic or offensive agents (Darwin & Darwin, 2009; Rozin & Fallon, 1987).

Cultural and societal convictions and norms determine what is considered disgusting, and the perception of disgust is deeply rooted in an individual’s culture. A predisposition to be easily disgusted (high disgust sensitivity) hinders the acceptance of novel foods, even when they are potentially beneficial (Tybur, Çınar, Karinen, & Perone, 2018). Disgust sensitivity predicts the lack of acceptance of novel foods, particularly for novel animal-based foods (Mancini, Moruzzo, Riccioli, & Paci, 2019; Siegrist, Sütterlin, & Hartmann, 2018) and novel food technologies (Egolf, Hartmann, & Siegrist, 2019).

Although disgust has a protective function, it can also restrict our diet by reducing our food choices. Egolf and colleagues (2018) reported that food disgust sensitivity was positively associated with picky eating and negatively associated with seeking variety in foods. While disgust and neophobia may be related, they are not identical constructs, as not all unfamiliar food products lead to disgust while some familiar food products may lead to disgust.

People with high levels of disgust sensitivity are more likely to reject foods with a certain textural property, such as chewy, slippery, or creamy (Egolf et al., 2018; Kauer, Pelchat, Rozin, & Zickgraf, 2015) and show low fruit and vegetable consumption (Van Trijp & Steenkamp, 1992; Egolf et al., 2018). Moreover, high levels of core disgust and contamination disgust were associated with low BMI and with a reduced desire to eat palatable, high calorie food. Overweight people, in contrast, appear to have a higher threshold for rejecting food products, which may explain their predisposition to overeat (Houben & Havermans, 2012).

Moreover, sensitivity to disgust is strongly associated with higher perception of bitter taste (Garcia-Burgos & Zamora, 2013; Schienle, Arendasy, & Schwab, 2015) and super-tasters were more responsive to these disgust triggers than tasters and non-tasters (Herz, 2011).

Alexithymia, defined as the inability of individuals to identify and name their emotional states (Nemiah, Freyberger, & Sifneos, 1976), was found to be associated with liking for alcohol, sweets, and fats/meats, and low liking for vegetables, condiments, and strong cheeses (Robino et al., 2016). Herbert et al. (2012) showed that interoceptive awareness, defined as an improved sensitivity to changes in stimuli arising within the body, is inversely associated with alexithymia features. Interoceptive awareness and bitter taste sensitivity could be related, via activation of similar brain areas, suggesting that the negative component of bitter perception could be mediated by alexithymia (Critchley, Wiens, Rotshtein, Öhman, & Dolan, 2004; Kringelbach, De Araujo, & Rolls, 2004). Moreover, alexithymics showed a deficit in the ability to detect negative emotions and several researches showed that individuals with difficulty recognizing their emotions were more sensitive to disgust than individuals with low alexithymia (Berenbaum, 1994; McDonald & Prkachin, 1990).

Private body consciousness (Miller, Murphy, & Buss, 1981) was developed to explore how internal bodily changes are perceived and is focused on awareness of changes in heart-beat, dryness of mouth, bodily tensions, hunger sensations, and body temperature. Several studies have hypothesised that subjects with a high level of self-awareness are also able to correctly identify sensory stimuli and to easily detect sensory changes, but the results are controversial (Byrnes & Hayes, 2013; Jaeger, Andani, Wakeling, & MacFie, 1998).

Sensitivity to punishment and sensitivity to reward describe individual differences in reactivity and responsivity to the behavioural inhibition and activation systems, respectively (Gray & McNaughton, 2003). Sensitivity to punishment was found to be negatively associated with liking of spicy foods (Byrnes & Hayes, 2013). Sensitivity to reward was found to be positively associated with chili intake, liking of spicy foods, and choice of pungent foods (Byrnes & Hayes, 2013, 2015). Recent studies have also highlighted an association between sensitivity to reward and unhealthy food behaviours, such as a preference for sweet and fatty foods, higher fat intake, higher alcohol consumption, and smoking frequency (Davis et al., 2007; Morris, Treloar, Tsai, McCarty, & McCarthy, 2016; Tapper, Baker, Jiga-Boy, Haddock, & Maio, 2015).

Sensation seeking is defined as a psychological trait with a biological basis defined by the 'seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience'. This trait is negatively correlated with food neophobia and positively correlated with sensitivity to reward (Byrnes & Hayes, 2013; Torrubia, Ávila, Moltó, & Caseras, 2001; Zuckerman, 1979) even if they cannot be considered interchangeable constructs (Scott-Parker, Watson, King, & Hyde, 2012). Sensation seeking is positively correlated with the willingness to taste novel foods and is involved in the increased intake and preference for spicy food (Byrnes & Hayes, 2013; Logue & Smith, 1986; Ludy & Mattes, 2012; Terasaki & Imada, 1988) and in the acceptance of pungent spices such as chipotle chili pepper and ginger (Scott, Burgess, & Tepper, 2019).

Sensation seekers, such as high-risk takers, were found to be much more likely to use alcohol, smoke, use other drugs, and be involved in deviant behaviours compared to low risk takers (Donohew, Helm, Lawrence, & Shatzer, 1990). Additionally, caffeine consumption is positively correlated with sensation seeking behaviour (Mattes, 1994).

Trait anxiety refers to the dispositional and relatively stable tendency of an individual to experience anxiety, defined as a set of physical and psychological reactions, such as an unpleasant state of inner agitation, nervous behaviour, somatic complaints, and rumination.

Randler and colleagues (2016) found that anxiety, as a preparatory response to potential threat, reduced food intake and re-directed energy for vigilance and preparedness in a dangerous, or at least in an unpredictable, environment.

Food neophobia has been linked to increased anxiety relating to food (Galloway et al., 2003; Pliner, Eng, & Krishnan, 1995; Pliner, Pelchat, & Grabski, 1993; Pliner & Hobden, 1992b), although the mechanism underlying the rejection of new foods as a result of anxiety is still unclear. Brown (2012) suggested that anxiety towards food could have an additive effect in the disgust response, based on different characteristics of foods. For example, if a person presents anxiety towards food and also thinks that a certain food has an unpleasant texture that produces aversion, this person will have a stronger reaction of disgust (and, therefore, more resistance to change) than if only one of these factors were present. Lafraire and colleagues (2016) point out that being forced to eat a food towards which one feels disgust may also heighten the disgust and the associated anxiety response. The hypothesis is supported by the fact that effective cognitive-behavioural treatments for food neophobia (Marcontell, Laster, & Johnson, 2003) have involved a combination of techniques traditionally used for treating anxiety-related disorders (i.e., desensitization, relaxation training, and cognitive restructuring).

State anxiety may play a role in food choices by modulating the perceived intensity of tastes. Several studies have shown that responses to basic tastes can be modulated by many conditions, since participants rated sweet solutions as less intense after exposure to mild stressors (Al'absi, Nakajima, Hooker, Wittmers, & Cragin, 2012; Dess & Edelheit, 1998). Additionally, exposure to mild stressors led to higher intensity ratings of bitter substances (DeMet et al., 1989; Dess & Edelheit, 1998; Platte, Herbert, Pauli, & Breslin, 2013), highlighting the potential for a shift in the hedonic properties of food with change in affect (Noel & Dando, 2015). Several studies have reported that sensitivity towards bitter taste could vary with self-reported negative affect, depression, or anxiety, either positively (Amsterdam, Settle, Doty, Abelman, & Winokur, 1987; Whittemore, 1986) or negatively (Thomas, Al-Mesaabi, Bahusain, & Mutawa, 2014). The relationship between mood, psychiatric disorders, and taste could be mediated by changes in neurotransmitter systems (serotonin and noradrenaline) that influence taste perception (Heath, Melichar, Nutt, & Donaldson, 2006). Therefore, this relationship merits further investigation.

1.2.2 Gender and age

Males and females are different and while physical differences in size and anatomy are obvious, the question of psychological differences between the genders is a lot more complicated and controversial. One of the most relevant studies in this field, published in 2001 by pioneering personality researchers Paul Costa, Robert McCrae and Antonio Terracciano, involved over 23,000 men and women from 26 cultures filling out personality questionnaires. Across these diverse cultures, women consistently rated themselves as being warmer, friendlier and more anxious and sensitive to their feelings than did the men. The men, meanwhile, consistently rated themselves as being more assertive and open to new ideas. These results are in line with the evolutionary perspective that suggests that our psychological traits today reflect the effect of survival demands experienced by our distant ancestors, and further, that these demands were different for men and women. For example, women with more nurturing personalities would have been more likely to succeed in raising vulnerable offspring, while men with bolder personalities would have been more successful in competing for mates. In turn, these traits would have been passed down to successive generations.

It is also well known that taste responsiveness can vary substantially as a function of gender (Landis et al., 2009; Pingel, Ostwald, Pau, Hummel, & Just, 2010), with women showing lower taste thresholds for PROP and evaluating suprathreshold concentrations of PROP as more intense than did men. Moreover, anatomical data also support the gender difference: women have more fungiform papillae and more taste buds (Bartoshuk, Duffy, and Miller 1994) and exhibit greater neural gustatory responses relative to men (Gemousakakis, Kotini, Anninos, Zissimopoulos, & Prassopoulos, 2011; Haase, Green, & Murphy, 2011).

Age also plays a key role in personality traits and taste perception evolution. Psychological traits are relatively persistent, however environmental factors and life events may play an important role in life span personality development. On one hand, personality maturity may increase as a result of adopting mature social roles, like parenthood or paid employment, on the other hand significant variation around average event-related trajectories are possible, suggesting that individuals differ in their reactions to life events (Denissen, Luhmann, Chung, & Bleidorn, 2019).

The deteriorating in taste acuity with aging can be partially related to physiological changes in the sensory organs and to attitudes and behaviours related to taste sensations and food consumption and gustatory dysfunction may indeed be related to the normal ageing process. These changes in taste acuity with aging have important implications for nutrition counselling of older individuals.

Several studies have reported that females perceived the bitterness of PROP as more intense than males and were more likely to be super-tasters (Bartoshuk, Duffy, & Miller, 1994; Dinnella et al., 2018; Shen, Kennedy, & Methven, 2016; Zhao & Tepper, 2007).

Females have significantly higher private body consciousness (Spinelli, De Toffoli, Dinnella, Laureati, Pagliarini, Bendini, Braghieri, Gallina Toschi, et al., 2018) and anxiety (Spielberger, 2008; Stewart, Taylor, & Baker, 1997), and are more sensitive to disgust and punishment than males (Caseras, Ávila, & Torrubia, 2003; Herz, 2011; Spinelli et al., 2018; Torrubia et al., 2001), while males are more neophobic (Monteleone et al., 2017; Nordin, Broman, Garvill,

& Nyroos, 2004), more sensitive to reward (Caseras et al., 2003; Torrubia et al., 2001), and more alexithymic (Bressi et al., 1996; Spinelli et al., 2018).

Several studies have revealed that females perceived and reported higher intensities for bitter compounds than males (Dinnella et al., 2018; Hyde & Feller, 1981; Shen et al., 2016), even though they did not differ in emotional responses to sweet and bitter tastes (Robin, Rousmans, Dittmar, & Vernet-Maury, 2003), probably because responses to the innately accepted sweet taste and to the innately rejected bitter taste could be genetically programmed and, consequently, very similar within genders.

Females and males significantly differ in food consumption attitudes and behaviours. Females showed higher general health interest and natural product interest measured with the Health and Taste Attitudes Scale (Monteleone et al., 2017; Roininen et al., 2001) and higher attention to moral and ecological misgivings about eating certain foods than males, who are more confident and demonstrate a rather uncritical and traditional view of eating. Females also eat more fruit and vegetables (Kiefer, Rathmanner, & Kunze, 2005) and perceive functional foods as healthier than males (Ares & Gámbaro, 2007).

Clear gender differences are also observed in terms of the stress-eating relationship. Epidemiological studies have shown that eating disorders are more common among females than males (Hoek, 2006; Striegel-Moore & Bulik, 2007), with females scoring significantly higher in emotional and restrained eating measured with the Dutch Eating Behaviour Questionnaire (Braet et al., 2008; Dakanalis et al., 2013; van Strien, Frijters, Bergers, & Defares, 1986).

Age affects taste discrimination and bitterness perception (Dinnella et al., 2018; Hyde & Feller, 1981). However, taste sensitivity decreases with age. Because perception of foods relies on information transmitted from oral somatosensory receptors and taste and olfactory receptors, age-related decreases in any of these sensations can cause decreased taste perception of foods. Both young and adult non-tasters were found to consume more vegetables and more bitter vegetables than the other taster phenotypes (Bell & Tepper, 2006; Shen, Kennedy, & Methven, 2016, respectively). Drewnowski, Henderson, Levine, & Hann (1999) showed that super-taster young women had lower preference for the bitter taste perceived from brassica vegetables such as broccoli and Brussel sprouts than non-tasters.

Sensitivity to reward, sensitivity to punishment, alexithymia, and, to a lower extent, private body consciousness decreased with age (Bressi et al., 1996; Caseras et al., 2003; Miller et al., 1981; Torrubia et al., 2001), while food neophobia and sensitivity to disgust increased with age (Herz, 2011; Laureati, Spinelli, Monteleone, Dinnella, Prescott et al., 2018; Meiselman, King, & Gillette, 2010).

Food consumption is strongly influenced by age, with an increase in general health interest and natural product interest (Roininen et al., 2001) with age (Monteleone et al., 2017).

Moreover, Dakanalis and colleagues (2013) showed that old individuals reported significantly lower emotional eating than younger individuals while no significant differences in restrained eating were found.

1.2.5 The relationship between biological and psychological variables: preliminary studies on a pre-existent database—the Italian Taste Project

Two studies (Spinelli et al., 2018 and Laureati et al., 2018) involving a pre-existing dataset acquired during the first two years of the Italian Taste project (n=1225) investigated the effects of psychological traits, PROP status, gender, and age on food choices and contributed to the detailed formulation of the research questions for the present thesis.

Age and gender were significant for most vegetables independently of taste categorization (mild/strong). In all cases, females and older subjects liked vegetables more than males and younger people, probably due to the increased awareness of healthy eating with age and in females (Margetts, Martinez, Saba, Holm, & Kearney, 1997).

Neophobics reported liking vegetables and beverages characterised by warning sensations, such as bitterness and astringency, and spicy foods less than neophilics. Additionally, both male and female neophobics also reported a lower chili yearly intake compared to neophilics. Conversely, few differences between food neophobia groups were found for the liking of mild vegetables and beverages, and of sweets and desserts.

No differences between subjects with different food neophobia levels for responsiveness to PROP and to taste stimuli in water solutions (sourness: citric acid 4 g/kg; bitterness: caffeine 3 g/kg; sweetness: sucrose 200 g/kg; saltiness: sodium chloride 15 g/kg; umami: monosodium glutamic acid salt 10 g/kg; astringency: K Aluminium Sulfate 0.8 g/kg; pungency: capsaicin 1.5 mg/kg) were found. One explanation may be that when a critical sensation is clearly perceptible (concentrations were chosen to represent a 'moderate/strong' intensity on the gLMS), the different reactions among groups are difficult to detect. By contrast, when the intensity of the sensation is subtle, the difference between neophobics and neophilics may become more evident.

Food neophobia affects sensory and hedonic evaluations of real foods characterised by warning sensations, suggesting a different modulatory effect of psychological traits when tastes are detected and evaluated in food.

Four samples varying in bitterness, astringency, and sweetness were produced by adding different amounts of sucrose (C1=38 g/kg; C2=83 g/kg; C3=119 g/kg; C4=233 g/kg) to the base dark chocolate pudding. As expected, sweetness increased with sugar concentration with no significant differences among the three groups (Low, Medium and High levels of food neophobia). Bitterness and astringency decreased with increased sugar concentration and neophobics perceived these warning sensations as more intense than neophilics and this increased perception was reflected in a decreased liking for the most bitter and astringent samples.

Four samples of tomato juice, each spiked with capsaicin at different concentrations (C1=0.30 g/kg; C2=0.68 g/kg; C3=1.01 g/kg; C4=2331.52 g/kg) were produced and the intensity of burning, sourness, sweetness, and overall flavour were evaluated. Neophobics perceived pungency and overall flavour in tomato juice samples spiked with capsaicin as more intense and liked the most pungent sample (C4) less than neophilics, suggesting that this trait was associated with a different perception of the key sensations and that the hedonic meaning assigned to the sensory stimuli was probably modulated by the intensity of these sensory properties.

Other psychological traits have been found to be associated with lower preference for pungent foods. Individuals highly sensitive to visceral disgust (disgust related to rotten food, vermin, and body fluids) found pungent foods more intense, liked them less, and chose them less often. Sensitivity to punishment was found to be negatively associated with liking of spicy foods and pungent food choice in females. Sensitivity to reward was found to be positively associated with chili intake, liking of spicy foods, and choice of pungent foods.

It is interesting to note that some psychological traits, such as food neophobia and sensitivity to disgust, affect liking and intensity of a series of tomato juice, while other psychological traits either play a role in perception but do not influence liking in females (sensitivity to punishment) or affect only liking but not intensity (sensitivity to reward). It can be hypothesised that the reason for these different responses is not associated with a differential taste function but with the meaning attributed to the stimulus. Food neophobia, sensitivity to punishment, and sensitivity to disgust have all been found to be associated with anxiety (FNS: Pliner et al., 1995, 1993; Pliner & Hobden, 1992; Pliner & Melo, 1997; Raudenbush & Capiola, 2012; DS: Viar-Paxton & Olatunji, 2016; SP: Torrubia et al., 2001). Recent studies reported that healthy individuals with mild anxiety were more sensitive to sensory inputs, such as pain (Thompson, Keogh, French, & Davis, 2008), tone loudness (Dess & Edelheit, 1998), and bitter taste (Platte et al., 2013). They were also found to be more sensitive to threatening information, which is explained by a generalised enhanced vigilance in this subject group (Mogg & Marden, 1990). Since food neophobia is a conservative behaviour, which keeps the organism's feeding behaviour 'locked in on a safe track' (Schulze & Watson, 1995, p. 230), it can be reasonably hypothesised that food neophobics may have developed a hypersensitivity to warning sensations that makes them extremely cautious when approaching unfamiliar food, especially if it tastes bitter, astringent, or pungent.

Therefore, individuals with high food neophobia, sensitivity to punishment, and sensitivity to disgust may be in a more anxious state during the tasting of stimuli, and thus perceive the key sensations with a heightened intensity. In other words, it can be hypothesised that these traits modulate the sensory response to a stimulus, and consequently affect liking. This is consistent with the assumption that the perception of danger and fear of negative consequences of eating novel food, as well as the expectation that sensory characteristics may be unpleasant, is a fundamental principle for food rejection (Pliner & Salvy, 2006). However, the relationship between sensory perception and liking needs to be further investigated.

2. Aim of the thesis

The aim of the present thesis is to investigate the effects of psychological traits and PROP status on the acceptability of phenol-rich foods characterized by warning sensations, such as bitterness and astringency. The studies in this thesis involved multidisciplinary and multidimensional approaches. Taste sensitivity, psychological traits, food attitudes, familiarity, choice, and sensory and hedonic responses to foods based on evaluations of samples and not only sample names were considered.

The investigation of these factors is of interest not only to fully understand food choice and preference, but also to understand the beneficial effects of the consumption of phenol-rich foods on physical and mental well-being (Roberfroid, 2000).

The detailed objectives of this research were as follows:

I. To select, adapt, and validate psychological questionnaires used in food science for the Italian population (chapter 4);
II. To investigate the influence of individual variation in psychological traits and PROP status on choice of and familiarity with phenol-rich vegetables and beverages (chapter 5);
III. To set-up experimental vegetable prototypes with the addition of phenol extracts from Olive Mill Waste Water (OMWW) (chapter 6) and to study the relationship between psychological traits, PROP status, and perceived intensity of warning sensations and liking for these functional foods (chapter 7).

Explorative large scale studies and the use of a wide perspective that takes into account taste sensitivity and biological, psychological, sensory, and hedonic responses to foods based on evaluations of samples will provide a deeper understanding of the underlying mechanisms of food perception and liking and help to identify the potential psychological barriers to the consumption of healthy foods.

3. Overview of the experimental plan

The studies of the present thesis followed the general conceptual plan showed in Figure 1. Data were collected as part of:

- **Italian Taste Project** funded by the Italian Sensory Science Society (SISS) – chapter 4
- Research Project: 20158YJW3W Programmi di Ricerca Scientifica di Rilevante Interesse Nazionale - **PRIN 2015: "Individual differences in the acceptability of healthy foods: focus on phenol and fat content"**, funded by the Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR) – chapters 5, 6, 7

All the studies were conducted in agreement with the Italian ethical requirements on research activities and personal data protection (D.L. 30.6.03 n. 196). The studies protocols were approved by the Ethics Committees of the Universities of Trieste (Italian Taste Project) and Florence (PRIN 2015) and the respondents gave their written informed consent at the beginning of the test according to the principles of the Declaration of Helsinki.

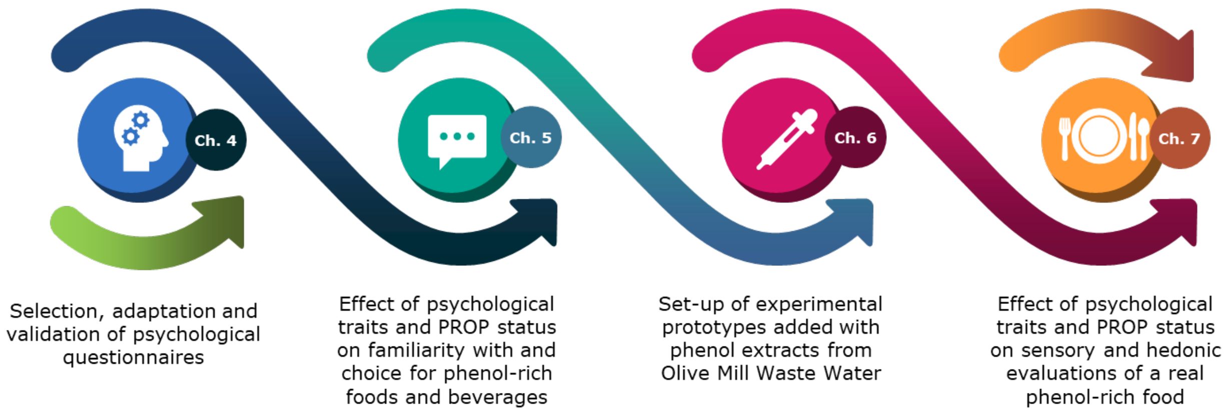

Figure 1. Conceptual plan of the present thesis.

3.1 Overview of Italian Taste Project

Data were collected on 19 sensory labs in Italy. The recruitment procedure aimed to reach a balance between genders, three age classes (18–30; 31–45; 46–60 years) and main geographical areas of the country. Using questionnaires, information was collected concerning socio-demographic and socio-economic, anthropometric and physical health; psychological traits; eating behaviours, food-related lifestyles and attitudes; food preferences, choice, familiarity and frequency of consumption of different categories of foods and beverages. Furthermore, the design included the collection of hedonic and sensory responses to food products, solutions and odours, taste function measurement (Fungiform Papillae Density (FPD) and PROP status) and the collection of saliva samples for DNA determination and genotyping.

At the time of recruitment, respondents were given general information about the study aims. They were asked to complete an online questionnaire, related to food familiarity and frequency of consumption, in the days preceding the data collection and invited to attend two sessions, in two different days, in a sensory lab. The data collection scheme is presented in Figure 2. Highlighted information was analysed in this PhD project and presented in Chapter 4.

On day 1, participants signed the informed consent and were introduced to the general organization of the day which included a liking and an odour session, followed by the measurement of PROP responsiveness. Before starting the hedonic evaluation of food samples participants were introduced to the use of the Labelled Affective Magnitude scale (LAM; Schutz and Cardello, 2001). They were seated in individual booths and introduced to the use of the PC for data collection. They were asked to rate their appetite and were presented with four series of products (pear juice, chocolate pudding, bean purée and tomato juice) for liking evaluations. Each series included four samples with varied intensities of target sensations. After the liking session, participants were presented with the Food Preference Questionnaire (Q1). Then, participants were instructed about the odour test and received general information about Food Related Life Style (Q2), Food Neophobia Scale (Q3) and Private Body Consciousness (Q4) questionnaires. They completed Q2 and the odour test, followed by a break during which they completed Q3 and Q4. Participants were then introduced to the use of the generalized Labelled Magnitude Scale (gLMS; Bartoshuk et al., 2004) for the intensity evaluation of PROP solutions. They were informed about Sensitivity to Punishment and Reward (Q5) and Alexithymia (Q6) questionnaires, then they rated the intensity of PROP solutions and filled in Q4 and Q5.

Day 2 started with a general introduction of the day, including instructions on saliva collection and the Food Choice Questionnaire (Q7) administration. Then, participants were seated in individual booths where they rated their appetite and, before completing the saliva collection procedure, completed questionnaire Q7. After that, the gLMS was briefly introduced again and the Health and Taste (Q8), the Dutch Eating Behaviour (Q9), the Portrait Values (Q10) and the Sensitivity to Disgust (Q11) questionnaires were illustrated. Then, the first part of intensity data collection started. Participants were first asked to rate the intensity of basic tastes, astringency and burn in a series of seven samples. They had a break and were asked to fill in Q8. Finally, taste and oral sensation intensities were collected from four series of the same food products (pear juice, chocolate pudding, bean purée and tomato juice) presented in day 1. During breaks between sample series, participants were asked to fill in the Q9, Q10 and Q11. The picture of the tongue for papillae counting was taken at the end of day 1 or day 2, according to individual availability.

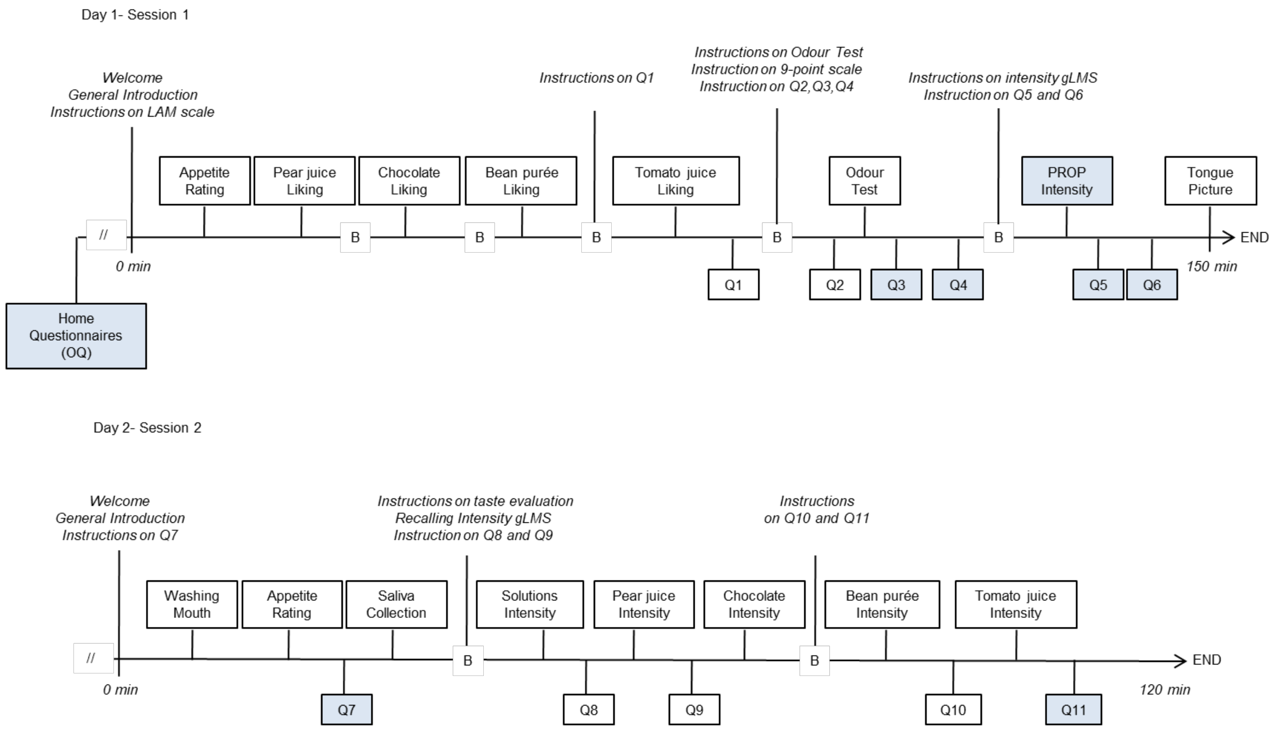

Figure 2. Overview of data collection of Italian Taste Project (Monteleone et al., 2017).

3.2 Overview of PRIN Project 2015: "Individual differences in the acceptability of healthy foods: focus on phenol and fat content"

The first step of the Project involved the study of the sensory and chemical properties of phenols extracted from Olive Mill Waste Water (OMWW) in water solutions and in plant-based foods varied in their macro-composition and the set-up of food experimental prototypes added with OMWW. The study is presented in Chapter 6.

The second step of the Project was related to a large-scale study on Italian adult respondents to better understand and overcome barriers to the consumption of phenol-rich foods.

Data were collected in 8 sensory labs in Italy. The study aims to investigate the effect of individual sensory responsiveness to bitter taste and astringency on consumer food liking, preference and behaviour and to contribute to the exploitation of by-products from olive oil production chains to improve relevant sustainability. This multisession study involved an online questionnaire session (at home) and two sessions in a sensory laboratory across 2 days.

At the time of recruitment, respondents were given general information about the study aims. They were asked to complete an online questionnaire in the days preceding the data collection and invited to attend two sessions, in two days, in a sensory lab. The online survey included the Food Preference, Food Familiarity and Food Choice questionnaires. The data collection scheme is presented in Figure 3. Highlighted information was analysed in my PhD project and presented in Chapters 5 and 7.

On day 1, participants signed the informed consent and were introduced to the general organization of the day which included a liking and an intensity session, followed by the measurement of PROP responsiveness. Before starting the hedonic evaluation of food samples participants were introduced to the use of the LAM scale. Subjects were seated in individual booths and were introduced to the use of the PC for data collection. They were asked to rate their appetite and to complete the State Anxiety Inventory (Q1) and were presented with a series of five samples of bean purée added with different concentrations of phenol from OMWW for liking evaluations. After the liking session, participants filled in the Sensation Seeking Questionnaire (Q2). Then, participants were introduced to the use of the gLMS scale and received general information about Trait Anxiety Inventory (Q3) and Meaning of Food in Life Questionnaire (Q4). They completed Q3, rated the intensity of target sensations of the same five samples of bean purée and filled in Q4. During the break participants were introduced to the evaluation of two series of tastes in water solutions. Five samples of bitterness and five samples of astringency were rated before the evaluation of PROP solutions.

Day 2 was dedicated to the evaluations of beetroot purée and cooked ham pâté with an increased concentration of phenols from Unripe Grapes (UG) and an increased addition of free fatty acids, respectively. These data were not part of the present PhD thesis.

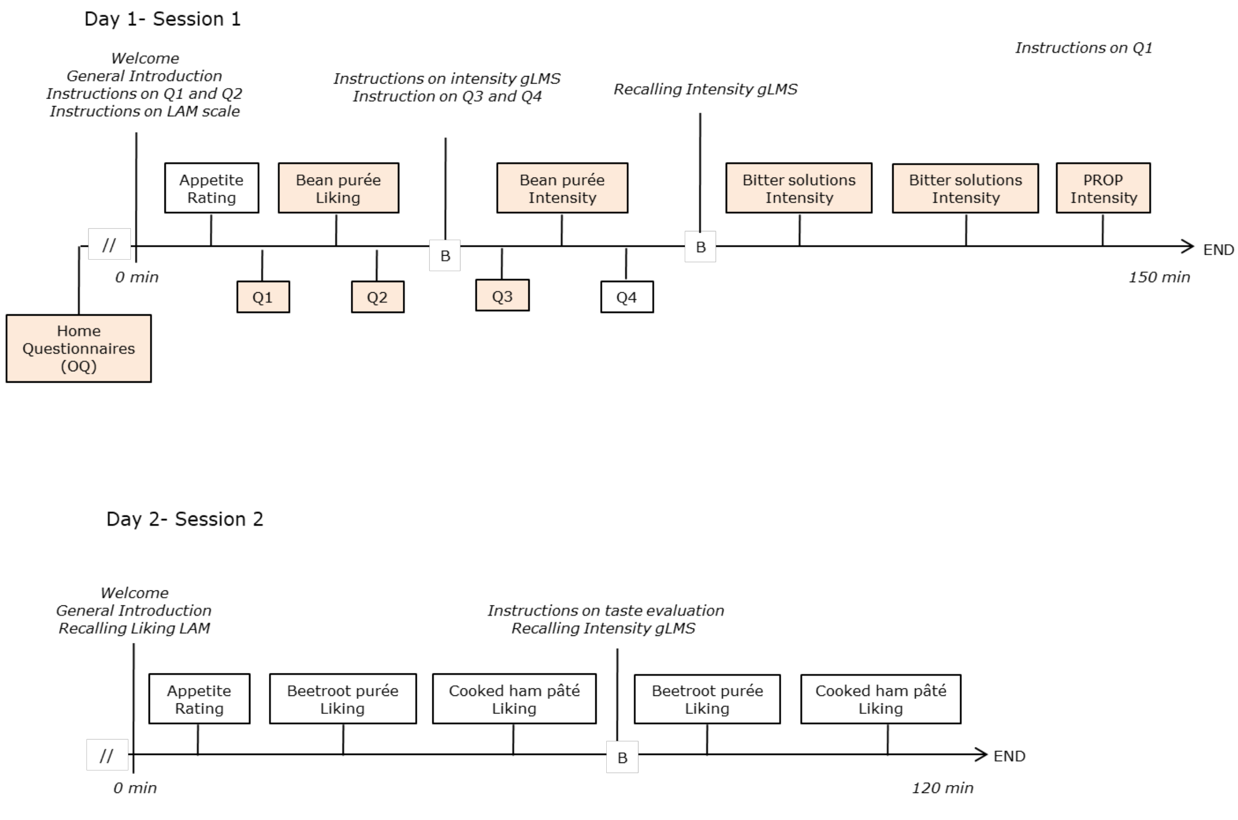

Figure 3. Overview of data collection of PRIN 2015 Project.

4. Selection, adaptation, and validation of psychological questionnaires

4.1 Introduction

Personality is the set of psychological traits and mechanisms within the individual that are organised and relatively enduring and that influence his or her interactions with, and adaptations to, the intrapsychic, physical, and social environments (Larsen & Buss, 2005). Psychological traits have two key assumptions. First, traits are stable over time. Most people would accept that an individual's behaviour naturally varies somewhat from occasion to occasion but remains consistent, which defines the individual's 'true nature'. Stability distinguishes traits from more transient properties of a person, such as temporary mood states. Second, it is generally believed that traits directly influence behaviours (Matthews et al., 2009).

Psychological traits are abstract concepts known as theoretical constructs and their measurement involves the definition of variables and the development and application of instruments to quantify these variables. As these measures are potentially vulnerable to distortion due to a range of factors including social desirability, dissimulation, and response style, the use of standardised and validated instruments appears to be fundamental. Validated self-report questionnaires have good reliability, provide data that can be gathered quickly and cheaply from different groups and large samples, can be easily replicated and responses to closed questions are quantifiable, and can be summarised into tables and graphs and compared.

If a questionnaire is not validated in the language of interest, a cross-cultural adaptation is required. It is time-consuming and requires careful planning and adoption of rigorous methodological approaches to derive a reliable and valid measure of the concept of interest in the target population. However, validating a questionnaire has many advantages over developing a new one. For example, it reduces the cost and time spent in development and allows the use of an instrument that already works to make intercultural comparisons, aiding the exchange of information within the international scientific community. Cross-cultural adaptation is a complex process with the aim of achieving equivalence between the source and target versions of the questionnaire.

4.2 Validation and adaptation of psychological questionnaires

Translation of an instrument is a crucial step in the validation process. However, 'adaptation' and 'translation' have different meanings. Translation is merely the first stage of the adaptation process. When adapting an instrument, the cultural, idiomatic, linguistic, and contextual aspects should be considered during its translation (Callegaro Borsa, Figueiredo

Damasio, & Ruschel Bandeira, 2012). Therefore, the cross-cultural adaptation process involves the development of versions of an assessment instrument which are equivalent to the original, but at the same time, have been linguistically and culturally adapted to a context different from the original.

The validation process includes translation, adaptation, and the assessment of reliability (internal consistency and repeatability) and validity (content validity, face validity, and construct validity).

4.2.1 Validation and adaptation

Forward translation. The initial translation from the original language to the target language should be made by at least two independent translators (Guillemin, Bombardier, & Beaton, 1993; Kennedy et al., 2013). Discrepancies between the two (or more) translations can be discussed and resolved by the original translators, or by an unbiased, bilingual translator who was not involved in the previous translations (Tsang, Royse, & Terkawi, 2017).

Backward translation. The initial translation should be independently back-translated to ensure the accuracy of the translation. Misunderstandings or unclear wordings in the initial translations may be revealed in the back-translation. As with the forward translation, the backward translation should be performed by at least two independent translators, preferably translating into their mother language (the original language) (Guillemin et al., 1993).

Preliminary pilot testing. As with developing a new questionnaire, the prefinal version of the translated questionnaire should be pilot tested on a small sample (about 30–50 people) (Perneger, Courvoisier, Hudelson, & Gayet-Ageron, 2015).

4.2.2 Assessment of reliability

The reliability of a questionnaire can be considered as the consistency of the survey results. As measurement error occurs due to content sampling, changes in respondents, and differences across raters, the consistency of a questionnaire can be evaluated using its internal consistency, test-retest reliability, and inter-rater reliability.

Internal consistency. Internal consistency reflects the extent to which the questionnaire items are inter-correlated, or whether they are consistent during the measurement of the same construct. Internal consistency is commonly estimated using the coefficient alpha (Cronbach, 1951), also known as Cronbach's alpha. Cronbach's alpha ranges from 0 to 1, with 0 indicating no internal consistency (i.e., none of the items is correlated with the other) and 1 reflecting perfect internal consistency (i.e., all the items are perfectly correlated with one another).

A Cronbach's alpha value greater than 0.70 has been suggested to indicate adequate internal consistency (Nunnally & Bernstein, 1994). A low Cronbach's alpha value may be due to poor inter-relatedness between items and items with low correlations with the questionnaire total score should be discarded or revised. The reliability of a questionnaire should be estimated each time the questionnaire is administered, including pilot testing and subsequent validation stages.

Test-retest reliability. Test-retest reliability refers to the extent to which the responses of individuals to the questionnaire items remain relatively consistent across repeated administration of the same questionnaire or alternate questionnaire forms. Provided the same individuals responded to the same questionnaires twice (or more), test-retest reliability can be evaluated using the Pearson's product moment correlation coefficient (Pearson's *r*) or the intraclass correlation coefficient. A larger stability coefficient indicates a stronger test-retest reliability, suggesting that the measurement error of the questionnaire is less likely to be attributable to changes in the responses of individuals over time.

4.2.3 Assessment of validity

The validity of a questionnaire is determined by assessing whether the questionnaire measures what it is intended to measure. Two major types of validity should be considered when validating a questionnaire: content validity and construct validity.

Content validity. Content validity refers to the extent to which the items in a questionnaire are representative of the entire theoretical construct the questionnaire is designed to assess (Shultz & Whitney, 2005). Although the construct of interest determines which items are written and/or selected in the questionnaire development/translation phase, content validity of the questionnaire should be evaluated after the first version of the questionnaire is available. The process of content validation is particularly crucial in the development of a new questionnaire.

A panel of experts who are familiar with the construct that the questionnaire is designed to measure should be tasked with evaluating the content validity of the questionnaire. The experts judge, as a panel, whether the questionnaire items adequately assess the construct they are intended to assess, and whether the items are enough to evaluate the domain of interest. Several approaches to evaluate the opinions of experts on content validity are also available, such as the content validity ratio and content validation form (Lawshe, 1975).

Face validity. Face validity refers to the degree to which the respondents judge the questionnaire items to be valid. Such judgment is based less on the technical components of the questionnaire items, but rather on whether the items appear to be measuring a construct that is meaningful to the respondents. Although this is the weakest way to establish the validity of a questionnaire, face validity may motivate respondents to answer more truthfully.

Construct validity. Construct validity is the most important concept in evaluating a questionnaire that is designed to measure a construct that is not directly observable. If a questionnaire lacks construct validity, it will be difficult to interpret results from the questionnaire, and inferences cannot be drawn from questionnaire responses to a behaviour domain. The construct validity of a questionnaire can be evaluated by estimating its association with other variables (or measures of a construct) with which it should be correlated positively, negatively, or not at all (Cronbach & Meehl, 1955).

4.3 Measurement of psychological traits

Based on literature review and data analysis on the pre-existing dataset (Spinelli et al., 2018; Laureati et al., 2018), the effects of the following psychological traits on the acceptability of healthy foods have been further investigated in this research project: Food Neophobia, Alexithymia, State and Trait Anxiety and Sensation Seeking questionnaires were already validated in Italian. Sensitivity to disgust, Private Body Consciousness and Sensitivity to Reward and Punishment questionnaires were validated in Italian during the Italian Taste Project and the adaptation and validation of these questionnaires was the first part of the present PhD research.

In each study of the present thesis Cronbach’s alpha for each trait was calculated and reported.

4.3.1 Psychological trait questionnaires already validated in Italian

Food neophobia (FN): quantified using the 10-statement scale developed by Pliner and Hobden (1992) and validated in Italian by Laureati and colleagues (2018). Individual food neophobia scores were computed as the sum of ratings given to the 10 statements using a 7-point Likert scale (disagree strongly/agree strongly). Items 1, 4, 6, 9, 10 were reversed. The individual scores ranged from 10 to 70, with higher scores corresponding to higher food neophobia.

Alexithymia (TAS): quantified using the Toronto Alexithymia Scale (TAS) developed by Parker, Bagby, Taylor, Endler, and Schmitz (1993) and validated in Italian by Bressi and colleagues (1996). Individual alexithymia total score was computed as the sum of ratings given to the 20 statements using a five-point Likert scale (disagree strongly/agree strongly). Items 4, 5, 10, 18, 19 were reversed. The questionnaire provides a total alexithymia score (TAS Total), and three subscale scores, which reflect the three main factors of the alexithymia construct: Difficulty identifying feelings; Difficulty describing feelings; Externally oriented thinking. The TAS Total score ranged from 20 to 100, with a higher score indicating a greater level of alexithymia.

State and Trait Anxiety: quantified using the State-Trait Anxiety Inventory developed by Spielberger (1983) and validated in Italian by Pedrabissi & Santinello (1989). In responding to the S-Anxiety items, subjects report the intensity of their feelings of anxiety "right now, at this moment" by rating themselves on the following 4-point Likert scale: (1) Not at all, (2) Somewhat, (3) Moderately so, (4) Very much so. Responses to the T-Anxiety items require subjects to indicate how they generally feel by reporting how often they have experienced anxiety-related feelings and cognitions on a 4-point scale: (1) Almost never, (2) Sometimes, (3) Often, and (4) Almost always. Individual score was computed for each scale as the sum of ratings given to the 20 statements. Items 1, 2, 5, 8, 10, 11, 15, 16, 19, 20 (S-Anxiety) and items 21, 23, 26, 27, 30, 33, 34, 36, 39 (T-Anxiety) were reversed. Scores for both scales can vary from a minimum of 20 to a maximum of 80, with a higher score indicating a greater level of anxiety.

Sensation Seeking (SS): quantified using the 4 subscales related to sensation seeking (SS1: Thrill and Adventure Seeking; SS2: Experience Seeking; SS3: Disinhibition; SS4: Boredom Susceptibility/Impulsivity) of the Zuckerman–Kuhlman–Aluja personality questionnaire (ZKA-PQ; Aluja, Kuhlman, & Zuckerman, 2010) validated in Italian by De Pascalis and Russo (2003). The questionnaire provides a total sensation seeking score (SS Total) and four subscale scores. Individual scores were computed as the sum of ratings given to each subscale, using a 4-point Likert scale (disagree strongly/agree strongly). Items 122, 142, 162, 182 (SS1), 127, 147, 167, 187 (SS2), 112, 132, 152, 172 (SS3) and 57, 77, 97, 117, 137, 157, 177, 197 (SS4) were reversed. The SS total scores range from 40 to 160, with higher scores corresponding to higher sensation seeking.

4.3.2 Validation of the Italian version of the sensitivity to punishment and sensitivity to reward questionnaire (SPSRQ), disgust scale-short form (DS) and private body consciousness (PBC)

The present study was published as Supplementary Data in Spinelli et al., 2018.

Title: Personality traits and gender influence liking and choice of food pungency

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4.3.2.1 Material and Methods

4.3.2.1.1 Participants

To evaluate the dimensional structure of the Italian version of SPSRQ and DS by means of cross-validation, the total sample (N=1223) was randomly divided into two subsamples, one used for calibration and one for validation.

- Sample 1 included a total of 614 subjects. 227 men (age M= 36.7 years; SD= 13; range: 18-60 years-old) and 387 women (age M= 36.6; SD= 12.5; range: 19-60 years-old).
- Sample 2 included a total of 609 subjects. 248 men (age M= 37.2 years; SD= 12.9; range: 19-60 years-old) and 361 women (age M= 36.8; SD= 12.7; range: 18-60 years-old).

The same procedure was applied to evaluate the dimensional structure of PBC. The total sample (N=1217) was randomly divided into two subsamples:

- Sample 1 included a total of 608 subjects. 227 men (age M= 36.4 years; SD= 13.2; range: 18-60 years-old) and 381 women (age M= 36.9; SD= 12.5; range: 19-60 years-old).
- Sample 2 included a total of 609 subjects. 246 men (age M= 37.5 years; SD= 12.7; range: 19-60 years-old) and 363 women (age M= 36.5; SD= 12.8; range: 18-60 years-old).

4.3.2.1.2 Psychological questionnaires

The items of each questionnaire were translated in Italian by two different bilingual Italian native-speakers and then back translated into the source language. Back translations were reviewed by an expert in semantics and adjustments were made when necessary to select the most appropriate translation. A set of analysis was conducted to evaluate the factor structure, reliability, stability over time, and validity of the Italian version of the SPSRQ, DS and PBC.

Sensitivity to core disgust (DS): was quantified using the eight-item short form of the Disgust Sensitivity Scale developed by Inbar, Pizarro, and Bloom (2009) and validated in Italian by Spinelli and colleagues (2018). The scale includes two subscales, each presented with a specific scale ranging from 1 = strongly disagree (very untrue about me) to 5 = strongly agree (very true about me) (subscale 1) and from 1 = not at all disgusting to 5 = extremely disgusting (subscale 2). Individual score was computed as the sum of ratings given to the 8 statements. Items 1 and 3 (subscale 1) were reversed. Scores ranged from 8 to 40, with higher scores reflecting a higher sensitivity to disgust.

Private body consciousness (PBC): quantified using the five-item instrument developed by Miller, Murphy, and Buss (1981) and validated in Italian by Spinelli and colleagues (2018). The individual score was computed as the sum of the ratings given for the five statements, using a five-point scale: extremely uncharacteristic/extremely characteristic. The scores ranged from 5 to 25, with higher scores reflecting higher private body consciousness.

Sensitivity to punishment (SP) and sensitivity to reward (SR). According to Gray's neuropsychological theory of personality (Gray & McNaughton, 2003), two basic brain systems control behaviour and emotions: the Behavioural Inhibition System (BIS) and the Behavioural Activation System (BAS). The responsiveness of these systems has been measured using the Sensitivity to punishment and sensitivity to reward questionnaire (SPSRQ, Torrubia, Ávila, Moltó, & Caseras, 2001) validated in Italian by Spinelli and colleagues (2018). The SP scale is formed by a set of items reflecting situations which describe individual differences in reactivity and responsivity to BIS. The BIS normally functions as a comparator, taking control of behaviour in response to signals of punishment, frustrative non-reward, and novel stimuli. In terms of individual differences in psychological, the BIS is related to the trait-anxiety dimension.

The SR scale was conceived as a single measure of the functioning of the BAS dealing with specific rewards (i.e. money, gender, social power and approval, and praising). The BAS is a conceptual system responsible for approach behaviour in response to incentives (signals of reward or non-punishment). Individual differences in the functional capacity of the BAS are related to the impulsivity dimension of psychological. The SP and SR scales were scored with a yes/no format. For each subject, scores for each scale were obtained by adding all the yes answers. In the original version, the score for each scale ranges from 0 to 24. Based on Exploratory and Confirmatory Factor Analysis 7 items were removed in the Italian version; thus, the scores range from 0 to 23 for SP and from 0 to 18 in SR, with higher scores reflecting, respectively, higher sensitivity to punishment and to reward.

4.3.2.1.3 Data analysis

To evaluate the dimensional structure of the Italian version of SPSRQ and DS by means of cross-validation, the total sample was randomly divided into two subsamples. For each questionnaire, skewness and kurtosis were calculated to check for non-normality. Reliability was assessed throughout inter-item correlation and the Cronbach's alpha and, when variables were categorical, using ordinal alpha, as suggested by Zumbo, Gadermann, & Zeisser (2007). Test-retest reliability was assessed throughout the Pearson's correlation coefficient in a subset of 116 participants randomly selected and balanced by gender and age that completed the SPSRQ, the DS and, the PBC and FNS at least eight months later (mean: 14 months, range: 8-19 months).

SPSRQ. The adequacy of the data for Factor Analysis was assessed using the Kaiser–Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (Tabachnick & Fidell, 2007). The factor structure was firstly studied in sample 1 through an Exploratory Factor Analysis (EFA) using the criterion of the principle factors on the tetrachoric correlation matrix, due to the nature of binary data of this questionnaire (yes/no responses), and Pearson correlation matrix with the aim to compare the results with the previous studies. Cattel's scree test (1966) was used to determine the number of factors to retain. A Varimax rotation was applied, based on the orthogonality of the factors reported by the authors who developed the scale (Torrubia et al., 2001), supported also by the low correlation found between the two subscales. Because differences were expected between females and males and with the aim to compare the results with the original study, the EFA was conducted on the all sample 1, with only males in sample 1, with only females in sample 1, both before and after rotation.

Secondly, Confirmatory Factor Analysis (CFA) models were computed on sample 2 with robust Diagonally Weighted Least Squares (robust DWLS), as suggested by Woods & Edwards (2007) for categorical variables: (a) a complete model with 48 items, (b) a trimmed 42-item model, and (c) a trimmed 41-item model, obtained in accordance with the criteria specified in the results section (Supplementary data 1).

DS. The adequacy of the data for factor analysis was assessed using the Kaiser–Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (Tabachnick & Fidell, 2007). Polychoric correlation matrix was used because the DS items were in part discrete (Likert scale/true-untrue about me), as suggested by Olatunji et al. (2007). Oblique rotation (Promax) was used, because it permits non zero correlation among factors and previous researches found correlation between the domains of disgust. The factor structure was firstly studied through factor analysis based on the criterion of principle factors on the correlation matrix in sample 1. Cattel's scree test (1966) was used to determine the number of factors to retain. Secondly, a Confirmatory Factor Analysis (CFA) models were computed on sample

2 with robust DWLS, as suggested by Woods & Edwards (2007) for categorical variables: (a) a one-factor model, and (b), a two-factor model.

PBC. The adequacy of the data for EFA was assessed using the Kaiser–Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (Tabachnick & Fidell, 2007). The factor structure was firstly studied through factor analysis on the correlation matrix in sample 1 with Maximum Likelihood estimation, in line with the procedure used in the original validation study (Miller et al., 1981). Cattel's scree test (1966) was used to determine the number of factors to retain. Secondly, a Confirmatory Factor Analysis (CFA) model was computed on sample 2 with Maximum Likelihood estimation.

CFA models were evaluated with the following set of fit indexes: Chi square/Degree of freedom ratio; Goodness-of-Fit Index (GFI), Tucker-Lewis Index (TLI), Comparative Fit Index (CFI), Root-Mean-Square Error of Approximation (RMSEA) and its confidence interval (90% CI), Standardized Root Mean Square Residual (SRMR).

4.3.2.2 Results

4.3.2.2.1 Sensitivity to punishment and sensitivity to reward (SPSRQ)

Internal reliability of the SPSRQ (sample 1). Cronbach alpha calculated on the tetrachoric matrix (ordinal Cronbach alpha; Zumbo, Gadermann, & Zeisser, 2007) was 0.90 for SP and 0.86 for SR. In order to compare internal reliability with previous study Cronbach alpha was calculated also on the Pearson correlation matrix, reporting respectively 0.83 for SP and 0.74 for SR. The two scales were poorly correlated with each other ($r = 0.12$, $p = 0.003$). The average inter-item correlation was 0.17 for SP and 0.11 for SR.

Exploratory factor analysis of the SPSRQ. EFA on the tetrachoric correlation matrix was conducted on the total sample 1, and separately for each gender. The tetrachoric matrix was chosen because of the binary nature of the responses. However, because in the original validation study of Torrubia, Ávila, Moltó, & Caseras (2001) and in the following studies of validation in different languages the Pearson correlation matrix was used (with the exception of Aluja & Blanch, 2011), the analysis was conducted also on this correlation matrix with the aim of comparing the results with previous studies.

The Scree test suggested that no more than three factors should be extracted. The first three factors explained respectively 17.64, 12.52 and 4.16 of variance before rotation. Both models with two and three factors were examined, however, the three-factor solution yielded some items that loaded on multiple factors and accounted for a very low variance. Thus, the more parsimonious two-factor solution was preferred. The use of the orthogonal rotation was based on the weak correlation between the two factors and on the hypothesis that the constructs on which SP and SR are based (BIS and BAS) are independent systems (Gray 1981, 1987).

Once rotated, the two-factor model explained 30.16 % of the variance. The first factor had higher loadings on the items of the SP scale, whereas the second factor was loaded by most of the items of the SR scale. Separate factor analysis by gender were conducted to better understand the results. The two factors accounted respectively for 12.5% and 8.5% of variance in males and 12.0% and 7.5% of variance in females. The factor loadings for the two-factor solution in the total sample1 and for males and females separately are reported in Table 1. The criteria to distinguish between substantial and non-substantial factor loadings were based on those by Comrey & Lee (1992), who suggested that loadings of less than 0.32 are poor and should not be interpreted. EFA revealed that some items were problematic in the whole sample (items 8, 25, 32, 34, and 36 did not load substantially on either factor, while item 16 tend to load on both factors and substantially on not expected one) and thus were removed. Some items were critical in the separate analysis of each gender because they loaded on both factors (Items 4, 10, 14, 31, 40, 41) for at least one gender but had salient loading when considered in the total sample. The item 22 loaded on SP for males, while it correctly loaded on SR for females and in the total sample.

The results on the EFA on the Pearson correlation matrix revealed that 8, 16, 25, 32, 34, and 36 were problematic, confirming the results obtained on the EFA tetrachoric matrix. In addition, Item 4 did not load on either factor in the total sample, while in the tetrachoric matrix it did not load only for males. In order to improve the model, we trimmed systematically all items that were problematic in both genders, creating a shorter questionnaire containing 42 of the original 48 items. The 6 trimmed items, one from the SP scale (Item 25) and five from the SR scale (Items 8, 16, 32, 34, and 36), are indicated in bold in Table 1. Because the results of the EFA based on the Pearson correlation matrix suggested that also item 4 was critical (factor loading <0.32), we tested also a 41-item model, where the Item 4 was removed as well. For this reason, the CFA were conducted both on a 42-item and 41-item models.

Table 1. Percentage of endorsement for each gender, differences between genders (chi square), and factor loading for the total sample 1, for males and for females in EFA after Varimax rotation of items of the SPSRQ. The factor loading >0.32 are emboldened. The trimmed items are highlighted.

Sensitivity to Punishment

Item	**% of endorsement**			**Factor loadings Total**		**Factor loadings Males**		**Factor loadings Females**	
	m	f	Difference	I	II	I	II	I	II
1	48	39	*	0.37	0.15	0.44	0.04	0.37	0.14
3	45	43		0.43	-0.13	0.46	-0.21	0.43	-0.20
5	39	53	**	0.71	0.00	0.72	0.01	0.71	-0.01
7	26	32		0.52	-0.01	0.54	-0.06	0.52	-0.03
9	35	29		0.43	0.09	0.58	0.04	0.38	-0.01
11	39	40		0.33	0.13	0.39	0.04	0.30	0.19
13	56	58		0.59	0.17	0.58	0.08	0.61	0.19
15	17	29	**	0.71	0.03	0.73	-0.07	0.71	0.10
17	49	48		0.60	-0.16	0.62	-0.16	0.57	-0.26
19	35	41		0.58	-0.21	0.51	-0.31	0.58	-0.18
21	24	20		0.51	0.06	0.54	0.09	0.51	-0.11
23	43	57	**	0.39	0.18	0.39	0.22	0.41	0.23
25	79	71	*	0.28	-0.15	0.16	-0.26	0.36	-0.18
27	46	43		0.39	0.03	0.30	0.03	0.44	-0.03
29	22	24		0.41	-0.08	0.43	-0.06	0.40	-0.16
31	63	69		0.60	0.29	0.69	0.25	0.58	0.34
33	48	63	**	0.57	-0.02	0.57	-0.01	0.55	-0.01
35	44	53	*	0.55	-0.20	0.42	-0.21	0.59	-0.20
37	48	53		0.75	0.07	0.76	0.12	0.76	-0.03
39	12	17		0.67	0.06	0.60	0.09	0.70	0.04
41	33	35		0.53	0.25	0.50	0.37	0.57	0.11
43	25	21		0.64	0.17	0.72	0.06	0.63	0.17
45	38	35		0.51	0.15	0.47	0.09	0.55	0.08
47	41	50	*	0.84	-0.01	0.82	-0.06	0.83	-0.01

Sensitivity to reward

Item	% of endorsement			Factor loadings Total		Factor loadings Males		Factor loadings Females	
	m	f	Difference	I	II	I	II	I	II
2	46	39		0.21	0.62	0.23	0.70	0.27	0.52
4	85	83		0.21	0.33	0.06	0.27	0.33	0.37
6	78	40	**	-0.01	0.58	0.15	0.57	0.03	0.50
8	13	8	*	0.06	0.27	0.17	0.07	0.05	0.32
10	30	21	*	0.28	0.55	0.34	0.63	0.33	0.42
12	32	29		-0.18	0.58	-0.17	0.58	-0.12	0.63
14	31	26		0.25	0.57	0.27	0.47	0.30	0.61
16	51	61	*	0.41	0.30	0.41	0.33	0.42	0.32
18	52	36	**	0.10	0.52	0.23	0.48	0.10	0.50
20	45	34	*	-0.28	0.51	-0.12	0.36	-0.30	0.62
22	32	25		0.13	0.32	0.31	0.16	0.07	0.38
24	12	6	*	0.11	0.64	0.14	0.72	0.17	0.54
26	27	20		0.12	0.48	0.18	0.55	0.15	0.37
28	19	8	**	-0.01	0.43	0.17	0.41	-0.10	0.37
30	53	34	**	-0.21	0.60	-0.15	0.69	-0.17	0.50
32	77	89	**	0.00	0.16	-0.01	0.36	-0.09	0.36
34	71	85	**	-0.08	0.05	-0.04	0.17	-0.17	0.20
36	11	7		0.04	0.18	-0.07	0.24	0.17	0.01
38	45	28	**	-0.03	0.53	0.06	0.55	-0.01	0.47
40	34	16	**	0.25	0.48	0.33	0.43	0.32	0.35
42	13	3	**	-0.21	0.66	-0.15	0.66	-0.22	0.54
44	67	50	**	-0.20	0.53	-0.18	0.64	-0.14	0.41
46	51	49		0.03	0.57	0.12	0.64	0.03	0.49
48	25	10	**	-0.15	0.62	0.07	0.58	-0.28	0.60

*p<0.05 **p<0.001

Items 4, 25, 32, and 34 were affirmatively answered by almost 70% of subjects, whereas items 8, 24, 36, and 42 had a low percentage of endorsement (less than 15%). Furthermore, most of the items of the SR scale showed a higher percentage of endorsement in males (6, 8, 10, 18, 20, 24, 28, 30, 38, 40, 42, 44, and 48), while, for the SP scale, most of the items showed a higher percentage of endorsement in females (1, 5, 15, 23, 33, 35, and 47).

Confirmatory Factor Analysis of the SPSRQ. CFAs were performed on sample 2, testing the 48-item model, the 42-item and the 41-item trimmed model. CFAs were carried out specifying two latent variables and the estimation method was robust DWLS. Table 2 shows fit indexes for the three models. RMSEA values (with p-values >0.05) indicate close fitting in three models. Tucker-Lewis Index (TLI) and Comparative Fit Index (CFI) values were higher in the 41- and 42-item models than in the 48-item model, indicating that these models were preferable. Furthermore, all items of the trimmed model loaded substantially on their respective factors, thus supporting the two-factors model.

Because both the 41- and 42-item models fit better than the 48-item, they were preferred to the original version. Given the similarity in the fit index in the two solutions, the 41-model was preferred because it ensured factor loading >0.32 on the specific scale in the factor analysis not only using a tetrachoric correlation matrix, but also a Pearson correlation matrix (method used by previous studies). In addition item 4 is the only item that has correlation with the factor SR lower than 0.2, that is not recommended by Nunnally & Bernstein (1994).

Table 2. Goodness-of-fit indexes for the three models of the Sensitivity to Punishment and Sensitivity to Reward Questionnaire items.

Model	**χ2**	**df**	**p**	**χ2/df**	**TLI**	**CFI**	**RMSEA (90% CI)**	**SRMR**
48-item model	2368.46	1079	<0.001	2.20	0.79	0.80	0.04 (0.04.0.05)	0.11
42-item model	1869.91	818	<0.001	2.29	0.83	0.84	0.05 (0.04-0.05)	0.11
41-item model	1815.08	778	<0.001	2.33	0.83	0.84	0.05 (0.04-0.05)	0.11

Note. N = 609. χ2/df is a ratio of chi-square divided by the degrees of freedom (see Kline, 1998); TLI=Tucker-Lewis Index; CFI = Comparative Fit Index, RMSEA = Root-Mean-Square Error of Approximation; CI = Confidence Interval for RMSEA; SRMR= Standardized Root Mean Square Residual. The best fitting model are indicated in boldface.

Ordinal Cronbach alpha calculated on the tetrachoric matrix on the 41-item model was 0.92 for SP and 0.87 for SR, and respectively 0.85 for SP and 0.77 for SR when calculated on the Pearson correlation matrix.

Stability over time of the SPSRQ. Our findings indicated that the two subscales have good test–retest reliability: 0.80, p<0.01 for SP and 0.86, p<0.01 for SR.

4.3.2.2.2 Disgust Scale-Short form (DS-Short form)

Internal reliability and descriptive statistics (sample 1) of the DS-Short form. Ordinal Cronbach's alpha coefficient was 0.75, with an average inter-item correlation of 0.22 that falls within the range 0.15-0.40 indicated by Clark and Watson (1995) as optimal for broad psychological constructs, as the disgust sensitivity. Furthermore, all items were strongly related to the total score ($p<0.01$). Given that DS-Short form contains discrete variables, the item distributions were expected to demonstrate some degree of non-normality. Thus, we adopted estimation procedures appropriate for non-continuous data, in line with Olatunji et al. (2007).

Table 3 presents the item analyses for the DS items. To improve the readability of the results, scores 1 and 2 of the Likert scale were grouped into the category "not disgusting", while scores 4 and 5 were grouped in the category "very disgusting". The inspection of the pattern of responses frequencies revealed that almost the 50% of participants evaluated 6 items (2, 3, 4, 5, 6, 8) as very disgusting.

Table 3. Item analysis (Mean, Standard Deviation, Skewness, Kurtosis) and response Frequencies (% not disgusting and % very disgusting) for the DS-short form scale.

Item	M	SD	Skewness	Kurtosis	% not disgusting	% very disgusting
1	3.38	1.47	-0.28	-1.35	32	49
2	3.75	1.29	-0.73	-0.65	20	65
3	3.32	1.40	-0.28	-1.22	32	50
4	3.61	1.48	-0.57	-1.14	27	59
5	3.93	1.21	-0.95	-0.08	14	70
6	4.14	0.95	-1.08	0.76	7	80
7	2.92	1.35	0.06	-1.14	39	35
8	4.39	0.88	-1.43	1.37	5	86

Exploratory factor analysis of the DS-Short form. Kaiser–Meyer–Olkin's (KMO) of 0.75 and the significant Bartlett's test of sphericity ($p<0.001$) indicated that the data was adequate for factor analysis. Exploratory factor analysis on polychoric correlation matrix was conducted, in line with Olatunji et al. (2007), on sample 1. The Scree test suggested that no more than two factors should be retained. EFA indicated that the first 2 factors explained respectively 30.81% and 6.16% of the total variance before rotation. Two solutions, one-factor and two-factors, were examined after oblique rotation (Promax). The one-factor solution indicated that one item (Item 3) did not demonstrated salient factor loading (>0.32). The two-factor solution indicated that four items (Items 2, 3, 5, 6, 8) demonstrated salient factor loading on Factor 1 and three items (Items 1, 4 and 7) on Factor 2.

Confirmatory Factor Analysis of the DS-Short form. CFA was performed on the sample 2 testing the original 8-items model, using robust DWLS as estimation method. Table 4 shows fit indices for the model. The two-factor model was found to fit better than the one-factor model, reporting a higher CFI and TLI and a lower SRMS. These values indicated adequate/good fit, while RSMEA higher than 0.05 (p-value=0.003) indicated a reasonably good fit.

Table 4. Goodness-of-fit indexes for the 8-item DS-Short form

Model	χ2	df	p	χ2/df	TLI	CFI	RMSEA (90% CI)	SRMR
one-factor model	103.22	20	<0.001	5.16	0.92	0.94	0.08 (0.07-0.10)	0.06
two-factor model	88.36	19	<0.001	4.65	0.93	0.95	0.08 (0.06-0.09)	0.05

Note. N = 609. χ2/df is a ratio of chi-square divided by the degrees of freedom (see Kline, 1998); TLI=Tucker-Lewis Index; CFI = Comparative Fit Index, RMSEA = Root-Mean-Square Error of Approximation; CI = Confidence Interval for RMSEA; SRMR= Standardized Root Mean Square Residual. The best fitting model is indicated in boldface.

Ordinal Cronbach alpha calculated on the tetrachoric matrix on the two-factor model on the sample 2 was 0.67 for the first factor (Items 2, 3, 5, 6, 8) and 0.56 for the second (item 1, 4, 7), while Cronbach alpha of the one-factor model was 0.75. These lower values in reliability for the two domains may be due to the low number of items for each domain as suggested by Nunnally & Bernstein (1994). This suggests that the subscales would need to be increased by a number of items in order to achieve acceptable internal consistency. Thus, the total score of the DS-short scale was preferred, instead of the two subscales highlighted by the factor analysis.

Stability over time of the DS-Short form. Test-retest reliability was acceptable (r=0.75, p<0.001) and test-retest correlations were significant for all items over the 14-months interval (range 8-19 months), even if a reduction in mean scores over the interval is shown (Table 5).

Table 5. Means (M) and Standard Deviations (SD) at time 1 and 2 and Test–Retest Reliability for each DS-Short form item.

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Total
Time 1 M	2.93	3.74	3.28	3.62	3.86	4.06	2.61	4.35	28.46
(SD)	(1.44)	(1.14)	(1.34)	(1.39)	(1.10)	(0.88)	(1.13)	(0.79)	(4.74)
Time 2 M	2.89	3.22	3.37	3.29	3.73	4.08	2.42	4.34	27.33
(SD)	(1.47)	(1.25)	(1.24)	(1.48)	(1.13)	(0.88)	(1.05)	(0.78)	(4.71)
Test-retest r	0.66**	0.52**	0.25*	0.54**	0.61**	0.53**	0.60**	0.59**	0.75**

* p< 0.01 ** p< 0.001

4.3.2.2.3 Private Body Consciousness (PBC)

Internal consistency and descriptive statistics (sample 1) of the PBC. Cronbach's alpha coefficient was 0.69 in sample 1, with an average inter-item correlation of 0.31. Table 6 presents the item analysis for the PBC items. Skewness and kurtosis supported univariate normality of the items. Scores 1 and 2 of the Likert scale were grouped into the category "extremely uncharacteristic", while scores 4 and 5 were grouped in the category "extremely characteristic". The inspection of the pattern of responses frequencies revealed that at least the 50% of participants had high consciousness of the aspects investigated by the five items. All items were strongly related to the total score (p<0.001).

Table 6. Item analysis (Mean, Standard Deviation, Skewness, Kurtosis) and response frequencies (% extremely uncharacteristic and % extremely characteristic) of the PBC.

Item	M	SD	Skewness	Kurtosis	% extremely uncharacteristic	% extremely characteristic
1	3.67	1.10	-0.65	-0.21	14	62
2	3.99	0.96	-0.97	0.66	9	77
3	3.35	1.21	-0.30	-0.89	27	50
4	3.89	1.02	-0.85	0.36	9	70
5	3.52	1.13	-0.42	-0.61	19	54

Exploratory Factor Analysis of the PBC. Kaiser–Meyer–Olkin's (KMO) of 0.78 and the significant Bartlett's test of sphericity (p<0.001) indicated that the data was adequate for a factor analysis. Exploratory factor analysis was conducted on sample 1. The Chi-square test (p=0.236) and the scree plot suggested that only one factor, which explained 31.06 % of the variance, should be retained. Each item had a salient factor loading (0.47-0.63).

Confirmatory Factor Analysis of the PBC. CFA was performed on the second subsample testing the original 5-item model, using Maximum Likelihood as estimation method. The model yielded a significant chi-square test, $\chi 2(5)=19.04$, however it has been highlighted that virtually any parsimonious model is rejected if N is large enough (Woods & Edwards, 2007). Table 7 presents the fit indices for the model, with GFI and CFI higher than 0.95 indicating good fit, while RMSEA 0.07 (p-value =0.152) indicate a reasonably good model fit (Browne & Cudeck, 1992). Furthermore, all items had significant loading on the latent variable (>0.56), thus supporting the unidimensional model. Cronbach alpha on sample 2 was 0.67.

Table 7. Confirmatory Factor Analysis of the Private Body Consciousness Scale Items in sample 2: Overall model fit with ML estimation**.**

Model	χ2	df	χ2/df	GFI	CFI	RMSEA	90% CI
5-item model	19.04*	5	3.80	0.99	0.96	0.07	0.04-0.10

*p=0.002 Note. N = 609. χ2/df is a ratio of chi-square divided by the degrees of freedom (see Kline, 1998); GFI = Goodness-of-Fit Index; CFI = Comparative Fit Index; RMSEA = Root-Mean-Square Error of Approximation; CI = Confidence Interval for RMSEA.

Stability over time of the PBC. Test-retest reliability was moderate (r=0.59, p<0.001) but test-retest correlations ranged between 0.44 and 0.59 and were significant for each item over the 14-months interval (range 8-19 months) (Table 8).

Table 8. Means (M) and Standard Deviations (SD) at time 1 and 2 and Test–Retest Reliability (r) for each PBC item.

	Item 1	Item 2	Item 3	Item 4	Item 5	Total
Time 1 M (SD)	3.57 (1.16)	3.91 (1.03)	3.26 (1.16)	3.79 (1.06)	3.41 (1.18)	17.96 (3.70)
Time 2 M (SD)	3.66 (1.09)	3.70 (0.99)	3.17 (1.09)	3.71 (1.04)	3.38 (1.17)	17.64 (3.49)
Test-retest r	0.50**	0.43**	0.57**	0.44**	0.47**	0.59**

** p < 0.001

4.3.3 Discussion

Our results provide evidence for the psychometric properties of the Italian version of SPSRQ, DS and PBC on a large sample including individuals aged from 18-64, with mean age of 37 years old. This allowed to integrate the results of previous studies that relied mainly on data obtained with university students and with participants of a mean age around 20 years old (SPSRQ: Torrubia et al. 2001; O'Connor et al. 2004; Cogswell et al. 2006; Sava & Sperneac 2006; Caci et al. 2007; Olatunji et al. 2007).

Sensitivity to punishment and sensitivity to reward questionnaire. SPSRQ was firstly validated by Torrubia et al. (2001) in Catalan and, later, in several languages (English: O'Connor, Colder, & Hawk, 2004; Romanian: Sava & Sperneac, 2006; French: Caci, Deschaux, & Baylé, 2007 and Lardi et al., 2008; Chilean: Dufey et al., 2011; Spanish: Aluja & Blanch, 2011). Our findings provided support for the use of a shorter 41-item SPSRQ with improved psychometric properties and indicated that the two subscales have good test–retest reliability (r=0.80, p<0.01 for SP and r=0.86, p<0.01 for SR) and high internal consistency, with ordinal Cronbach alpha of 0.92 for SP and 0.87 for SR. When Cronbach alpha was calculated the Pearson correlation matrix the results were in line with previous findings in other languages (Dufey et al., 2011; O'Connor et al., 2004; Torrubia et al., 2001). Only the French validation study reported a higher Cronbach alpha, mostly for the SR scale. This result may be due to the use of a 4-point Likert scale instead of the original dichotomous scale.

Both in males and in female samples, SP and SR were not correlated, that perfectly respect the assumption of orthogonality established by Torrubia et al. (2001). The exploratory factor analysis run in this study replicated previous results (Aluja & Blanch, 2011; O'Connor et al., 2004; Torrubia et al., 2001) in that several poorly loading items were apparent. Our findings, based on the tetrachoric correlation matrix, revealed that item 8, 16, 25, 32, 34, and 36 yielded factorial loadings below 0.32, while when considering Pearson correlation matrix item 4 as well was critical. Past research has reported low factor loading for several items. Factor analysis based on Pearson correlation matrices using orthogonal rotation reported factor loadings below 0.30 in the original Catalan version for items 1, 6, 8, 32, 34, and 37 (Torrubia et al., 2001), in the English version (with a US sample) for items 1, 6, 8, 11, 23, 27, 32, 34, and 36 (O'Connor et al., 2004) and for items 1, 4, 6, 8, 11, 29, 30, 32, and 34 (Cogswell et al., 2006). Moreover, in the study conducted by Caci et al. (2006) using a French translation of the questionnaire and a Likert scale items 1, 8, 9, 11, 23, 27, 32, 34, 36, 40, and 41 loaded below 0.30. Principal Component Analysis on a tetrachoric correlation matrix using a Spanish translation revealed that only items 32 and 34 yielded a poor factorial loading, while item 16 loaded in both components simultaneously (Aluja & Blanch, 2011). This result was in line with previous studies that found that item 16 loaded on both factors (Cogswell et al., 2006; O'Connor et al., 2004). Therefore, it could be hypothesized that the criticalities with these items are not attributable to the Italian translation or to cultural differences, given the consistency of these results in different languages. The only exception concerns Item 25 ("Do you think a lot before complaining in a restaurant if your meal is not well prepared?") that had a poor factor loading with a high percentage of endorsement only in our study. We may hypothesise that the response to this item could be strongly influenced by the Italian culture in which is considered highly impolite to complain about food in a restaurant.

A Confirmatory Factor Analysis of the proposed measurement model suggested poor fit with the two-factor model using the 48 items. Once problematic items were trimmed from the model, a final measurement model with 23 (SP) and 18 (SR) items suggested mixed support for the two-factor model. Although improved compared to the original 48-item model, some fit indices suggested poor fit (CFI, TLI), while some others such as RMSEA, X2/df and the pattern of factor loadings suggested adequate fit in the validation sample. These results were in line with previous studies that proposed trimmed models in different languages who reported higher fit index for trimmed measurement models compared to the original 48 models, but only in one case (of 20-item model) reported values higher than 0.90 for GFI (Aluja & Blanch, 2011). However, Nye & Drasgow (2011) noted that simple rules of thumbs do not work well to assess the goodness of fit with DWLS estimation because appropriate cut-off values vary considerably across conditions. Further studies are required to better assess the goodness of fit of the model with DWLS estimation. It may be also recommended to develop new items to replace the ones we identified as critical for both males and females and for a gender only, to get two balanced scales with the same number of items and to improve the factor structure of the questionnaire.

Disgust Scale-Short form. The 8-item short form of the Disgust Scale (Haidt, 2004) has been used in some studies (Herz, 2011, 2014; Inbar et al., 2009) but, to our knowledge, its psychometric properties and its factorial structure have not been investigated yet. Particular attention has been paid to exploratory and confirmatory factor analysis, the 8 items belonging to different subscales in the original version (Haidt, McCauley, & Rozin, 1994; Olatunji et al., 2007). In fact, in the original validation study (Haidt et al., 1994), item 1 belongs to Food domain, items 2, 6, and 8 to Body product domain, items 3 and 5 to Animal domain and items 4 and 7 to Sympathetic Magic domain. In the DS-R proposed by Olatunij (2007), items 1, 2, 3, 4, 5 and 6 belong to the subscale called Core Disgust sensitivity, while item 8 to the Contamination-Based Disgust sensitivity. Item 8 was removed in the DS-R proposed by Olatunij (2007) due to a content overlapping with item 6. Interestingly, Exploratory factor analysis suggested a one- and two-factor models. A Confirmatory Factor Analysis of the proposed models reasonably good model fit, and the two-factor solution was more satisfactory. The items that had salient factor loading on the second factor were 1, 4 and 7, which reported disgust associated with an eating situation. Thus, we may hypothesise the presence of two domains in the Italian translation of the DS-SR: eating disgust (Items 1, 4, 7) and core disgust (Items 3, 2, 5, 6), including body product and animals according the original classification of Haidt (1994).

Stability over time and internal consistency were acceptable (test-retest reliability: $r=0.75$, $p<0.001$; Cronbach alpha= 0.75), in line with prior researches; Olatunji (2007) reported acceptable internal consistency of Core Disgust ($\alpha=0.74$) and lower internal consistency for Contamination-Based Disgust ($\alpha=0.61$), while Haidt (2004) demonstrated inacceptable internal consistency of the subscales (Food $\alpha=0.34$, 0.27; Body Products $\alpha=0.55$, 0.49; Animals $\alpha=0.47$, 0.45; Sympathetic Magic $\alpha=0.44$, 0.45) in two independent samples. We may hypothesize that the relatively low value of alpha could depend on the low number of items in this questionnaire because Cronbach's alpha estimation is sensitive to the scale length (Cronbach, 1951) and to the selection of the items. However, in our study, the scale of the scores showed enough variation allowing to identify individual differences between subjects.

Further studies could improve the scale, allowing for a further differentiation between disgust propensity (the ease with which one becomes disgusted), disgust sensitivity (how negatively one interpret the experience of disgust) and disgust reactivity (the level of disgust experienced in the presence of an elicitor), as suggested by Viar-Paxton & Olatunji (2016).

Private body consciousness. PBC is a scale of the Body Consciousness Questionnaire developed in English by Miller, Murphy and Buss (1981) not been validated in other languages to our knowledge. Our findings indicated that the instrument in the Italian translation presents adequate psychometric properties and factor loadings. Exploratory factor analysis suggested the unidimensionality of the questionnaire. The fit indices after confirmatory factor analysis on the validation sample indicated overall good fit. Internal consistency was acceptable but rather low (0.69-0.67), slightly higher compared to previous studies that reported 0.66 in a British sample and 0.64 in a Danish translation (Jaeger et al., 1998), with an average inter-item correlation of 0.44. This suggests that while the items are reasonably homogenous, they do contain sufficiently unique variance so as to not be isomorphic with each other. As for the DS, we may hypothesize that the questionable value of alpha could depend on the low number of items.

Test-retest reliability (range 8-19 months) was moderate (r=0.59), and lower compared to previous findings after 2 months (r=0,69; Miller, Murphy, & Buss, 1981).

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5. Influences of psychological traits and PROP status on familiarity with and choice of phenol-rich foods and beverages

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Title: Influences of psychological traits and PROP status on familiarity with and choice of phenol-rich foods and beverages

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Abstract

Plant phenolics are powerful antioxidants and free radical scavengers that can contribute to the healthy functional properties of plant-based foods and beverages. Thus, dietary behaviours rich in plant-based foods and beverages are encouraged. However, it is well-known that bitter taste and other low-appealing sensory properties that characterize vegetables and some other plant-based foods act as an innate barrier for their acceptance. The aim of this study was to investigate the influence of psychological traits and PROP status (the responsiveness to bitter taste of propylthiouracil) on choice of and familiarity with phenol-rich vegetables and beverages varying in recalled level of bitterness and astringency. Study 1 aimed at assessing the variations of the sensory properties of vegetable and coffee/tea items with two Check-all-That-Apply (CATA) questionnaires (n=201 and n=188 individuals, respectively). Study 2 aimed at investigating how sensitivity to punishment, to reward and to disgust, food neophobia, private body consciousness, alexithymia and PROP responsiveness affect choice and familiarity with phenol-rich foods (n=1200 individuals). A Choice Index was calculated for vegetables (CV) and coffee/tea (CC) as a mean of the choices of the more bitter/astringent option of the pairs and four Familiarity Indices were computed for vegetables (FV) and coffee/tea (FC) higher (+)/lower (-) in bitterness and astringency. Subjects higher in food neophobia, sensitivity to punishment or sensitivity to disgust reported significantly lower Choice Indices than individuals low in these traits, meaning that they systematically opted for the least bitter/astringent option within the pairs. Familiarity with vegetables was lower in individuals high in sensitivity to punishment, in food neophobia and in alexithymia irrespective to their sensory properties. Familiarity Index with coffee/tea characterised by higher bitterness and astringency was lower in individuals high in food neophobia, in sensitivity to disgust and in alexithymia. No significant effect of PROP was found on any indices. The proposed approach based on product grouping according to differences in bitterness and astringency allowed the investigation of the role of individual differences in chemosensory perception and of psychological traits as modulators of phenol-rich foods preference and consumption.

Keywords: choice; familiarity; PROP; food neophobia; sensitivity to disgust; sensitivity to punishment; vegetables; caffeinated beverages; bitterness; astringency.

5.1 Introduction

Diets rich in plant-based food and beverages are encouraged given general agreement on their positive health outcomes. Meta-analyses of the effects of such foods indicate that reduced risk of coronary heart disease, stroke, and diabetes are associated with regular intake of non-starchy vegetables and moderate consumption of tea and coffee (Mozaffarian, 2016).

Plant phenolics are powerful antioxidants and free radical scavengers that can contribute to the healthy functional properties of plant-based foods and beverages (Shahidi & Ambigaipalan, 2015). However, phenol compounds from vegetable sources are characterized by bitterness, astringency and pungency (De Toffoli et al., 2019; Lesschaeve & Noble, 2005; Erminio Monteleone et al., 2004), sensations that may limit food acceptability (Köster, 2009; John Prescott, 2012). Human beings long sensitized to the bitter taste of plant toxins consider excessive bitterness the principal reason for food rejection (Drewnowski & Gomez-Carneros, 2000). The tactile sensation of astringency discourages animals from ingesting foods too high in tannins, thus protecting them from tannin’s potential harmful anti-nutritional effects (Shimada, 2006). High intensity of perceived astringency negatively impacts the acceptance for high phenol containing foods (Lesschaeve & Noble, 2005). The high phenol binding proteins from parotid glands exert a protective role against dietary phenols and astringency arises from phenol interactions with the adsorbed glycoprotein layer with the consequent oral cavity delubrication (Dinnella, Recchia, Fia, Bertuccioli, & Monteleone, 2009; Nayak & Carpenter, 2008).

Sensory properties drive liking for vegetables (Dinnella et al., 2016), and it is well-known that bitterness and other unpalatable sensory properties may act as a barrier for vegetable acceptance (Appleton et al., 2019; Drewnowski, 1997; Drewnowski & Gomez-Carneros, 2000; Shimada, 2006). Moreover, while bitterness and astringency are important qualities in tea and coffee, and may contribute to consumer appreciation of these products (Ágoston et al., 2018; Giacalone et al., 2019), in actual consumption conditions, masking ingredients (sweeteners, milk) are often used to modify these sensations to levels compatible with individual preferences (Masi et al., 2015).

Healthy individuals substantially differ in chemosensory perception, and such variability has been extensively studied in recent years. Most notably, the inherited capacity to perceive the bitterness of propylthiouracil (PROP) is considered a reliable broad marker for individual differences in taste responsiveness that may influence food preferences and eating behaviour (Tepper et al., 2014). The effect of PROP phenotype (PROP bitterness ratings on gLMS ≤ 17 non-taster: NT, 18-52 medium taster: MT and ≥53 supertaster: ST according to Hayes et al. 2010 and Fischer et al. 2013 (Fischer et al., 2013; Hayes et al., 2010)) on intake and preference of bitter foods and beverages has been examined in several studies with mixed results, mainly because demographics, genetics, and other environmental factors may influence both phenotypic responses to oral stimulation and affective response to food (Piochi et al., 2018; Tepper et al., 2017). Those who are insensitive to PROP bitterness (non-tasters) were found to consume more vegetables and more bitter vegetables than the other taster phenotypes, PROP medium-tasters and super-tasters (Bell & Tepper, 2006; Shen et al., 2016). The super-taster PROP phenotype was associated to lower preference of bitter vegetables (Adam Drewnowski et al., 1999). On the other hand, no differences by PROP phenotypes were found in preference for plant-based bitter foods (Catanzaro et al., 2013) or for actual vegetable intake in children (Baranowski et al., 2011; Keller & Tepper, 2004; Lumeng, Cardinal, Sitto, & Kannan, 2008b). PROP supertasters gave higher bitterness, sourness and astringency ratings for coffee, but these did not significantly affect liking (Masi et al., 2015) or consumption (Ly, 2002). In general, these results are inconsistent and the causal models envisaging straight associations of variations of taste abilities with food perception and choice show a weak predictive power.

Recent studies have highly an important role for personality in preference and choices and, in some cases, in determining sensory responses to foods. One such key personality variable is the trait of food neophobia (FN), originally defined as the reluctance to try or eat unfamiliar foods. High levels of food neophobia have been associated with reduced preference and intake for many food products belonging to different categories, including fruits and vegetables in adults (Knaapila et al., 2011; Törnwall et al., 2014) and children (Kral, 2018). In particular, food neophobia was found to affect liking for foods and beverages characterized by high intensities of bitterness, astringency, sourness, pungency. Those high in food neophobia (neophobics) reported liking for such vegetables, beverages, fruits and spicy foods lower than did those low in food neophobia (neophilics). Conversely, few such differences between food neophobia groups were found for bland vegetables and beverages or for sweets and desserts (Laureati et al., 2018; Törnwall et al., 2014). Neophobics perceive pungency and astringency in food products as more intense, and like the most pungent and astringent samples less than neophilics (Laureati et al., 2018; Spinelli, De Toffoli, Dinnella, Laureati, Pagliarini, Bendini, Braghieri, Gallina Toschi, et al., 2018).

Other personality traits have been found to be associated with lower preferences for pungent foods. Individuals highly sensitive to visceral disgust (disgust related to rotten food, vermin, body fluids) (Herz, 2011, 2014) find pungent foods more intense and like and choose them less (Spinelli, De Toffoli, Dinnella, Laureati, Pagliarini, Bendini, Braghieri, Gallina Toschi, et al., 2018). Two other personality traits, sensitivity to punishment and sensitivity to reward, describe individual differences in reactivity and responsivity to the Behavioural Inhibition and Activation Systems, respectively (Gray & McNaughton, 2008). Sensitivity to punishment was found to be negatively associated with liking of spicy foods (Byrnes & Hayes, 2013) and pungent food choice in females (Spinelli, De Toffoli, Dinnella, Laureati, Pagliarini, Bendini, Braghieri, Gallina Toschi, et al., 2018). Sensitivity to reward was found to be positively associated with chili intake, liking of spicy foods and choice of pungent foods (Byrnes & Hayes, 2013, 2015; Spinelli, De Toffoli, Dinnella, Laureati, Pagliarini, Bendini, Braghieri, Gallina Toschi, et al., 2018). Recent studies have also highlighted an association between sensitivity to reward and unhealthier food behaviours, such as preference for sweet and fatty food, higher fat intake, higher alcohol consumption and smoking frequency (Davis et al., 2007; Morris et al., 2016; Tapper et al., 2015). Alexithymia, defined as the inability of individuals to identify and name their emotional states (Nemiah et al., 1976), was found to be associated with food preferences, with high alexithymia associated to liking for alcohol, sweets and fats/meats, and lower alexithymia to liking for vegetables, condiments and strong cheeses (Robino et al., 2016).

The complexity of these factors and the sometimes mixed reports on their effects indicate that the interplay of several dimensions, such as gender, age, personality traits and taste responsiveness, influence choice and intake of foods and beverages. In addition, food products are selected based on culture, which means that some products are far more contextually appropriate and/or familiar than others. While a positive relationship between familiarity and choice can be expected, the strength of this relationship is unclear. Many contextual situational factors may play a role in choice, while familiarity covers both features of frequency of consumption (occasional and regular) and levels of knowledge (from product name to product taste) that are less affected by contextual factors (see, for example, the scale developed by Tuorila and colleagues (Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001a). In addition, it is not known if, or in what way, the relationship between choice and familiarity is affected by personality traits or taste responsiveness. Although some studies have investigated how taste responsiveness affects food familiarity or food choice, the literature on the role of psychological traits is quite limited, and the relationships between these variables remained little explored (Spinelli, De Toffoli, Dinnella, Laureati, Pagliarini, Bendini, Braghieri, Gallina Toschi, et al., 2018). Exploring the factors that influence choice of and familiarity with phenol-rich foods and beverages is of interest to better understand food behaviour and to shed light on the role of personality traits and taste responsiveness as barriers to heathy eating.

The grouping of food and beverages based on their overall sensory characteristics has already been used to explore individual differences in preferences and consumption. PROP status only marginally affects the preference expressed for specific foods selected to represent sensations generally disliked by PROP supertasters, such as bitterness and pungency (Catanzaro et al., 2013). Food neophobia level significantly influenced preference for and familiarity with food and beverages categorized as "mild" and "strong" flavour (Laureati et al., 2018). Grouping vegetables as low and high appealing was used to investigate demographic and attitudinal variables affecting vegetable consumption in European adolescents (Appleton et al., 2019). Existing data from sensory evaluation of trained and untrained assessors, as well as the chemical composition, were the criteria generally used for grouping the foods (Appleton et al., 2019; Cox, Melo, Zabaras, & Delahunty, 2012; Dinehart et al., 2006; Dinnella et al., 2016, 2011; Lease, Hendrie, Poelman, Delahunty, & Cox, 2016; Wiener, Shudler, Levit, & Niv, 2012).

In the present study, an original approach to phenol-rich product grouping based on differences in bitterness and astringency is proposed. This approach was used to investigate the influence of individual variation in psychological traits and PROP status on choice of and familiarity with phenol-rich vegetables and beverages varying in recalled levels of bitterness and astringency. Furthermore, the relationship between familiarity with, and choice of, phenol-rich vegetables and beverages with high recalled level of bitterness and astringency as a function of personality traits and PROP status was investigated.

In this chapter, the interplay of several dimensions, such as gender, age, psychological traits, and taste responsiveness, on familiarity with and choice for phenol-rich foods and beverages has been investigated.

5.2 Materials and Methods

The experimental plan consisted of two independent studies: one preliminary study and one main study, conducted with two different subject groups. The preliminary study was conducted in order to validate the differences in expected level of bitterness and astringency within each pair included in the vegetable choice questionnaire (V-IT-FCQ) and coffee/tea choice questionnaire (C-IT-FCQ) used in the main study. The main study aimed at investigating how PROP responsiveness and psychological traits affect familiarity with, and choice of, vegetables and coffee/tea, presented in pairs with two options with different levels of bitterness and astringency.

5.2.1 Participants

Participants were recruited on a national basis by means of announcements published on social networks (Facebook), articles published in national newspapers, and in magazines. Furthermore, each research unit recruited subjects locally by means of social networks, mailing lists, pamphlet distribution, and word of mouth. The exclusion criteria were pregnancy and not having lived in Italy for at least 20 years.

5.2.1.1 Preliminary Study—Validation of the Differences in Bitterness and Astringency within Pairs of the Choice Questionnaires used in the Main Study

Subjects completed an online questionnaire aimed at measuring the sensory response (bitterness and astringency) to vegetables (201 subjects: 77.7% females; age range 18–70; mean age 40.3 ± SD 14.1) and coffee/tea (188 subjects: 75.4% females; age range 19–68; mean age 40.1 ± SD 14.3) products (presented with names) selected for the questionnaires used in the main study (§ 5.2.1.2).

5.2.1.2 Large Scale Data Collection

Data were collected on 1200 Italian subjects (58% females; age range 18–60 years; male mean age 35.9 years ± SD 12.8; female mean age: 35.2 years ± SD 12.9) on a national basis. In order to explore possible age-related differences, subjects were divided into three age groups: 18–30 years (45.6%), 31–45 years (28.0%), 46–60 years (26.4%).

5.2.2 Procedure

5.2.2.1 Preliminary Study—Validation of the Differences in Bitterness and Astringency within Pairs of the Choice Questionnaires

Two check-all-that-apply (CATA) questionnaires (Jaeger et al., 2013) with forced choice (yes/no) were developed to describe the sensory properties of items to be included in the vegetable food choice questionnaire (V-IT-FCQ) and coffee/tea choice questionnaire (C-IT-FCQ) used in the main study. The vegetable CATA questionnaire included fourteen items: "pumpkin risotto", "risotto with radicchio", "lettuce and valerian salad" (Valerianella locusta, also known as corn salad or mâche), "radicchio and rocket salad", "green salad", "bean sprout salad", "chard", "chicory", "zucchini", "asparagus", "carrots", "cauliflowers", "cucumber", and "radish". The coffee/tea CATA questionnaire included coffee and tea items with/without ingredients (milk and sugar) masking the perception of bitterness and astringency. The coffee/tea CATA questionnaire included six items: "coffee with sugar"; "coffee without sugar"; "tea with sugar"; "tea without sugar", "macchiato", and "cappuccino". The list of sensory properties included 19 and 13 descriptors in the vegetable and coffee/tea questionnaires, respectively, but in the present study only bitterness and astringency were considered. Both the products and the sensory properties were presented using words in a randomized order. The participants filled in the questionnaire online. The online platform SurveyGizmo (surveygizmo.eu) was used for data collection.

5.2.2.2 Large Scale Data Collection

Socio-demographic (gender, age, education) information and familiarity with foods were collected through online questionnaires before the test sessions. In the lab session, participants were asked to fill in a set of questionnaires to measure psychological traits and to complete the choice questionnaires. PROP responsiveness was also measured.

5.2.2.2.1 Psychological Traits

Participants completed questionnaires to assess the following psychological traits: food neophobia (FN); sensation seeking (SS); state (STAI-S) and trait anxiety (STAI-T) and agreeableness, openness to experience and emotional stability.

5.2.2.2.2 PROP status

PROP taster status was assessed using a 3.2mM PROP solution, prepared by dissolving 0.545 g/L of 6-n-propyl-2-thiouracil (European Pharmacopoeia Reference Standard, Sigma Aldrich, Milano, IT) into deionized water (for example, see Prescott, Soo, Campbell, & Roberts (2004). Subjects were presented with two identical 10 ml samples, each coded with a three-digit code. Subjects were instructed to hold each sample in their mouth for 10 s, then expectorate, wait 20 s and evaluate the intensity of bitterness using the gLMS (Bartoshuk et al., 2004). Subjects had a 90 s break in order to control for carry-over effects after the first sample evaluation. During the break, subjects rinsed their mouth with distilled water for 30 s, ate some plain crackers for 30 s, and finally rinsed with water for a further 30 s. PROP taster status was based on the average rating of the two replicates, and groupings were based on arbitrary cut-offs (Fischer et al., 2013; Hayes et al., 2010): PROP non-tasters (NT)<17; PROP medium tasters (MT), 17–53; and PROP supertasters (ST)> 53 on the gLMS.

5.2.2.3 Choice of and Familiarity with Vegetable and Coffee/Tea items

The choice of phenol-rich vegetables and coffee/tea between pairs of two food items characterized by different levels of bitterness and astringency was assessed with the V-IT-FCQ and C-IT- FCQ (Table 9). Vegetable and coffee/tea pairs in the choice questionnaires were selected so that the options in each pair significantly differed for bitterness and astringency, based on the results of the preliminary CATA study. V-IT FCQ consisted of seven pairs of vegetables, selected to represent possible options for the same main dish (risotto with different condiments: pumpkin or zucchini) and for similar side dishes consisting of raw (leafy/green salads: lettuce and valerian or radicchio and rockets; green salad or bean sprouts; salad ingredients: cucumbers or radishes) or cooked (leafy green: chard or chicory; others: zucchini or asparagus; carrot or cauliflower) vegetables. Similarly, coffee and tea options were selected to represent possible alternatives of the same hot beverage, including or excluding ingredients masking the perception of bitterness and astringency (i.e., milk and sweeteners).

For each pair, participants were asked to indicate which food they would ideally choose, pointing out that the answer would describe not what they usually choose but rather what they would like to choose in a situation of absence of restrictions (e.g., due to health or weight concerns). The choice for vegetables was asked in the context of a main meal and the choice for coffee/tea was asked in the context of breakfast. Options within the pairs were coded as "0" for the lowest level of bitterness and astringency and "1" for the highest level of bitterness and astringency. Here, for each subject, a choice index was calculated for vegetables (CV) and coffee/tea (CC) as a mean of the choices of the more bitter/astringent option (range from 0 to 1).

Table 9. Pairs of food items included in the vegetable choice questionnaire (V-IT-FCQ) and coffee/tea choice questionnaire (C-IT-FCQ).

Vegetable Choice Questionnaire (V-IT-FCQ)	
0: Options lower in bitterness and astringency	**1: Options higher in bitterness and astringency**
Pumpkin risotto	Risotto with radicchio
Lettuce and valerian salad	Radicchio and rocket salad
Green salad	Bean sprout salad
Chard	Chicory
Zucchini	Asparagus
Carrots	Cauliflower
Cucumber	Radish
Coffee/Tea Choice Questionnaire (C-IT-FCQ)	
0: Options lower in bitterness and astringency	**1: Options higher in bitterness and astringency**
Macchiato	Coffee
Coffee with sugar	Coffee without sugar
Cappuccino	Coffee
Tea with sugar	Tea without sugar

Familiarity with vegetables and coffee/tea items was assessed by a five-point labelled scale (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) developed by Tuorila and colleagues (2001). Two indices of familiarity with vegetables and coffee/tea higher in bitterness and astringency (+) were obtained by the sum of ratings of familiarity with the items that, within each pair, were higher in these sensations, based on the results of the preliminary study: FV+: risotto with radicchio, radicchio and rocket salad, bean sprout salad, chicory, asparagus, cauliflower, radish; ranging from 7 to 35; FC+: coffee and tea without sugar; ranging from 2 to 10. Two indices of familiarity with vegetables and coffee/tea lower in bitterness and astringency, respectively, were obtained by the sum of ratings of familiarity with the items that, within each pair, showed a lower level of bitterness and astringency (-), based on the results of the preliminary study: FV-: pumpkin risotto, lettuce and valerian salad, chard, zucchini, carrots, cucumber; ranging from 6 to 30; FC-: coffee and tea with sugar; ranging from 2 to 10.

The presentation order of the food items in the familiarity and choice questionnaires was randomized across participants.

5.2.3 Data Analysis

5.2.3.1 Preliminary study—Validation of the Differences in Bitterness and Astringency within Pairs of the Choice Questionnaires

Cochran Q-tests were performed to assess the differences between the frequency of selection of bitterness and astringency within the pairs of the V-IT-FCQ and C-IT-FCQ. Post-hoc pairwise comparisons were calculated using the McNemar procedure and the level of significance was set at 5% (Jaeger et al., 2013; Tapper et al., 2015).

5.2.3.2 Large Scale Study

Cronbach's α was computed to check for the internal reliability of each psychological trait questionnaire. Two-way ANOVA models were used to determine the main effects of gender (males; females) and age class (18–30; 31–45; 46–60) and their interactions on psychological trait scores and on PROP bitterness intensity. Three-way ANOVA models were used to test the effects of gender, age, and psychological trait level (low, medium, and high) and PROP status (NT, MT, and ST) and their interactions on choice (CV and CC) and familiarity (FV+, FV-, FC+, FC-) indices.

The robustness of the ANOVA models was verified; the residuals of each ANOVA model were inspected for normality by histograms and Q–Q plots and for heteroscedasticity using Levene's test. A p-value of 0.05 was considered the threshold for statistical significance and post-hoc using the Bonferroni test adjusted for multiple comparisons were used. Pearson's correlation coefficients were computed to explore the association between familiarity and choice (FV+ and CV; and FC+ and CC, respectively) in subject groups with different levels of expression of psychological traits (L, M, and H) and PROP status (NT, MT, and ST). A p-value of 0.05 was considered the threshold for statistical significance. Fisher's r to z transformation was used on the correlation coefficient to assess the significance of the differences (p-value of 0.05).

The XLSTAT statistical software package version 19.02 (Addinsoft) was used for data analysis.

5.3 Results

5.3.1 Preliminary Study—Validation of the Differences in Bitterness and Astringency within Pairs of the Choice Questionnaires

Significant differences were found between the items of each pair belonging to the vegetable choice questionnaire (V-IT-FCQ) and to the coffee/tea choice questionnaire (C-IT-FCQ) in both bitterness and astringency frequency of selection, with the exception of green salad/bean sprout salad in bitterness ($p = 0.262$) and carrots and cauliflower in astringency ($p = 0.827$) (Table 10).

Table 10. Percentage of participants who selected the terms "bitterness" and "astringency" in the check-all-that-apply (CATA) experiment. Cochran's Q test was used to determine significant differences between samples.

Vegetable Choice Questionnaire (V-IT-FCQ)							
Option 0 (lower in bitterness and astringency)	**Option 1 (higher in bitterness and astringency)**	**Bitterness (%)**			**Astringency (%)**		
		p	option 0	option 1	p	option 0	option 1
Pumpkin risotto	Risotto with radicchio	**	1.6	69.9	**	7.1	21.9
Lettuce and valerian salad	Radicchio and rocket salad	**	18.9	82.1	**	6.5	27.9
Green salad	Bean sprout salad		16.4	12.9	*	6.0	13.4
Chard	Chicory	**	27.4	81.6	**	13.4	30.3
Zucchini	Asparagus	**	11.9	34.8	**	5.0	13.4
Carrots	Cauliflower	**	3.0	16.9		7.5	7.0
Cucumber	Radish	**	31.3	46.3	*	19.4	29.9
Coffee/Tea Choice Questionnaire (C-IT-FCQ)							
Option 0 (lower in bitterness and astringency)	**Option 1 (higher in bitterness and astringency)**	**Bitterness (%)**			**Astringency (%)**		
		p	option 0	option 1	p	option 0	option 1
Macchiato	Coffee	*	50.5	97.9	*	13.3	41.0
Coffee with sugar	Coffee without sugar	*	19.7	97.9	*	20.2	41.0
Cappuccino	Coffee	*	21.8	97.9	*	6.4	41.0
Tea with sugar	Tea without sugar	*	4.3	67.0	*	30.3	44.1

* $p \leq 0.01$, ** $p \leq 0.001$

5.3.2 Large Study on Familiarity with and Choice of Phenol-Rich Foods and Beverages

5.3.2.1 Psychological Trait Questionnaires

The internal reliability of the questionnaires measuring psychological traits was satisfactory, with Cronbach's alpha ranging from 0.86 to 0.70 (Table 11). Based on the percentile limits, the population was grouped into Low-L (1°quartile), Medium-M (interquartile), and High-H (3° quartile) levels of expression of each trait (Table 11).

Table 11. Psychological traits: internal reliability (Cronbach's α–α), limits of the first (1st Q) and the third (3rd Q) quartiles of questionnaire score distributions, number of observations (n) for each group (Low, Medium, High).

Trait	α	1st Q	3rd Q	*n* Low	*n* Medium	*n* High
DS	0.70	25	33	303	533	364
FN	0.86	18	36	334	558	308
PBC	0.71	16	21	368	490	334
SP	0.85	5	13	310	537	353
SR	0.77	3	9	329	540	331
TAS	0.82	38	55	314	567	312

DS: sensitivity to disgust, FN: food neophobia, PBC: private body consciousness, SP: sensitivity to punishment, SR: sensitivity to reward, TAS: alexithymia

Both gender and age affected individual variation in psychological traits (Table 12). A significant gender effect was found for private body consciousness, sensitivity to punishment, sensitivity to reward, and sensitivity to disgust. Females were significantly higher in private body consciousness, sensitivity to punishment, and sensitivity to disgust than males, while males were more sensitive to reward. A significant effect of age was found for sensitivity to punishment, sensitivity to reward, sensitivity to disgust, alexithymia, and food neophobia. Sensitivity to punishment, sensitivity to reward, and alexithymia decreased with age, while food neophobia and sensitivity to disgust increased with age. The effect was further characterized by an interaction in the case of gender with private body consciousness: a decrease in private body consciousness with age was found in males, but not in females.

Table 12. Two-way ANOVA: gender, age and their interaction effect on psychological traits and on propylthiouracil (PROP) bitterness scores. F, p, and mean values. Significant differences (p≤0.05) are emboldened.

Trait	Gender				Age					Gender × Age	
	F	p-Value	Mean Values		F	p-Value	Mean Values			F	p-value
			Females	Males			18–30	31–45	46–60		
SP	**37.1**	**<0.0001**	**9.9**	**8.0**	**32.4**	**<0.0001**	**10.5 a**	**8.2 b**	**8.2 b**	1.6	0.2058
SR	**72.7**	**<0.0001**	**5.1**	**6.8**	**85.8**	**<0.0001**	**7.6 a**	**5.6 b**	**4.7 c**	0.8	0.4343
FN	0.5	0.4701	27.2	27.7	**10.0**	**<0.0001**	**26.1 b**	**26.6 b**	**29.7 a**	0.2	0.8198
DS	**90.1**	**<0.0001**	**30.6**	**27.6**	**14.6**	**<0.0001**	**28.0 b**	**29.2 a**	**30.1 a**	3.0	0.0513
PBC	**25.3**	**<0.0001**	**18.7**	17.4	1.1	0.3410	18.2	18.1	17.7	**7.2**	**0.0008**
TAS	0.1	0.7899	46.0	**46.2**	**37.9**	**<0.0001**	**49.8 a**	**43.4 b**	**45.0 b**	0.4	0.6821
PROP	**22.8**	**<0.0001**	**44.6**	**36.9**	**12.6**	**<0.0001**	**45.2 a**	**41.3 a**	**35.6 b**	**3.0**	**0.0495**

SP: Sensitivity to punishment; SR: Sensitivity to reward; FN: Food neophobia; DS: Sensitivity to disgust; PBC: Private Body consciousness; TAS: Alexithymia; PROP: PROP status. Different letters indicate significantly different values (p ≤ 0.05)

5.3.2.2 PROP Responsiveness

Effects of both gender and age were found on responsiveness to PROP (Table 12). The effects were further characterized by an interaction with gender, in that females were more responsive to PROP. PROP responsiveness decreased from the age class 18–30 to 31–45 and then remained stable in females, while a decrease in PROP responsiveness in males was reported in the age class 46–60.

5.3.2.3 Vegetable Choice Index (CV) and Coffee/Tea Choice Index (CC)

The effects of individual variation in psychological traits and PROP status, gender, age, and their interactions on choice indices are reported in Table 13.

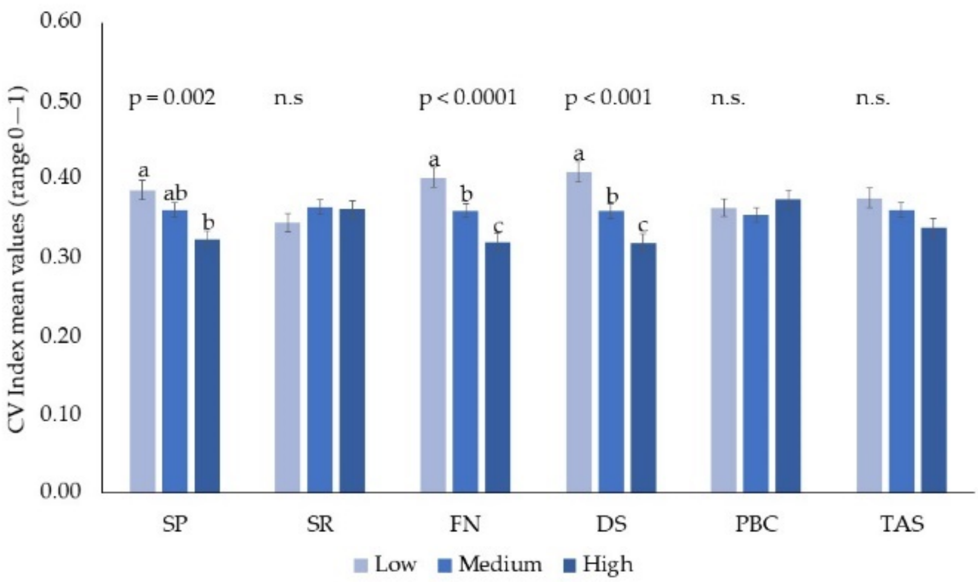
Table 13. Three-way ANOVA. Psychological trait level (Low; Medium; High), PROP Status (NT, MT, ST), gender (males; females), age (18-30; 31-45; 46-60), and relevant two-way interaction effects on the choice index for vegetables (CV), choice index for coffee/tea (CC), indices for familiarity with vegetables with high (FV+) and low (FV-) bitterness and astringency and indices for familiarity with coffee/tea with high (FC+) and low (FC-) bitterness and astringency. F and p values. Significant differences (p≤0.05) are emboldened.

	Choice Index for vegetables		Choice Index for coffee/tea		Familiarity with vegetables higher in bitterness and astringency		Familiarity with vegetables lower in bitterness and astringency		Familiarity with coffee/tea higher in bitterness and astringency		Familiarity with coffee/tea lower in bitterness and astringency	
	F	p	F	p	F	p	F	p	F	p	F	p
SP	**6.40**	**0.00**	3.40	0.03	**11.50**	**<0.00**	**4.40**	**0.01**	2.10	0.13	1.60	0.21
Gender	**21.20**	**<0.00**	0.60	0.43	**9.30**	**0.00**	**64.70**	**<0.00**	0.30	0.57	0.00	0.95
Age	**33.00**	**<0.00**	2.20	0.11	**31.40**	**<0.00**	**10.80**	**<0.00**	0.00	0.99	0.60	0.53
Gender*SP	0.00	0.97	2.00	0.14	0.30	0.76	0.50	0.62	2.80	0.06	0.80	0.47
Age*SP	1.80	0.13	0.80	0.54	1.00	0.41	1.70	0.16	0.50	0.76	0.50	0.77
SR	0.80	0.44	1.30	0.27	0.10	0.95	0.10	0.92	0.10	0.92	0.10	0.94
Gender	**25.40**	**<0.00**	0.40	0.53	**4.40**	**0.04**	**56.30**	**<0.00**	0.80	0.38	0.00	0.86
Age	**36.20**	**<0.00**	1.80	0.16	**37.80**	**<0.00**	**12.60**	**<0.00**	0.20	0.81	0.10	0.93
Gender*SR	1.70	0.18	0.60	0.57	0.50	0.62	0.30	0.74	1.50	0.23	0.30	0.76
Age*SR	0.20	0.95	0.60	0.69	1.00	0.42	0.20	0.93	1.40	0.23	0.40	0.78
FN	**11.70**	**<0.00**	**6.80**	**0.00**	**34.10**	**<0.00**	**14.90**	**<0.00**	**16.10**	**<0.00**	**5.40**	**0.00**
Gender	**32.00**	**<0.00**	0.20	0.64	3.60	0.06	**58.50**	**<0.00**	0.10	0.80	0.00	0.83
Age	**40.00**	**<0.00**	**4.20**	**0.02**	**47.90**	**<0.00**	**18.30**	**<0.00**	0.70	0.52	0.30	0.72
Gender*FN	1.50	0.21	0.40	0.66	0.80	0.45	1.30	0.28	1.10	0.33	0.20	0.83
Age*FN	0.20	0.93	2.00	0.10	1.00	0.41	0.80	0.50	0.90	0.47	0.70	0.60
DS	**13.00**	**<0.00**	**4.20**	**0.02**	**10.10**	**<0.00**	**2.90**	**0.05**	**3.80**	**0.02**	2.20	0.11
Gender	**14.40**	**0.00**	0.80	0.36	**9.60**	**0.00**	**58.80**	**<0.00**	2.90	0.09	0.10	0.79
Age	**45.70**	**<0.00**	**3.90**	**0.02**	**49.60**	**<0.00**	**16.90**	**<0.00**	0.60	0.53	0.50	0.62
Gender*DS	0.20	0.78	0.30	0.77	0.20	0.86	0.70	0.48	1.30	0.27	0.90	0.41
Age*DS	0.70	0.63	1.40	0.25	1.80	0.12	1.00	0.38	1.40	0.23	1.10	0.37
PBC	0.90	0.42	0.00	0.97	**4.40**	**0.01**	1.70	0.18	2.00	0.13	1.20	0.29
Gender	**24.40**	**<0.00**	0.40	0.52	**3.90**	**0.05**	**49.30**	**<0.00**	0.30	0.58	0.00	0.90
Age	**40.10**	**<0.00**	2.40	0.09	**42.90**	**<0.00**	**15.50**	**<0.00**	0.70	0.49	0.40	0.69
Gender*PBC	**3.60**	**0.03**	0.20	0.84	2.20	0.11	0.40	0.70	0.20	0.81	1.70	0.19
Age*PBC	2.00	0.09	1.50	0.19	2.30	0.06	0.80	0.53	1.30	0.29	0.70	0.60
TAS	2.10	0.12	**2.90**	**0.05**	**7.70**	**0.00**	**5.40**	**0.00**	**3.50**	**0.03**	1.50	0.21
Gender	**20.80**	**<0.00**	1.20	0.28	**5.50**	**0.02**	**56.30**	**<0.00**	0.70	0.41	0.20	0.67
Age	**30.50**	**<0.00**	2.00	0.14	**32.20**	**<0.00**	**10.00**	**<0.00**	0.00	1.00	0.40	0.66
Gender*TAS	0.80	0.44	**3.00**	**0.05**	0.40	0.69	0.00	0.95	2.00	0.14	1.40	0.24
Age*TAS	1.30	0.25	1.20	0.33	0.10	0.97	0.30	0.89	0.60	0.63	0.30	0.89
PROP	0.50	0.60	0.60	0.54	0.10	0.88	0.00	0.96	0.30	0.74	1.50	0.23
Gender	**25.70**	**<0.00**	0.80	0.36	**7.40**	**0.01**	**67.00**	**<0.00**	1.10	0.29	0.00	0.91
Age	**33.20**	**<0.00**	2.50	0.08	**39.20**	**<0.00**	**14.10**	**<0.00**	0.40	0.67	0.40	0.66
Gender*PROP	1.20	0.30	0.20	0.84	**3.00**	**0.05**	**5.50**	**0.00**	1.80	0.17	0.00	0.98
Age*PROP	0.90	0.49	0.50	0.71	0.70	0.63	0.20	0.96	0.30	0.89	1.70	0.14

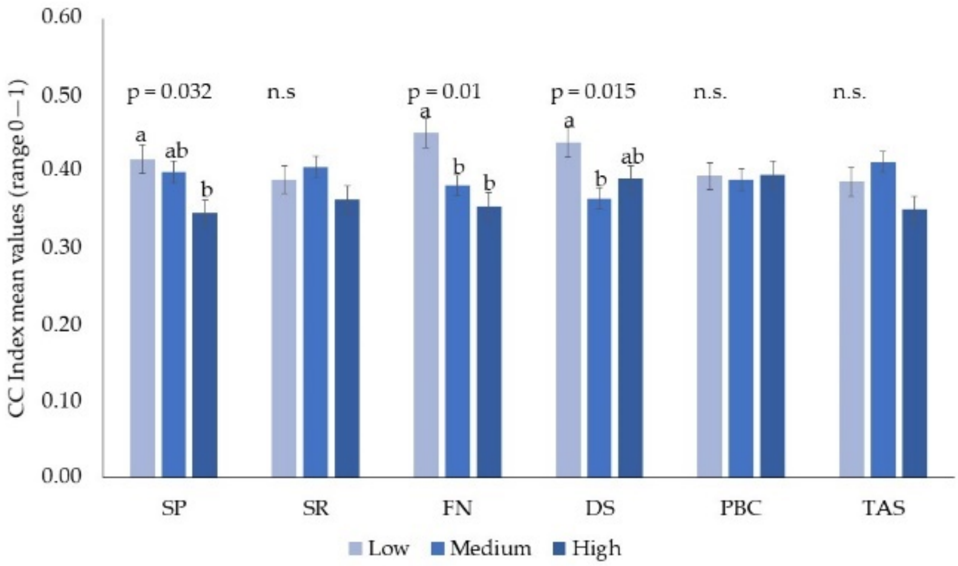
SP: Sensitivity to punishment; SR: Sensitivity to reward; FN: Food neophobia; DS: Sensitivity to disgust; PBC: Private Body consciousness; TAS: Alexithymia; PROP: PROP status.

A significant effect of both gender and age was found for the vegetable choice index in each ANOVA model. The coffee/tea choice index was significantly affected by age only in the food neophobia and sensitivity to disgust models, while no effect of gender on the coffee/tea choice index was reported. These effects were not further characterized by an interaction between gender and age. The vegetable choice index was higher in males and increased with age. When the effect was found to be significant, the coffee/tea choice index increased with age.

The effect of food neophobia, sensitivity to punishment, and sensitivity to disgust was significant for both the vegetable choice index and coffee/tea choice index. These effects were not further characterized by interactions with age and gender. Individuals who scored higher in food neophobia, sensitivity to punishment, or sensitivity to disgust reported significantly lower choice indices than individuals low in these traits, meaning that they systematically opted for the least bitter/astringent option within the pairs (Figures 4a–b).



a)



b)

Figures 4. (a) Effects of psychological traits (Low; Medium; High) on the choice index for vegetables (CV Index). (b) Effects of psychological traits (Low; Medium; High) on the choice index for coffee/tea (CC). Different letters represent significantly different values ($p \leq 0.05$). n.s.= non-significant ($p>0.05$). SP: Sensitivity to punishment; SR: Sensitivity to reward; FN: Food neophobia; DS: Sensitivity to disgust; PBC: Private Body consciousness; TAS: Alexithymia.

A significant interaction was found for alexithymia (TAS) and gender (coffee/tea choice index), but no significant difference was found in a Bonferroni pairwise comparison. A significant interaction was found for private body consciousness (PBC) and gender (vegetable choice index), with males medium and high in private body consciousness reporting a higher choice index than females medium and high in private body consciousness.

PROP responsiveness. No effect of PROP responsiveness was found on either choice index.

5.3.2.4 Familiarity with Vegetables (FV+ and FV-)

Individual variation in psychological traits significantly affected familiarity with vegetables in the case of sensitivity to punishment ($F = 9.6$; $p < 0.0001$), food neophobia ($F = 30.1$; $p < 0.0001$), disgust sensitivity ($F = 7.8$ $p = 0.0004$), and alexithymia ($F = 8$; $p = 0.0003$). Higher levels in these traits corresponded to a lower familiarity with vegetables. This was further investigated, considering the vegetable groups varying in bitterness and astringency. Table 13 reports the effects of individual variation in psychological traits, PROP status, gender, age, and their interactions on familiarity indices with vegetables high (+) and low (-) in bitterness and astringency.

A significant effect for both age and gender were found on the familiarity index for vegetables higher in bitterness and astringency and the familiarity index for vegetables lower in bitterness and astringency in each ANOVA model, with the only exception being gender in the model with food neophobia. These effects were not further characterized by an interaction (gender and age). Females were more familiar with vegetables irrespective to their bitterness and astringency level. Both vegetable familiarity indices increased with age.

A significant effect for food neophobia, alexithymia, and sensitivity to punishment was found on both indices, while a significant effect for private body consciousness and sensitivity to disgust was found only on the familiarity index with vegetables higher in bitterness and astringency. These effects were not further characterized by an interaction with age or gender. Both familiarity indices were lower in neophobics, in individuals higher in sensitivity to punishment and higher in alexithymia. The familiarity index with vegetables characterized by high unappealing sensations was lower in individuals higher in sensitivity to disgust. For private body consciousness, the post hoc test did not show significant differences between individuals high and low in this trait. The effect of individual variation in psychological traits on the familiarity index with vegetables high in bitterness and astringency is reported in Figure 5.

No effect of PROP responsiveness was found on either index, while a significant interaction between PROP and gender was observed on the familiarity index with vegetables lower in bitterness and astringency, confirming that females were more familiar than males with vegetables lower in bitterness and astringency, irrespective of PROP status.

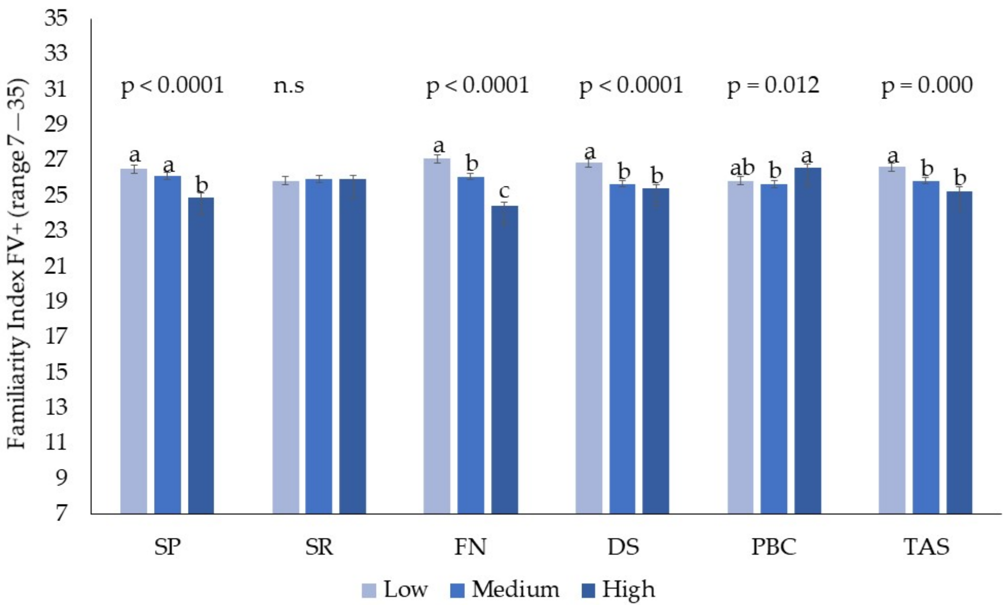


Figure 5. Effect of psychological traits (Low; Medium; High) on the familiarity index with vegetables higher in bitter and astringency (FV+). Different letters represent significant different values (p ≤ 0.05). n.s.= non-significant (p>0.05). SP: Sensitivity to punishment;

SR: Sensitivity to reward; FN: Food neophobia; DS: Sensitivity to disgust; PBC: Private Body consciousness; TAS: Alexithymia.

5.3.2.5 Familiarity with Coffee/Tea (FC+ and FC-)

No effect of age, gender, or their interaction was found on the familiarity index with coffee/tea characterized by high or low bitterness and astringency in any model.

A significant effect of food neophobia was found on both indices. Neophobic subjects were less familiar with coffee/tea without sugar and more familiar with their version with sugar. Neophilic subjects showed a median familiarity score for this beverage group of eight; this means that, at least occasionally, they consumed both unsweetened coffee and tea or that they regularly consumed only one of these beverages. Neophobic subjects showed a median familiarity value of seven, indicating that they do not consume one of the items and only occasionally consume the other. Individual variations in sensitivity to disgust and alexithymia significantly affected the familiarity index, with coffee/tea characterized by highly unappealing sensations. Subjects with high sensitivity to disgust and high alexithymia were found to be less familiar with the without sugar coffee/tea group of products. The effect of individual variation in psychological traits on the familiarity index for coffee/tea high in bitterness and astringency level is reported in Figure 6.

No significant effect of PROP was found on either index of familiarity.

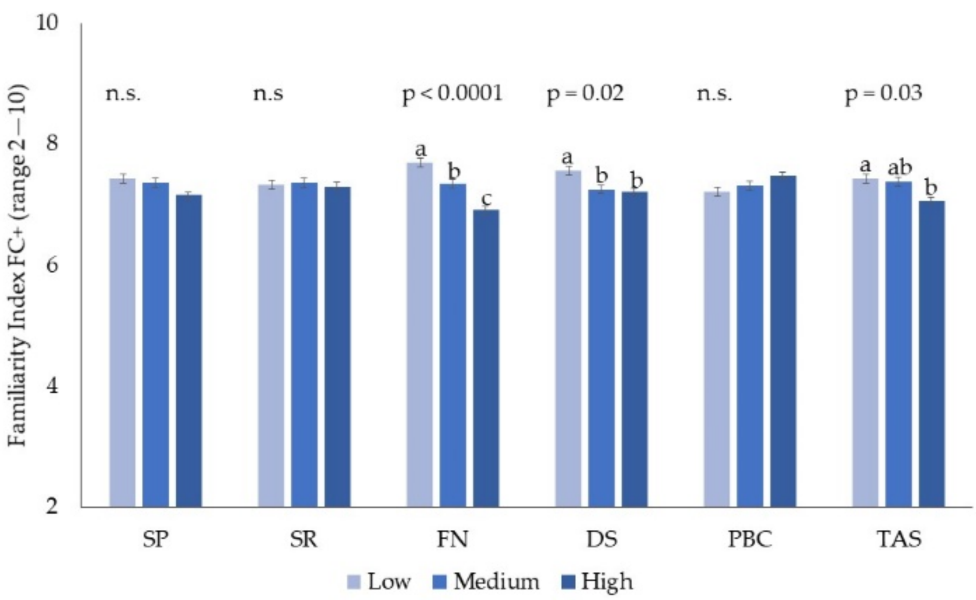


Figure 6. Effect of psychological traits (Low; Medium; High) on the familiarity index with coffee/tea higher in bitterness and astringency (FC+). Different letters represent significant different values ($p \leq 0.05$). SP: Sensitivity to punishment; SR: Sensitivity to reward; FN: Food neophobia; DS: Sensitivity to disgust; PBC: Private Body consciousness; TAS: Alexithymia.

5.3.2.6 Correlation between Choice of and Familiarity with Bitter/Astringent Option

Significant positive correlations between the vegetable choice index and familiarity index with vegetables higher in bitterness and astringency, and between the coffee/tea choice index and familiarity index with coffee/tea higher in bitterness and astringency, were found in each subgroup of individuals (low, medium, high) for each psychological trait and in each PROP status class (NT, MT, and ST). The correlation coefficient ranged from 0.25 to 0.41 in the case of vegetables and from 0.42 to 0.57 in the case of beverages (Table 14).

Table 14. Pearson correlation coefficients between the vegetable choice index (CV) and familiarity index with vegetables higher in bitterness and astringency (FV+) and the Pearson correlation coefficients between the coffee/tea choice index (CC) and familiarity index with coffee/tea higher in bitterness and astringency (FC+) within the three levels (low, medium, high) of each psychological trait and PROP status (NT, MT, ST).

Vegetable choice index/familiarity index with vegetables higher in bitterness and astringency (CV/FV+)

Trait	**Low**	**Medium**	**High**	**Diff. among groups**
SP	0.25	0.38	0.38	*
SR	0.28	0.40	0.37	*
FN	0.25	0.37	0.41	*
DS	0.34	0.39	0.32	n.s.
PBC	0.34	0.41	0.32	n.s.
TAS	0.33	0.36	0.37	n.s.
PROP status	**NT**	**MT**	**ST**	
PROP	0.30	0.38	0.37	n.s.

Coffee/tea choice index/familiarity index with coffee/tea higher in bitterness and astringency (CC/FC+)

Trait	**Low**	**Medium**	**High**	**Diff. among groups**
SP	0.49	0.50	0.56	n.s.
SR	0.56	0.51	0.49	n.s.
FN	0.57	0.53	0.42	*
DS	0.55	0.51	0.50	n.s.
PBC	0.54	0.49	0.54	n.s.
TAS	0.55	0.52	0.48	n.s.
PROP status	**NT**	**MT**	**ST**	
PROP	0.49	0.49	0.57	*

SP: Sensitivity to punishment; SR: Sensitivity to reward; FN: Food neophobia; DS: Sensitivity to disgust; PBC: Private Body consciousness; TAS: Alexithymia; PROP: PROP status.

All correlations are significant ($p \leq 0.05$). * significant pairwise differences. Vegetables—Sensitivity to Punishment: Low–Medium ($p = 0.02$), Low–High ($p = 0.03$); Sensitivity to Reward: Low–Medium ($p = 0.03$); Food Neophobia: Low–Medium ($p = 0.03$), Low–High ($p = 0.01$). Coffee/tea—Food Neophobia Low–High ($p = 0.01$), Medium–High ($p = 0.02$), PROP status: Medium–High ($p = 0.05$). n.s.= non-significant ($p>0.05$)

Individuals lower in food neophobia, sensitivity to punishment, and sensitivity to reward reported significantly lower correlations between the vegetable choice index and familiarity index with vegetables higher in bitterness and astringency compared to individuals higher in these traits. Individuals lower in food neophobia reported a significantly higher correlation coefficient between the coffee/tea choice index/familiarity index with coffee/tea higher in bitterness and astringency compared to individuals higher in food neophobia. The correlation coefficients for the coffee/tea choice index/familiarity index with coffee/tea higher in bitterness and astringency increased in ST compared to NT and MT.

5.4 Discussion

The selection of food and beverages to be included in the CATA questionnaire was performed based on pre-existing sensory data from consumers and trained panels. The vegetable CATA questionnaire included vegetables described by potentially unpleasant sensory properties due to their chemical composition, such as a bitter taste, astringent sensations, objectionable flavours, and a dark, unattractive colour (radicchio, rocket, chicory, asparagus, and radish) (Cozzolino et al., 2016; Dawid & Hofmann, 2012; Pasini, Verardo, Cerretani, Caboni, & D'Antuono, 2011; Schonhof, Krumbein, & Brückner, 2004) and vegetables characterized by a sweet taste, delicate flavour, and a bright, appealing colour (pumpkin, lettuce, valerian, green salad, chard, and zucchini) (Baxter, Schröder, & Bower, 2000; Engel, Martin, & Issanchou, 2006; Poelman, Delahunty, & de Graaf, 2017). The range of differences between the two options in each pair was relatively high, with the exception of two pairs (carrot versus cauliflower, and lettuce versus bean sprout), for which these sensory properties were checked by less than 20% of the respondents and a significant difference was found for only one of the two sensory properties. These pairs were included in Study 2 based on the fact that a subtle but significant difference was found for at least one of these sensations (carrot versus cauliflower for bitterness and lettuce versus bean sprout for astringency). The coffee/tea CATA questionnaires included versions of the of the same hot beverage varying in bitter and astringency due to the inclusion or exclusion of ingredients masking the perception of bitterness and astringency (i.e., milk and sweeteners). Findings from the CATA questionnaires confirmed that vegetable and coffee/tea items included in the choice and familiarity indices significantly varied in bitterness and astringency. This substantiates the screening of items based on the hypothesis that they should represent phenol-rich dishes/beverages varying in the level of bitterness and astringency sensations.

Based on the results from the two CATA questionnaires, it was possible to divide questionnaire items into two groups, each representing the lower and higher bitterness/astringency option for vegetable-based dishes or for coffee/tea beverages, according to consumer expectations. Two main features characterized the approach for food grouping proposed in the present paper: (1) sensory differences between selected vegetable/beverages items were defined according to the response of the target population rather than derived from existing data on other consumer groups (e.g., other food cultures or trained panels); (2) the individual propensity to prefer more or less bitter/astringent options of the phenol-rich foods and beverages was investigated by means of indices computed on choice of and familiarity responses with vegetable and coffee/tea groups rather than considering the response to specific single food/beverage items. These features allowed the highlighting of the importance of individual differences in psychological traits and chemosensory ability in affecting familiarity with, and choice for, phenol-rich foods. The approach based on CATAs to group foods differing in bitter and astringency limits bias due to misinterpretation of the consumer expectation for sensory differences between foods. Furthermore, the computation of indices minimized the impact of individual preferences for specific food/beverages items (for example, a specific bitter vegetable might be very popular and well accepted in some regions and not in others).

The characteristics of the population participating in the study confirmed existing data on gender and age effects on psychological traits and PROP status. We found no effect of gender on neophobia, in line with previous findings that reported no (Knaapila et al., 2015) or small (Monteleone et al., 2017) effects, and we confirmed an increase in neophobia with age (Meiselman et al., 2010; Siegrist, Hartmann, & Keller, 2013; Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001b). The gender effect for the other traits was also consistent with previous results, with females more sensitive to punishment than males, and males more sensitive to reward than females (Caseras et al., 2003; Torrubia et al., 2001), females more sensitive to disgust (Herz, 2011), and no gender effect on alexithymia (Bressi et al., 1996). For age, with some exceptions, comparisons with previous studies are more limited, considering that much of the extant literature involved younger individuals or a specific age class. In our sample, we found a decrease in alexithymia with age, in contrast to findings in an adult population in Finland (Mattila, Salminen, Nummi, & Joukamaa, 2006).

Results from this study confirmed previous findings on the age and gender effect on PROP responsiveness, with aging negatively associated with PROP responsiveness (Bartoshuk, Duffy, & Miller, 1994; Dinnella et al., 2018; Mennella, Pepino, Duke, & Reed, 2010). Females rated PROP bitterness higher than males, confirming other results showing that females are more sensitive to PROP than males, and more likely to be tasters (Bartoshuk et al., 1994; Zhao & Tepper, 2007). While females were more familiar with vegetables, independent of their bitterness and astringency, the choice of the most bitter and astringent vegetable option was higher in males than females and increased with aging, irrespective of their psychological traits. A higher preference for sweetness in females is well documented (Tuorila, Keskitalo-Vuokko, Perola, Spector, & Kaprio, 2017) and this may explain our results in the choice test.

The comparison of choice and familiarity indices for vegetables indicated that bitterness and astringency did not represent a barrier to vegetable consumption in females. At the same time, the choice for bitter/astringent food did not appear a reliable predictor of vegetable consumption in males. A greater appreciation of health-related food aspects, greater nutritional and culinary knowledge, and an increased interest in preparing home-cooked meals are all positively associated with vegetable consumption (Appleton et al., 2016) and were likely to be responsible for the higher familiarity for vegetables in females than in males in the current study.

The positive association of aging with the choice of vegetables higher in bitterness and astringency can be explained by the repeated exposure—an effect that may allow initial avoidance to be overcome, at least partly through "learned safety" (Kalat & Rozin, 1973). Thus, a food that is initially disliked could become familiar and potentially preferred (Aldridge, Dovey, & Halford, 2009; Methven, Langreney, & Prescott, 2012). Furthermore, the increased attention to the health-related aspects of eating associated with aging (Saba et al., 2019) might further help in promoting choices for healthier vegetable options, even if they are less palatable initially.

Neither choice of nor familiarity with vegetables was affected by PROP status, consistent with the results of previous study showing a lack of association of bitter vegetable preference with responsiveness to PROP bitterness (Catanzaro et al., 2013; Laureati et al., 2018; Shen et al., 2016). Evidence from recent studies highlighted that a complex network of both genetic and environmental factors appears to influence responsiveness to PROP (Tepper et al., 2014, 2017). However, this phenotype is still widely used, with the purpose of exploring the associations of chemosensory ability and vegetable preferences (Keller & Tepper, 2004; Shen et al., 2016). However, based on the results from the present study, and in line with the newer multidimensional models of food preference and choice, environmental factors might mitigate the impact of biology in determining food preferences, such that phenotype differences in responsiveness to bitterness may not be enough to influence food choice and intake (Hayes, Feeney, & Allen, 2013).

In general, data on choice of and familiarity with vegetables indicated the relevant roles of food neophobia, sensitivity to punishment, and sensitivity to disgust as determinants of vegetable eating. These psychological traits were negatively associated with both the choice of vegetables with higher bitterness and astringency and the familiarity with vegetables in general, irrespective of their sensory properties. This is in line with previous findings, which show that food neophobia in adults is associated with a reduced dietary variety, which is most evident in a lower acceptability and intake, particularly of vegetables, fruits, and protein foods (Knaapila et al., 2011). Our findings align also with the hypothesis that higher punishment sensitivity is associated with more unhealthy behaviours, as it was found previously to be associated with a higher sugar intake (Tapper et al., 2015). Individuals with higher alexithymia declared a lower familiarity with vegetables independently of their bitterness and astringency, while no effect on choice was reported. Similarly, Robino and colleagues (2016) reported a negative relationship between alexithymia and stated liking for vegetables. The fact that we did not find an effect of this trait on choice may suggest that this trait modulates vegetable consumption independently from the sensory characteristics of vegetables and thus affects the whole product category.

The correlation between choice and familiarity indices significantly varied according to the level of food neophobia and sensitivity to punishment, thus indicating potential differences between what individuals would like to choose and what they declare they consume normally. The correlation value decreased with neophobia and sensitivity to punishment, indicating that low food neophobia and sensitivity to punishment individuals were likely to have a wider vegetable repertoire. In older adults, a positive association between the willingness to try new foods and a wider variety of consumed vegetables has already been observed (Appleton et al., 2017). On the other hand, the high level of food neophobia and sensitivity to punishment traits were associated with an increased correlation between choice and familiarity. Neophobic individuals tended to be more consistent with what they preferred and what they declared to consume, and this possibly indicates a restricted spectrum of vegetables included in their daily diet.

Aging was positively associated with the choice of the more bitter/astringent coffee/tea options, suggesting the effects over time of learned positive flavour–flavour and/or flavour consequence conditioning via the stimulatory impact of caffeine, leading to the bitter taste of coffee/tea becoming acceptable (Rogers & Smith, 2011; Tinley, Yeomans, & Durlach, 2003). Taste motives are among the main reasons for caffeinated beverages consumption (Samoggia & Riedel, 2018) and a bitter taste contributes to the appreciation for caffeinated beverages drinkers (Ágoston et al., 2018).

PROP status did not affect choice and familiarity with coffee/tea items, thus adding to the negative findings in data on causal relationships between PROP bitterness perception and coffee/tea preference and consumption (Masi et al., 2015; Ong et al., 2018). Several factors other than sensory properties, such as functional motives, health beliefs, tradition, and culture, shape the personal preferences for caffeinated beverages (Samoggia & Riedel, 2018). Recent findings on genetic of bitterness perception indicate an opposite causal relationship between PROP responsiveness and coffee and tea consumption (Ong et al., 2018).This possibly further accounts for the lack of significant effect of PROP status on choice and familiarity indices, since they are based on responses to both tea and coffee. However, differences in correlations between choice and familiarity indices indicated that ST, more than MT and NT subjects, tended to consume the most preferred option. This may imply that these subjects, more sensitive than the rest of the population to unappealing sensations, tended to adopt more strictly the consumption conditions that better adapt to their personal preference.

Food neophobia, sensitivity to punishment, and sensitivity to disgust appeared to act as barriers to the choice of the more bitter/astringent coffee/tea options. High food neophobia and sensitivity to disgust levels were associated with a lower familiarity with the unsweetened version of coffee/tea items and to a higher familiarity with the least bitter/astringent option for neophobic subjects only. A lower preference for coffee has been already reported for individuals higher in neophobia (Jaeger et al., 2017).

Food neophobia significantly affected the strength of the correlation between the choice and familiarity indices of the most astringent/bitter coffee/tea options. The correlation value was significantly higher in subjects with lower than with higher food neophobia. Habit, defined as a ritual or a daily routine, was one of the main motivational factors for caffeinated beverages consumption (Ágoston et al., 2018), but neophobic subjects were less familiar with coffee/tea and were only occasional consumers of unsweetened coffee/tea beverages, and this could account for the weaker correlation between choice and familiarity for unsweetened coffee/tea indices. It has been shown that a variety of motivations play a role in the consumption of coffee beverages (Labbe, Ferrage, Rytz, Pace, & Martin, 2015) and that sensory properties are more relevant for individuals who consume more coffee daily and with a faster caffeine metabolism index (Spinelli et al., 2017). We may hypothesise, therefore, that while for individuals lower in neophobia the sensory properties are of importance, thus explaining their preference for the unsweetened options, for those higher in neophobia, coffee preference may be more explained by situational and social factors (e.g., social rituals).

While this study benefits from a large sample and the study of the impact of psychological traits on choice, some aspects have remained underexplored. Thus, the foods and beverages considered in the study might differ for properties other than bitterness and astringency, such as texture or energy content. Differences in these aspects might have a role in choice and familiarity that has not been taken into account in the present paper, thus possibly limiting the interpretation of the results. Further studies are encouraged, taking into account a larger variety of dimensions.

5.5 Conclusions

The approach proposed in this study for product grouping based on sensory properties was effective and allowed the investigation of the role of individual differences in chemosensory perception and psychological traits as modulators of phenol-rich foods preference and consumption. Individual differences in psychological traits (food neophobia, sensitivity to punishment and sensitivity to disgust), rather than responsiveness to PROP, influenced both preference and consumption of phenol-rich foods. Furthermore, psychological traits significantly affected the degree of coherence between what individuals preferred and what consumed in their daily life thus, in ultimate analysis, determining their diet variety.

A positive correlation between familiarity and choice was confirmed, but the two measures were found to provide different information. While in vegetables the traits food neophobia, sensitivity to punishment and sensitivity to disgust were found to be associated with a lower familiarity with vegetables independently from their sensory properties, in coffee/tea food neophobia, sensitivity to disgust and alexithymia were associated with a lower familiarity with the unsweetened options. To build on these interpretations of food preference and consumption behaviour, the systematic explorations of individual differences in psychological traits should also take place in applied settings.

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6. Set-up of experimental prototypes with the addition of phenol extracts from Olive Mill Waste Water (De Toffoli et al., 2019)

The present study (De Toffoli, A. et al., 2019) was published on Food Research International.

Title: Sensory and chemical profile of a phenolic extract from olive mill waste waters in plant-based foods with varied macro-composition

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Abstract

Phenols from Olive Mill Waste Water (OMWW) represent valuable functional ingredients. The negative impact on sensory quality limits their use in functional food formulations. Chemical interactions phenols/biopolymers and their consequences on bioactivity in plant-based foods have been widely investigated, but no studies to date have explored the variation of bitterness, astringency and pungency induced by OMWW phenols as a function of the food composition.

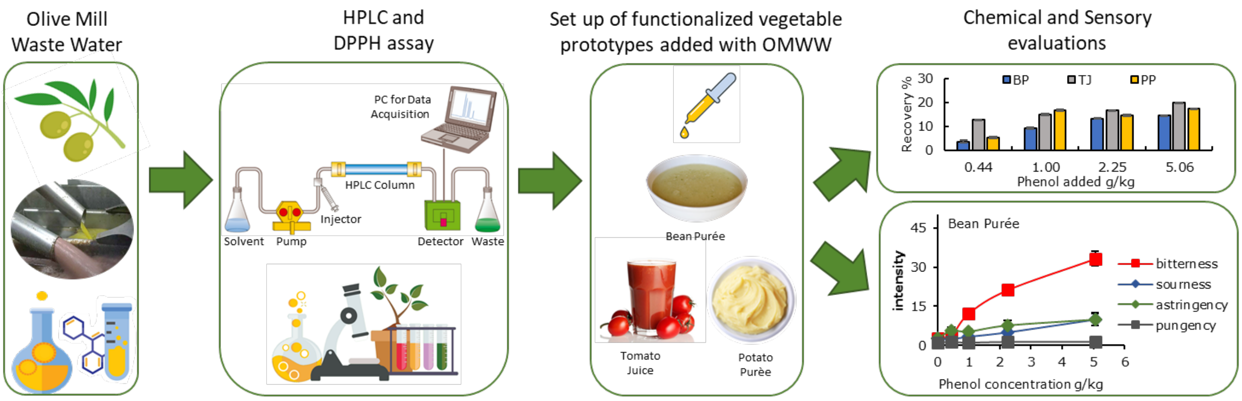
The aim of the paper was to profile the sensory and chemical properties of phenols from OMWW in plant-based foods varied in their macro-composition.

Four phenol concentrations were selected (0.44, 1.00, 2.25, 5.06 g/kg) to induce significant variations of bitterness, sourness, astringency and pungency in three plant-based foods: proteins/neutral pH - bean purée (BP), starch/neutral pH - potato purée (PP), fiber/low pH - tomato juice (TJ). The macro-composition affected the amount of the phenols recovered from functionalized food. The highest recovery was from TJ and the lowest from BP. Two groups of 29 and 27 subjects, trained to general Labelled Magnitude Scale and target sensations, participated in the evaluation of psychophysical curves of OMWW phenols and of functionalized plant-based foods, respectively. Target sensations were affected by the food macro-composition. Bitterness increased with phenol concentration in all foods. Astringency and sourness slightly increased with concentration, reaching the weak-moderate intensity at the highest phenol concentration in PP and TJ only. Pungency was suppressed in BP and

perceived at weak-moderate intensity in PP and TJ sample at the highest phenol concentration.

Proteins/neutral pH plant-based food (BP) resulted more appropriate to counteract the impact of added phenol on negative sensory properties thus allowing to optimize the balance between health and sensory properties.

Graphical abstract



Keywords: functional foods, by-products, bitterness, pungency, astringency, proteins, carbohydrates.

Highlights

- Food macro-composition affects the amount of recovered phenols
- The lowest recovery was from proteins/neutral pH plant-based food
- Intensities of sensations depend by phenol concentration and food macro-composition
- Proteins/neutral pH food counteracted phenol induced "warning" sensations

6.1 Introduction

Plant phenolics are powerful antioxidants and free radical scavengers whose protective effects against cardiovascular diseases and oxidative stress related pathologies have been demonstrated (Shahidi & Ambigaipalan, 2015). Plant by-products represent a valuable source of these natural antioxidants and the recovery of such high-value bioactive compounds may have beneficial effects on the economic and environmental sustainability of agro-industry (Kowalska et al., 2017).

Phenolic compounds from olive fruit belong to the class of secoiridoids. Oleuropein, ligstroside, demethylcarboxyoleuropein and nüzhenide are the most abundant glucoside forms of secoiridoids in olive drupe (Servili et al., 2004). Because of the enzymatic and non-enzymatic phenomena along the oil extraction process (Trapani et al., 2017), phenolic compounds in virgin olive oils are mainly represented by the secoiridoid aglycon forms such as 3,4-DHPEA-EDA, *p*-HPEA-EDA, *p*-HPEA-EA and 3,4-DHPEA-EA, and phenolic alcohols (3,4-DHPEA and *p*-HPEA). These phenols are abundant in olive mill waste water (OMWW), the main waste of the virgin olive oil production industry. The phenolic compounds from virgin olive oils and from their by-products are characterized by antioxidant, antimicrobial, anti-inflammatory, chemo-preventive properties (Bendini et al., 2007; Servili et al., 2014). Moreover, OMWW disposal represents a major cost in olive oil production, and the recovery of bioactive phenols may greatly help the sustainability of the olive oil industry.

Phenols from plant by-products (Torri et al., 2016; Świeca, Gawlik-Dziki, Sęczyk, Dziki, & Sikora, 2018; Nirmala, Bisht, Bajwa, & Santosh, 2018), including OMWW (Araújo, Pimentel, Alves, & Oliveira, 2015; Esposto et al., 2015; Servili et al., 2011a; Servili et al., 2011b), have been proposed as functional ingredients that are able to enhance food and beverage antioxidant activity and its potential pro-health effects. Unfortunately, phenol compounds are mainly responsible for the bitterness, astringency and pungency in phenol rich foods (Lesschaeve & Noble, 2005). For instance, secoiridoid aglycons 3,4-DHPEA-EDA and *p*-HPEA-EDA induce intense bitter taste and pungent sensations (Vitaglione et al., 2015). The intensity of these phenol-induced 'warning' sensations significantly affects preference and choice of phenol rich vegetable foods (Dinnella, Recchia, Tuorila, & Monteleone, 2011).

Developing a phenol-enriched functional food can be a challenging task since consumers are not willing to compromise on sensory quality when it comes to functional foods (Verbeke, 2006; Krystallis, Maglaras, & Mamalis, 2008; Jaeger, Axten, Wohlers, & Sun-Waterhouse, 2009). Hence, strategies to control for the intensity of warning sensations need to be considered when developing phenol enriched functional foods. Three main strategies can be envisaged to reduce the intensity of the unacceptable sensory properties of phenols (Ares, Barreiro, Deliza, & Gámbaro, 2009; Gaudette & Pickering, 2012; Keast, 2008).

The first of these is to take advantage of common perceptual interaction in which the suppression of the target sensations occurs through the addition of a counteracting tastant. Sweeteners, fats and salt can lead to perceptual interactions that reduce the impact of phenols on sensory properties of functional food, but these sensory stimuli may also negatively impact on functional food pro-health properties due to the energy and salt intake. Furthermore, the perceived level of healthiness in food is frequently linked to naturalness which may also imply the absence of unnecessary ingredients (Román, Sánchez-Siles, & Siegrist, 2017). Functional foods perceived as natural are more likely to be consumed (Carrillo, Prado-Gascó, Fiszman, & Varela, 2013). Thus, the appropriate strategy to mitigate the impact of phenols on sensory properties of functional food should be to lower the intensity of phenol-induced sensations and limit the use of ingredients that can compromise the pro-health expectations for this food product category.

Secondly, tasteless ingredients that compete for phenol receptor binding, such as cyclodextrin derivates, can be employed (Gaudette & Pickering, 2012).

Finally, the chemical interactions between phenols and biopolymers naturally occurring in vegetable foods (Zhang et al., 2014) can be seen as an appropriate strategy to lower functional phenol bitter and astringent potential. Plant biopolymers can act as a physical barrier for phenol stimuli utilized, thus hindering their interactions with sensory receptors and saliva. Many factors affect phenol/biopolymer binding including pH and reagent features such as chemical compositions, structure, hydrophobic/hydrophilic character (Kroll, Rawel & Rohon, 2003). Several studies have investigated the chemical features of phenol/biopolymer interactions and their consequences on bioactivity (Jakobek, 2015; Ozdal, Capanoglu, & Altay, 2013) but no studies to date have explored the systematic variation of target sensations induced by functional phenols in plant-based foods.

The aim of the paper was to profile the sensory and chemical properties of phenols extracted from OMWW in plant-based foods varied in their macro-composition in which different phenol/biopolymer interactions might occur. Selected plant-based foods were proteins/neutral pH - bean purée (BP), starch/neutral pH - potato purée (PP), fibers/low pH - tomato juice (TJ).

6.2 Materials and Methods

6.2.1 OMWW phenol extract preparation

The phenolic fraction was extracted from OMWW of Peranzana, Ogliarola, Coratina and Moraiolo cultivars harvested at ripening in region from Central Italy. The extraction and purification of phenolic fraction from OMWW was carried out as described by Esposto et al., 2015. Three steps of tangential membrane filtration were applied to obtain a crude phenolic concentrate from OMWW previously treated with an enzymatic solution of pectinase from Aspergillus niger, BIODEP (Biotec s.r.l., Roma, Italy) (Servili et al., 2011a).

Phenolic compounds from crude concentrate were recovered by liquid-liquid extraction with ethyl acetate. A rotavapor was used to completely evaporate the ethyl acetate at 35 °C. The phenolic extract obtained was dissolved in ethanol, which was then evaporated using a flow of nitrogen (Servili, et al., 2011b).

6.2.2 Chemical Analysis

6.2.2.1 Phenol profile

The analysis of phenolic composition of the extract was performed by HPLC, after sample solubilization with methanol/water (50:50 v/v) and filtration over a 0.2 µm PVDF filter.

Extraction of phenols from OMWW from plant-based foods was carried out mixing 2 g of sample and 10 ml of ethanol/acetone (50:50 v/v) with T25 digital Ultra-Turrax (IKA® Works, Wilmington, NC 28405 USA) at 17000 rpm. The sample was centrifuged, made up to volume, filtered over a 0.2 µm PVDF filter and directly injected into HPLC system.

The HPLC analysis was conducted using an Agilent Technologies Model 1100 following the operating conditions described by Veneziani et al. (2015). DAD with a wavelength of 278 nm was used to detect secoiridoid derivatives and phenolic alcohols. The p-HPEA and vanillic acid were purchased from Sigma Aldrich (Milan, Italy), whereas 3,4-DHPEA and verbascoside were provided by Cabru s.a.s. (Arcore, Milan, Italy) and Extrasynthese (Genay, France), respectively. The 3,4-DHPEA-EDA and p-HPEA-EDA were extracted from virgin olive oil (VOO) as previously reported by Selvaggini et al. (2014). The data were expressed as mg of phenols kg-1 of extract or foods.

6.2.2.2 Antioxidant activity

Free radical scavenging activity was evaluated by the DPPH assay (Brand-Williams, Cuvelier, & Berset, 1995). A solution of DPPH (6*10-5 M) was prepared by dissolving 0.236 mg of DPPH in 100 mL of methanol. A volume of 0.1 mL of sample was mixed with 3.9 mL of DPPH solution. For the reference sample, 0.1 mL of methanol was added to 3.9 mL of DPPH solution to measure the maximum DPPH absorbance. All samples were left in the dark for 30 min at 30°C then the absorbance decrease was measured at 515 nm with a Perkin Elmer Lambda 10 spectrophotometer (Massachusetts, USA). Free radical scavenging activity was expressed as µmol of Trolox equivalents antioxidant capacity (TEAC). Trolox standard solutions were prepared in ethanol at concentrations ranging from 10 to 600 µmol/L. Each assay was performed in triplicate.

6.2.3 Sensory evaluations

6.2.3.1 Participants

Participants were recruited on a regional basis by means of announcements published on research unit websites, emails, pamphlet distribution and word of mouth. At the time of recruitment, respondents were asked to complete an online questionnaire on socio-demographic and physical health characteristics. Pregnancy, food allergies and history of perceptual disorders were exclusion criteria. Two respondent groups were recruited to evaluate OMWW extract (Group 1: n=29; 59 % females; mean age 27.5 ± 7.1) or functionalized plant-based foods (Group 2: n=27; 70 % females; mean age 31.5 ± 9.4).

6.2.3.2 Procedure

Subjects from group 1 took part in one session for OMWW extract evaluation, group 2 took part in two sessions, held over two days, for the evaluation of three series of functionalized foods. In the first session, participants signed the informed consent according to the principles of the Declaration of Helsinki and were introduced to the general organization of the experiment. Subjects (Ss) were then trained in the use of general Labelled Magnitude Scale (gLMS; 0: no sensation - 100: the strongest imaginable sensation of any kind) (Bartoshuk, 2000; Green et al., 1996; Green, Shaffer, & Gilmore, 1993). Participants were told that the top of the scale - the strongest imaginable sensation of any kind - represented the most intense sensation that subjects could ever imagine experiencing. Ss were focussed on a variety of remembered sensations from different modalities including loudness, oral pain/irritation and tastes. The Ss were then trained to recognize the following target sensations in water solutions prepared to be at "moderate/strong" intensity on gLMS: bitterness (caffeine 3.00 g/kg), sourness (citric acid - 4.00 g/kg), saltiness (NaCl-15 g/kg), astringency (aluminium potassium sulphate – 0.8 g/kg) and pungency (capsaicin – 1.5 mg/kg)(Monteleone et al., 2017). At the end of the training, while all Ss were seated in individual booths, group 1 evaluated OMWW extracts (nine samples), and group 2 evaluated one series of food prototype (five samples). On day two, the gLMS and target sensations were briefly introduced again to group 2, who then they were seated in individual booths to evaluate two series of functionalized foods (five samples each). The two sessions were separated by between 1 and 7 days, according to availability of Ss from group 2. Ss received a gift to compensate them for their time.

6.2.3.3 Sensory stimuli

6.2.3.3.1 OMWW extract

The OMWW extract was diluted in EtOH 1% to obtain eight solutions at 0.29, 0.44, 0.66, 1.00, 1.50, 2.25, 3.37, 5.06 g/L phenol concentrations. These concentrations were chosen based on preliminary informal assessment by expert laboratory personnel to induce bitterness intensity from weak to strong. A further solution consisting of the solvent was considered and indicated as 0.00 g/L phenol. In total, nine OMWW extract solutions were prepared for evaluation. These solutions were stored at room temperature in a tightly closed container protected from light and used within 10 hours.

6.2.3.3.2 Functionalized foods

Three vegetable foods with different macro-composition were selected for the development of phenol functionalized foods: proteins/neutral pH - bean purée (BP), carbohydrates/neutral pH - potato purée (PP), water/low pH - tomato juice (TJ). Canned or powdered ingredients produced by large food companies were used to prepare the functionalized food since their composition is constant, and they are easily available without seasonality restrictions. The three foods had four levels of phenol from OMWW extract added: 0.44, 1.00, 2.25, 5.06 g/kg. A further sample for each series consisting of the vegetable food without OMWW extract added, and indicated as 0.00 g/kg, was considered. In total, five levels of phenol concentration for each vegetable food were considered for evaluation. Samples were evaluated immediately after preparation, within 15 min of extract addition.

6.2.3.4 Evaluation conditions

The OMWW solutions (7 mL) and functionalized foods (6 g) were presented in 80cc plastic cups identified by a 3-digit random code. Food samples (BP, TJ, PP) were presented with a plastic tea-spoon. Ss from group 1 were presented with a set consisting of the nine OMWW solutions arranged in three subsets of three samples each. Samples were presented in randomized order across Ss. The three series of functionalized foods (BP, PP and TJ) were presented to Ss from group 2 in independent sets, each consisting of five samples of the same food arranged in two subsets of three and two samples each. The presentation order of the three series of foods was balanced across Ss. The presentation order of samples within each series was randomized across subjects. Ss had a 3 min break between subsets a 10 min break between the sets.

During tasting, Ss were instructed to hold the whole OMWW sample in their mouth for 10 s, then expectorate and evaluate the intensity of target sensations (bitterness, sourness, saltiness, astringency and pungency). For the food samples, subjects were instructed to take a spoonful of the sample, wait for 10 s, then swallow and evaluate the intensity of bitterness, sourness, astringency and pungency. The order of sensation evaluation was randomized for the tastes (bitterness, sourness and saltiness), while astringency and pungency were evaluated in penultimate and last position to allow for the full development of their intensity.

After each sample, Ss rinsed their mouth with water for 30 s, had some plain crackers for 30 s and finally rinsed their mouth with water for a further 30 s. To control for odor cues, Ss were asked to wear nose clips. Evaluations were performed in individual booths under red lights. Data were collected with the software Fizz (ver.2.51. A86, Biosystèmes, Couternon, France).

6.2.4 Data Analysis

Two-ways ANOVA models were used to assess the effect of phenol concentration and food macro-composition on the amount of phenols extracted from functionalized samples and on their total recovery. Two-way ANOVA mixed models (fixed factor: phenol concentration; random factor: subjects) were used to assess the effect of phenol concentration on the intensity of target sensations in OMWW solutions and food prototype samples. Three-way mixed models (fixed factors: food matrix and phenol concentration; random factor: subjects) with interactions were used to assess the effect of food matrix on the intensity of target sensations. A Fisher LSD post hoc test was applied to test significant differences in multiple comparison test (significant for $P \leq 0.05$)

The XLSTAT statistical software package version 19.02 (Addinsoft) was used for data analysis.

6.3 Results

6.3.1 Chemical characterization

6.3.1.1 OMWW extract: phenol profile and antioxidant activity

Phenols represented approximately 70 % of the OMWW extract. The phenolic composition of the OMWW extract was characterized by the main phenolic compounds of olive fruit and virgin olive oil. The most abundant phenolic compounds were secoiridoid derivatives: 3,4-DHPEA-EDA, the dialdehydic forms of elenolic acid linked to hydroxytyrosol, (605.4±0.5 mg/g of extract), hydroxytirosol - 3,4-DHPEA, (43.8±0.2 mg/g of extract) and tyrosol - p- HPEA (7.6±0.6 mg/g of extract). The OMWW is rich of verbascoside, a phenlyethanoid glycoside, which was also present in the purified extract (23.8±1.2 mg/g of extract)(Veneziani, Novelli, Esposto, Taticchi, & Servili, 2017). Antioxidant activity of the extract was 3.060± 0.071TEAC eq/mg phenols.

6.3.1.2 Functionalized foods: OMWW phenol recovery and profile

The amount of OMWW phenols in food samples functionalized with increasing concentrations was determined after extraction and expressed as percentage of recovery (Figure 7). The phenol recovery increased with the added amount ($p \leq 0.001$) and ranged from 3.7 to 13. 9 % in bean purée, from 12.6 to 19.9 % in tomato juice and from 5.4 to 17.3 % in potato purée. The recovery was significantly influenced by food macro-composition ($p \leq 0.001$). The lowest recovery of OMWW phenols was from functionalized bean purée samples irrespective to the amount initially added. The highest recovery was from tomato juice added with 0.44, 2.25 and 5.06 g/kg of phenols. Potato purée showed the highest recovery when 1.00 g/kg of phenols was used.

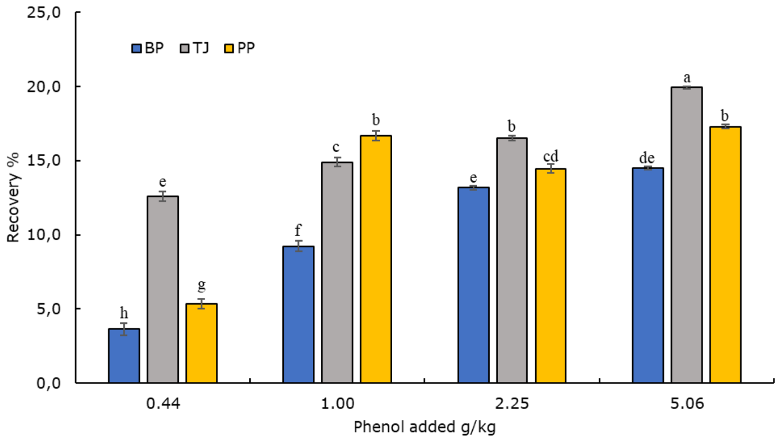


Figure 7. Percentage of OMWW phenols recovered (recovery%) form bean purée (BP), tomato juice (TJ) and potato purée (PP) functionalized with increasing amount of phenols from OMWW extract. Bars represent standard deviation, different letters indicate significantly different values ($p \leq 0.001$).

The amount of individual OMWW phenols from functionalized food regularly increased with the total amount initially added ($p \leq 0.0001$) and was affected by food macro-composition ($p \leq 0.001$) in a different extent depending on the specific phenol and the added amount (Table 15).

Table 15. Recovery (mean values g/kg) of individual phenols from foods (BP-bean purée, TJ-tomato juice, PP-potato purée) functionalized with increasing amount of phenols from OMWW extract. Different letters indicate significantly different values ($p \leq 0.0001$).

	Concentration of phenols from OMWW (g/kg)				
	0	**0.44**	**1.00**	**2.25**	**5.06**
3.4- DHPEA					
BP	0 h	5.34 gh	45.24 f	112.36 e	283.09 c
TJ	0 h	7.89 g	48.74 f	127.78 d	378.86 b
PP	0 h	6.57 gh	51.29 f	122.96 d	333.80 a
p-HPEA					
BP	0 f	0 f	10.85 e	15.52 d	31.07 b
TJ	0 f	0 f	15.11 d	23.42 c	38.44 a
PP	0 f	9.02 e	17.59 d	27.77 b	37.04 a
Verbascoside					
BP	0 i	10.75 gh	36.15 f	74.62 de	171.09 c
TJ	0 i	13.75 gh	18.07 g	80.43 d	222.28 a
PP	0 i	7.96 h	31.35 f	68.58 e	194.24 ab
3.4-DHPEA-EDA					
BP	0 i	0 i	0 i	93.73 f	203.63 c
TJ	0 i	34.03 h	67.09 g	140.21 d	368.72 a
PP	0 i	0 i	66.53 g	106.18 e	310.05 b

In general, the lowest amount of each phenol was recovered from bean purée and the largest differences were found among food functionalized with the highest amount of phenols (≥2.25 g/kg). Phenol profiles recovered from BP, TJ and PP functionalized with 5.06 g/kg were compared to the profile of OMWW extract (Figure 8). The relative content of 3,4-DHPEA-EDA, 3,4-DHPEA, p-HPEA and verbascoside largely differ between OMWW extract and functionalized food. 3,4-DHPEA-EDA represented the most abundant phenol of OMWW extract (89 %) but its proportion lowered to approx. 27, 35 and 36 % of total OMWW phenols recovered from BP, PP and TJ, respectively. 3,4-DHPEA and verbascoside represented 6.4 and 3.5 %, of the total phenol content of OMWW extract respectively, and approximately 40 and 22 %, of the total phenols recovered from functionalized foods. p-HPEA was 1 and approximately 4 % of total phenols in OMWW extract and functionalized foods, respectively.

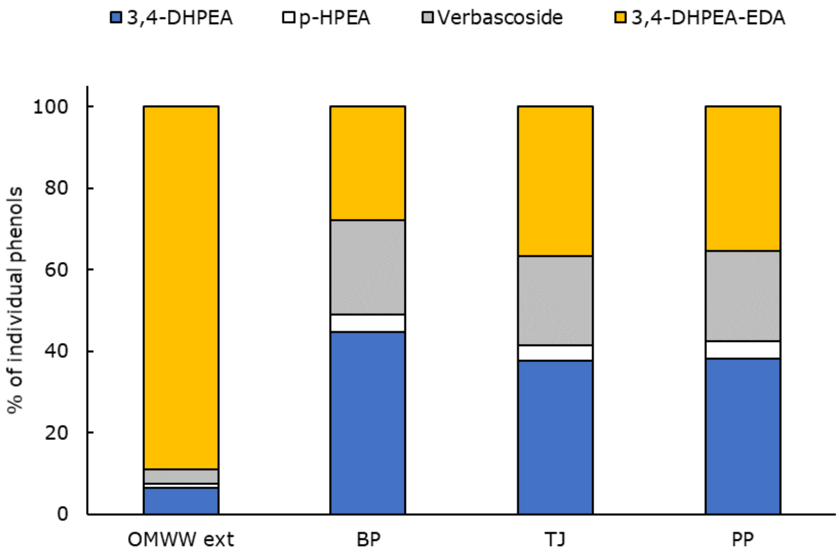


Figure 8. Percentage of individual phenols detected in the OMWW extract (OMWW ext) and in bean purée (BP), tomato juice (TJ) and potato purée (PP) functionalized with 5.06 g/kg phenols from OMWW extract.

6.3.2 Sensory evaluation

6.3.2.1 OMWW extract solutions

Phenol concentration of OMWW solutions significantly affected the intensity of target sensations (Table 16). According to F values the increase of phenol concentration had the strongest effect on bitterness and, to a lesser extent, on other target sensations. Significant bitterness and astringency increases were observed in the samples with phenols from OMWW as compared to the sample without phenol added (0.00 g/L). Bitterness increased from weak/moderate to strong/very strong across the phenol concentration range. Sourness showed the same trend of increasing intensity, but only in a narrow range from weak to moderate. Astringency showed a limited intensity increases from moderate to moderate strong on the scale. Pungency did not differ across samples from 0.00 and 0.66 g/L of phenols, while higher concentrations induced significant pungency increasing from weak to moderate/strong. Saltiness represents a marginal sensation, its intensity reaching a weak/moderate intensity at the highest phenol concentration, and thus was not considered further.

Four concentration levels, which cover the whole range of significant variations of intensity of target sensations, were selected to fortify the vegetable matrices: 0.44, 1.00, 2.25 and 5.06 g/L.

Table 16. 2-Way ANOVA mixed model (random effect assessors): Phenol concentration effect on intensity of target sensations in OMWW extract solutions. Mean. F and p values.

			Concentration (g/L)								
	F	**p**	**0.00**	**0.29**	**0.44**	**0.66**	**1.00**	**1.50**	**2.25**	**3.37**	**5.06**
Bitterness	106.62	p<0.0001	1.69 f	9.95 e	13.23 de	17.18 d	23.18 c	26.91 c	34.28 b	38.28 ab	40.75 a
Sourness	17.30	p<0.0001	1.65 e	4.47 de	5.37 de	7.17 cd	8.13 bcd	8.75 bcd	10.10 bc	11.98 ab	16.21 a
Saltiness	13.83	p<0.0001	1.83 d	2.56 cd	2.72 cd	4.35 bcd	5.55 bc	5.59 bc	5.78 bc	7.17 b	11.07 a
Astringency	17.69	p<0.0001	1.65 c	14.53 b	14.44 b	17.12 ab	18.26 ab	21.62 a	22.31 a	22.78 a	21.75 a
Pungency	47.79	p<0.0001	1.62 e	1.88 e	2.83 e	4.17 de	8.52 cd	9.34 bc	14.21 b	19.51 a	23.73 a

Different letters indicate significantly different values ($p \leq 0.0001$)

6.3.2.2 Functionalized foods

The impact of OMWW extract on the sensory profile of the three vegetable matrices was independently assessed in each series of prototype as a function of the concentration of added phenols. The intensity of target sensations significantly changed in all the three vegetable prototypes as a function of increasing phenol concentrations, the only exceptions being pungency in bean purée (Table 17). F values indicated that the increase of phenol concentration induced the strongest effect on bitterness in all the three prototypes. The intensity of sourness, astringency and pungency were influenced by both the increase of phenol concentration and, to a lesser extent, by the matrix macro-composition. All the sensations were barely detectable in bean purée sample without phenol added, while in the rest of samples, bitterness increased from weak to strong/very strong, and sourness and astringency increased slightly from barely detectable to weak/moderate. All sensations were rated as weak in the tomato juice sample without phenol added; in the rest of samples, bitterness increased from weak to strong, and sourness, pungency and astringency increased from weak to weak/moderate as a function of the concentration of added phenols. In the potato purée sample without added phenols, all sensations were rated at barely detectable/weak intensity. Bitterness increased from barely detectable to strong with increasing with phenol concentration, and astringency, pungency and sourness increased slightly, reaching weak/moderate intensity level.

Table 17. 2-Way ANOVAs mixed model (random effect: assessors): Phenol concentration effect on intensity of target sensations in food models. Mean. F and p values.

			Concentration of phenols from OMWW (g/kg)				
			0.00	**0.44**	**1.00**	**2.25**	**5.06**
	F	p					
Bitterness							
Bean Purée	68.09	< 0.0001	2.89 d	3.81 d	12.19 c	21.23 b	33.27 a
Tomato Juice	45.39	< 0.0001	4.22 d	6.00 d	15.15 c	27.00 b	32.67 a
Potato Purée	57.68	< 0.0001	3.15 d	4.08 d	14.92 c	25.69 b	35.15 a
Sourness							
Bean Purée	7.63	< 0.0001	2.70 b	2.50 b	3.35 b	5.08 b	10.00 a
Tomato Juice	4.72	0.002	8.41 c	11.41 bc	10.89 bc	16.70 a	14.74 ab
Potato Purée	12.75	< 0.0001	2.73 c	2.85 c	5.04 bc	8.46 b	14.96 a
Astringency							
Bean Purée	5.14	0.001	2.85 c	5.73 bc	5.42 bc	7.73 ab	9.92 a
Tomato Juice	5.04	0.001	4.89 c	5.11 c	7.07 bc	8.96 ab	11.04 a
Potato Purée	4.62	0.002	6.81 c	8.11 bc	8.35 bc	11.11 ab	14.81 a
Pungency							
Bean Purée	0.26	0.905	1.15 a	1.50 a	1.11 a	1.50 a	1.50 a
Tomato Juice	9.98	< 0.0001	2.41 c	3.11 c	4.89 bc	6.78 b	12.67 a
Potato Purée	12.53	< 0.0001	1.08 b	0.96 b	2.19 b	4.31 b	11.54 a

Different letters indicate significantly different values ($p \leq 0.001$)

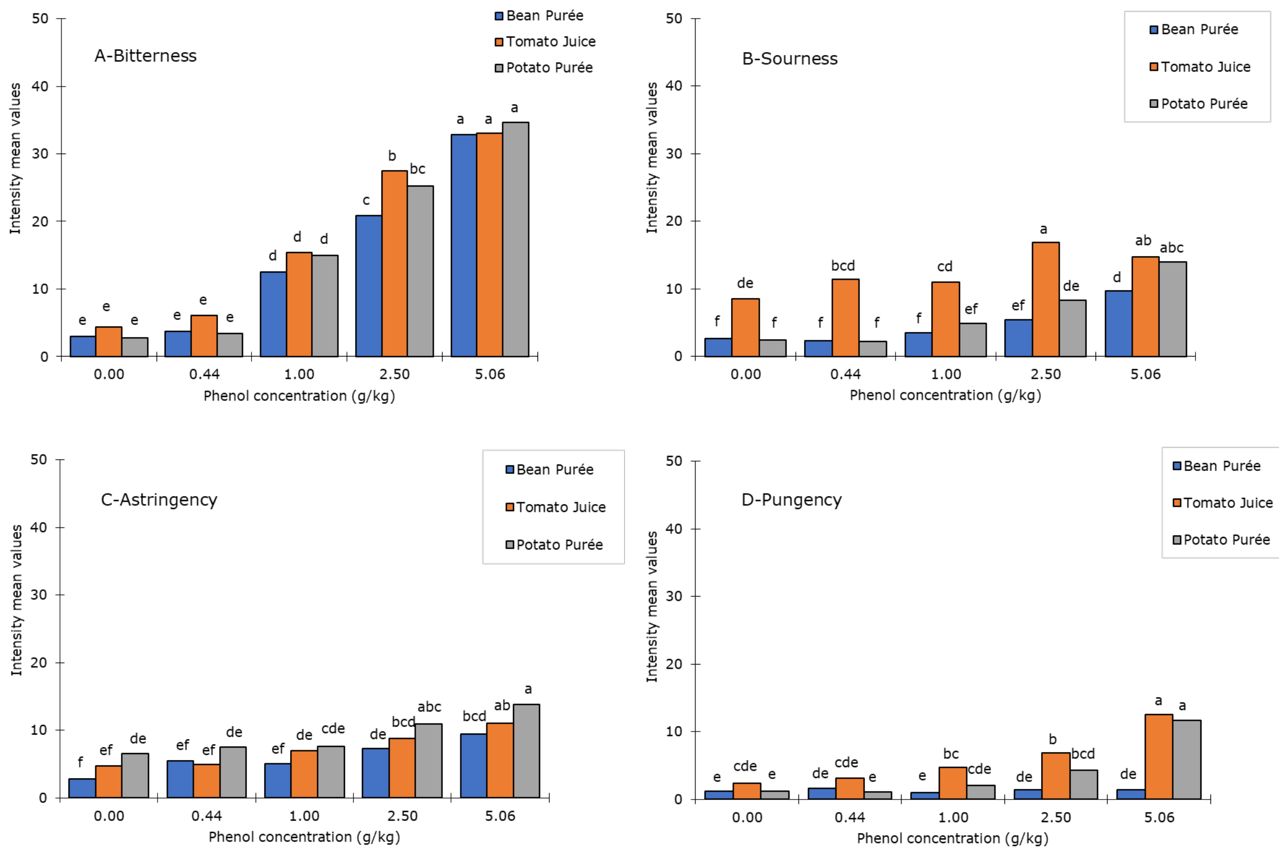
In general, these intensity data indicate a significant impact of the addition of OMWW extracts on the sensory properties of the three prototypes as a function of the added phenol concentration, and in particular on the perception of bitterness. Sourness, pungency and astringency intensities were significantly modified by OMWW extract, but the extent of these effects appears to be affected by the matrix macro-composition.

The effect of vegetable matrix composition on the intensity of sensations contributed by OMWW phenols was further explored and the intensities of target sensations in the three matrices at different added phenol concentration were compared (Table 18).

Table 18. 3-Way ANOVA mixed model (random effect assessors): Vegetable matrix. phenol concentration and their interactions effects on intensity of target sensations in food models. F and p values.

	Bitterness	**Sourness**	**Astringency**	**Pungency**
Vegetable matrix				
F	2.81	36.02	6.64	23.33
P	0.06	< 0.0001	0.001	< 0.0001
Concentration				
F	147.52	17.61	10.79	20.30
P	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Vegetable matrix*Concentration				
F	0.56	1.83	0.22	4.85
p	0.81	0.07	0.99	< 0.0001

The vegetable matrix significantly affected the intensity of sourness. The concentration of added phenol significantly affected the intensity of target sensations, with the greatest effect on bitterness. The vegetable matrix*concentration interaction was significant only for pungency, due to the suppression of this sensation in bean purée samples. No significant differences were found comparing bitterness from the three matrices at 0.00, 0.44, 1.00 and 5.06 g/L phenol concentrations, but at 2.25 g/L, bitterness was significantly higher in tomato juice than in bean purée (Figures 9-a). Sourness was rated as more intense in tomato juice than in either bean purée and potato purée in a concentration range from 0.00 to 2.25 g/L, at 5.06 g/L the lowest intensity was perceived in bean purée and no significant differences were found between tomato juice and potato purée (Figure 9-b). The three vegetable matrices did not differ for the intensity of astringency at 0.44 and 1.00 g/L of added phenol, however in the rest of samples, this sensation was lower in bean purée than in potato purée and no significant differences were found comparing tomato juice and potato purée (Figure 9-c). Pungency was significantly higher in tomato juice (from 1.00 to 5.06 g/kg) and in potato puree (5.06 g/kg) than in bean purée, but no significant differences were found between tomato juice and potato purée (Figure 9-d).



Figures 9. Effect of the vegetable matrix on the perceived intensity of (a) bitterness, (b) sourness, (c) astringency, (d) pungency in prototypes functionalized with different concentrations of phenols from OMWW extract. Different letters represent significant different values ($p \leq 0.001$).

In general, these data indicate that the different composition of vegetable matrices does not affect the contribution to bitterness of phenols from OMWW extract since the same regular trend and the same range of increasing intensity with added phenols was observed in the all three series of prototypes. On the other hand, the increasing intensity range observed for sourness, astringency and pungency differed across the series of prototypes indicating an active role of their macro-component in modulating the sensory impact of phenols from OMWW.

6.4 Discussion

The amount of OMWW phenols recovered from the functionalized food prototypes was much lower than expected, thus indicating the existence of strong chemical interactions between functional phenols and food components, the lowest amount was recovered from bean purée, the protein rich food matrix. These findings are in line with the previously documented interactions between phenols and food biopolymers. Proteins strongly interact with plant polyphenols through covalent and non-covalent binding, and high basic-residue content and open and flexible structure are the major features of proteins highly reactive towards phenols (Kroll, et al., 2003; Xiao & Kai, 2012; Zhang et al., 2014). Binding involves hydrophobic and hydrogen interactions, and proline-rich regions of leguminous proteins have been reported as preferred sites of interactions for plant phenol/food protein in *in vitro* conditions (Rawel, Czajka, Rohn, & Kroll, 2002). The formation of aggregates with proteins significantly impacts on the bioactivity of phenols and the reduction of both extractability from raw material and antioxidant activity has been reported (Kroll et al., 2014). The overall bioavailability of phenols from protein aggregates is still a matter of debate, and several sources of evidence indicate a lowering of the blood content of phenols after intake of food protein sources (Ozdal et al., 2013). However, the longer duration of the aggregates in the stomach followed by a delayed phenol release has been observed (Ozdal et al., 2013). Furthermore, after *in vitro* digestion of protein/phenol aggregates, the recovery of phenol related antioxidant activity was reported (Drummond e Silva et al., 2017; Kroll et al., 2003). Thus, it is possible to hypothesize that the interactions between food proteins and phenols do not lower the functional potential of the phenols, but rather influence their kinetic of phenol adsorption and bioactivity (Zhang et al., 2014).

Phenolic compounds bridge or cross-link with starch and other polysaccharides, and a large fraction of the so called "NEPP" (not extractable polyphenols) consists in phenol associations with polysaccharides (Pérez-Jiménez, Díaz-Rubio, & Saura-Calixto, 2013). The consequences of phenol/carbohydrate interactions on phenol bioactivity depends on phenol and carbohydrate chemical characteristics, and both enhancement or suppression of antioxidant activity and bio-accessibility have been observed (Zhang et al., 2014). The majority of NEPP arrive almost intact to the colon where they are fermented by microflora or depolymerized via enzymes, leading to phenol metabolites being available for adsorption (Pérez-Jiménez et al., 2013).

Based on these considerations, the low recovery from functionalized prototypes should not be interpreted as the mere loss of the bioactive compounds, and further investigations on phenol bioavailability and bio-accessibility will clarify the potential pro-health effects of experimental food matrices enriched with OMWW phenols.

The profile of phenol fractions extracted from functionalized foods differed substantially from the profile of the OMWW extract, mainly because of the strong decrease of 3,4-DHPEA-EDA relative to the other phenol compounds. Several phenol features, including their structure, the arrangement of hydroxyl groups, and the planarity of molecules, actively modulate the interactions phenols/environment and might be responsible for the observed differences (Jakobek, 2015; Ozdal et al., 2013). Investigating the associations of the chemical features of OMWW phenols with the strength and the modality of their interaction with biopolymers was behind the aim of the present work but further studies should be encouraged for a deeper understanding of the mechanism underlying phenol/biopolymer interactions in real food systems.

Bitterness was the most intense sensation induced by OMWW extracts, astringency and pungency were perceived at lower intensities, while sourness represented a marginal sensation. The observed sensory properties are consistent with the phenol profile of the extract. Secoiridoid derivatives of hydroxytyrosol are considered the main contributors to olive oil bitterness (Bendini et al., 2007). 3,4-DHPEA-EDA represents the main extract component and has been described as mainly bitter and slightly pungent (Taticchi, Esposto, & Servili, 2014). Pungency is instead mainly attributed to *p*-tyrosol derivatives which, when tested at the same concentration 3,4-DHPEA-EDA, primarily produced bitter tastes and low pungency, while *p*-HPEA-EDA mainly induced pungency (Andrewes, Busch, De Joode, Groenewegen, & Alexandre, 2003). Bitterness represents the main contribution of OMWW phenols to sensory profile of functional prototypes. The vegetable matrix macro-composition did not significantly affect the perceived intensity of this sensations. Thus, the strong interactions of OMWW phenols with vegetable biopolymers prevent the chemical extraction of phenols, and in particular of 3,4-DHPEA-EDA, but do not suppress the bitter taste of phenol compounds. In line with the documented *in vivo* release of phenols from biopolymer aggregates (Ozdal et al., 2013) and in vitro action of saliva enzymes on phenol structures (Walle et al., 2005), it might be possible to speculate about their possible release in the oral environment. The relatively high temperature of oral environment, and the presence of salts and hydrolytic enzymes in saliva, may favor phenol release from biopolymer aggregates, their diffusion across bitter taste receptors and a consequent stimulation of these receptors. Moreover, the contribution to bitter taste of 3,4 DHPEA, verbascoside and p-HPEA should be reconsidered. The vegetable matrix composition affected the perceived intensity of pungency and sourness. Pungency perception is suppressed in the protein rich prototype, and this could be tentatively related to 3,4-DHPEA-EDA/protein binding. This could lower the 3,4-DHPEA-EDA concentration so that bitterness is not affected, but the capacity to induce these secondary sensations is instead inhibited.

6.5 Conclusions

Food macro-composition actively impacts on the chemical and sensory properties of phenols from an OMWW extract with the strongest effects observed in protein-based foods.

Interactions between food proteins and phenols appear a possible strategy to produce a compromise between the health potential of phenols and sensory acceptability of phenol-enriched foods since lower the intensity of warning sensations, while at the same time avoiding extraneous ingredients in their formulations. Specificities were found between phenol chemical structure and strength of their interactions with food components. Systematic investigations in real food systems would help in clarifying the mechanisms underlying the phenol-biopolymer aggregate formation, thus helping in optimizing functional food formulations.

7. Influences of Psychological Traits and PROP Taster Status on sensory and hedonic evaluations of phenol-enriched bean cream

7.1 Introduction

In this chapter, the interactions among several dimensions, such as psychological traits, taste responsiveness, gender, and age, on the acceptability of bean purée prototypes mixed with different concentrations of phenol extract from Olive Mill Waste Water (OMWW) was investigated. The previous study (chapter 6; De Toffoli et al., 2019) demonstrated the existence of strong chemical interactions between functional phenols and food components. Proteins strongly interact with plant polyphenols through covalent and non-covalent binding, and high basic-residue content and open and flexible structure are the major features of proteins highly reactive with phenols (Kroll et al., 2003; Xiao & Kai, 2012; Zhang et al., 2014).

The formation of aggregates with proteins significantly affects the bioactivity of phenols (Kroll et al., 2014) and the perception of negative sensory properties. The binding of functional phenols with endogenous proteins represents an appropriate strategy to optimize the balance between health and sensory properties at the same time avoiding the use of exogenous ingredients/additives to counteract the impact of added phenols.

Several studies have reported that the perceived level of healthiness of food is frequently linked to naturalness (Román et al., 2017) and that functional foods perceived as natural are more likely to be consumed (Carrillo et al., 2013).

It is still unclear whether food rejection/acceptability is directly related to the perceived intensity of warning sensations. Additional factors may modulate this relationship and these factors need to be further investigated using a multidisciplinary approach.

Although some studies have investigated how attitudes affect functional food choice (Bower, Saadat, & Whitten, 2003; Cox, Koster, & Russell, 2004; Urala & Lähteenmäki, 2004), the literature on the role of psychological traits is quite limited, and the relationships between these variables remain unexplored (Urala & Lähteenmäki, 2004). Attitude can be defined as 'a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour' (Eagly & Chaiken, 1995). Because attitudes strongly affect food choice behaviour, they can help to explain the food choices of consumers (Roininen & Tuorila, 1999). Attitudes related to health (Urala, Arvola, & Lähteenmäki, 2003), naturalness (Frewer, Scholderer, & Lambert, 2003), and novelty seem to be essential for the prediction of choices of functional foods. Even the deep meaning that individuals attach to food in their lives can play a crucial role in the acceptance of healthy products that may have unpleasant sensory characteristics (Arbit, Ruby, & Rozin, 2017).

Laureati et al. (2018) and Spinelli et al. (2018) hypothesised that higher arousal in psychological traits related to anxiety could increase perceptual sensitivity via increased alertness when approaching food and that arousal could be unpleasant, leading to the dislike of a stimulus. This mechanism has been studied using familiar and accepted foods (e.g. chocolate pudding and tomato juice) and needs to be further investigated using functionalised foods.

The aims of the study were 1) to investigate the effect of phenol concentration on intensity of warning sensations and liking of bean purée samples; 2) to explore whether psychological traits, PROP status, and their interaction could affect the perceived intensity of target sensations and the acceptability of such functional foods; and 3) whether psychological traits could modulate the relationship between intensity and liking.

7.2 Materials and Methods

7.2.1 Participants

Data were collected from 797 subjects recruited by means of announcements published on blogs, social networks, emails, pamphlet distribution, and word of mouth. In the sample, 54.2% of the subjects were females with a mean age of 38.4 ± 13.2 (standard deviation) years. In order to explore possible age-related differences, subjects were divided into three age groups: 18–30 years (37.4%), 31–45 years (29.6%), and 46–60 years (33.0%).

7.2.2 Procedure

Participants were asked to complete an online questionnaire. They then attended two sessions at the laboratory. Socio-demographic information (gender, age, and education) were collected and during the laboratory sessions, participants were asked to taste bean cream prototypes mixed with different concentrations of phenols from Olive Mill Waste Water (OMWW) and to evaluate their liking for the samples and the intensity of target sensations. Before the evaluations, participants were informed that the samples were mixed with natural antioxidants that may have important positive effects on health.

To evaluate psychological traits, the participants were also asked to complete a set of questionnaires. PROP responsiveness was also assessed. The study included sensory tests, questionnaires, and the collection of other relevant data (see Chapter 3 for a complete overview of data collection), but only a number of variables are presented here.

7.2.2.1 Psychological traits

Participants completed questionnaires to assess the following psychological traits: alexithymia (TAS), food neophobia (FN), private body consciousness (PBC), sensation seeking (SS), sensitivity to core disgust (DS), sensitivity to punishment (SP) and reward (SR), state anxiety (STAI-S), and trait anxiety (STAI-T).

7.2.2.2 Food attitudes

Participants completed two questionnaires to assess food attitudes.

Health and Taste Attitude Scale (HTAS): This scale was developed by Roininen, Lähteenmäki and Tuorila (1999) and validated in Italian by Saba et al. (2019) to evaluate the importance that consumers assign to perceived health and hedonic characteristics of foods in relation to their food choices. The scale consists of six subscales focusing on perceived health and taste aspects of foods. The three subscales of health predicted general health interest (eight items that evaluate general interest in healthy eating), light product interest (six items that evaluate interest in eating reduced-fat or reduced sugar food products), and natural product interest (six items that evaluate interest in eating food that does not contain additives or food that is unprocessed). Only one of the three subscales of taste was considered in the present study: using food as a reward (six items that measure attitudes towards using foods as a reward). Craving for sweet food and Pleasure subscales are not relevant for this study. Each subscale is composed of an equal number of positively and negatively worded statements (Roininen et al., 1999). As proposed by Roininen et al. (1999), negative statements were reversed and re-coded for calculation of the final scores. All items were scored on a seven-point category scale with the scales labelled from 'disagree strongly' to 'agree strongly'. For each participant and each subscale, after the recodification of negatively-worded items, a mean score was computed from the individual scores.

Meaning of Food in Life Questionnaire (MFLQ): The meaning of food in life was quantified with the 21 items developed by Arbit, Ruby and Rozin (2017) using a 7-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. The meaning of food in life represents the degree to which people feel and comprehend their relationship with their food as having significance beyond the immediate demands of the situation and as connected to their larger life-world. Five domains are related to different meanings attributed to food: social (five items; food is a way to connect individuals to each other and with their cultural traditions), aesthetics (three items; food represents aesthetic experience), sacred (four items; food choices are a way to connect individuals with the sacred), health (four items; food is related to health and psychical and mental well-being), and moral (five items; food choices may impact the world and the natural environment). Individual scores were computed as the mean of ratings given to the statements of each domain. Scores ranged from 1 to 7, with a higher score indicating a greater importance of the factors to the general construct of the meaning of food in life.

7.2.2.3 PROP status

PROP taster status was assessed using a 3.2 mM PROP solution, prepared by dissolving 0.545 g/L of 6-n-propyl-2-thiouracil (European Pharmacopoeia Reference Standard, Sigma Aldrich, Milano, IT) in deionised water (for example, see Prescott, Soo, Campbell, & Roberts,2004). Subjects were presented with two identical 10 ml samples, each coded with a three-digit code. Subjects were instructed to hold each sample in their mouth for 10 s, then expectorate, wait 20 s, and evaluate the intensity of bitterness using the gLMS (Bartoshuk et al., 2004). Each subject had a 90-s break in order to control for carry-over effects after the first sample evaluation. During the break, subjects rinsed their mouth with distilled water for 30 s, ate some plain crackers for 30 s, and finally rinsed with water for a further 30 s. PROP taster status was based on the average rating of the two replicates, and groupings were based on arbitrary cut-offs (Fischer et al., 2013; Hayes et al., 2010): PROP non-tasters (NT)<17; PROP medium-tasters (MT), 17–53; and PROP super-tasters (ST)>53 on the gLMS.

7.2.2.4 Intensity and liking ratings of bean purée mixed with OMWW

Based on the previous study (chapter 6; De Toffoli et al., 2019), bean purée prototypes were selected for this study. Four samples varying in phenol concentration were produced by adding different amounts of phenol extract from OMWW (C0 = 0 g/kg; C1 = 0.44 g/kg; C2 = 1.00 g/kg; and C3 = 2.25 g/kg) to the bean purée. The addition of phenols was expected to increase bitterness, astringency, and overall flavour, while decreasing liking. The choice of phenol concentrations was based on previous results (De Toffoli et al., 2019).

Firstly, liking was evaluated using the Labelled Affective Magnitude Scale, LAM (0–100) (Schutz & Cardello, 2001) and secondly, the intensity of bitterness, astringency, and overall flavour for each of the samples was evaluated using the generalized Labelled Magnitude Scale, gLMS (0–100) (Bartoshuk et al., 2004). The experiment conductors provided instructions for the use of both scales prior to tasting.

In each session, samples were served at room temperature and presented simultaneously in plastic cups coded with 3-digit numbers. Each sample consisted of 6 g of bean purée. The respondents were instructed to eat one spoon full of the bean purée provided prior to rating liking/intensity. An interval of 90 s was allowed between tastings, during which water (tap or mineral water) was provided for palate cleansing. The order of the sample presentation was systematically varied according to a William's Latin square.

7.2.3 Data analysis

Cronbach's α and item-total correlations were computed to assess the internal reliability of each psychological trait and food attitude questionnaire. Pearson's correlation coefficients were computed for an overall view of the relationships between psychological traits.

Two-way analysis of variance (ANOVA) models were used to determine the main effects of gender (male or female), age class (18–30, 31–45, and 46–60), and their interactions on psychological trait, PROP bitterness intensity, and food attitude scores.

Based on the median, the participants were added to groups which comprised of subjects that expressed either low or high levels of each trait and food attitude. Participants with a median score were not considered.

One-way ANOVA was used to further characterise subjects as having either a high or low state of anxiety and to investigate the effect of state anxiety on psychological traits and food attitudes.

Two-way ANOVA models were used to test the effects of samples (C0, C1, C2, and C3), psychological trait level (Low or High), food attitudes (Low or High), PROP status (NT, MT, or ST), and their interactions on bitterness, astringency, overall flavour, and liking of bean purée samples.

Principal component analysis on psychological traits that played a role in the sensory and hedonic evaluations of samples was computed and two clusters based on the first component were identified. One-way ANOVA models were used to test the effect of cluster on psychological traits, PROP responsiveness, and food attitudes. Two-way ANOVA models were used to evaluate the effect of cluster, sample, and their interaction on bitterness, astringency, overall flavour, and liking of bean purée samples.

Frequency distribution, mean, and median of liking for each sample were calculated. Based on the median of C1, subjects were divided into Likers and Dislikers. One-way ANOVA models were used to further characterise these groups and to test the effect of cluster (Likers or Dislikers) on perceived intensity of sensory properties of C1, psychological traits, PROP responsiveness, and food attitudes.

A *p*-value of 0.05 was considered the threshold for statistical significance and post-hoc testing was performed using the Bonferroni test adjusted for multiple comparisons.

The XLSTAT statistical software package version 19.02 (Addinsoft) was used for data analysis.

7.3 Results

7.3.1 The reliability of questionnaires and correlations between psychological traits

The internal reliability of the questionnaires for evaluating psychological traits and food attitudes was satisfactory, with Cronbach's alpha ranging from 0.63 to 0.91 and from 0.68 to 0.82, respectively (Table 19). The Cronbach's alpha for social and aesthetic domains of MFLQ was low (0.55 and 0.58, respectively). Therefore, the social and aesthetic domains of MFLQ were not considered in the analysis.

Item-total correlation analyses were performed. Nearly all item-total correlations were more than 0.4, indicating good internal consistency, and correlations between domains and total scores were significant ($p<0.05$) and consistent. Only the item 'I am polite and attentive to someone even if I do not find their conversation interesting' of the sensation seeking questionnaire (boredom susceptibility subscale) was weakly correlated with the total score ($r=0.15$). Therefore, it was not considered in the analysis.

Based on the median, the participants were added to groups which comprised of subjects that expressed either low or high levels of each trait and food attitude (Table 19). Participants with a median score were not considered.

Table 19. Psychological traits and food attitudes questionnaires: the internal reliability (Cronbach's α– α), median, and number of observations for each group (Low; High) are reported.

Psychological trait	α	Median	n Low	n High
DS	0.67	30	377	362
FN	0.88	26	376	393
PBC	0.74	18	348	363
SP	0.84	9	380	352
SR	0.78	5	336	373
SS	0.87	93	384	394
SS - BS	0.75	18	350	377
SS - ES	0.75	28	336	389
SS - TAS	0.76	23	390	356
SS - D	0.73	24	361	384
STAI-S	0.88	30	338	390
STAI-T	0.91	40	392	362
TAS	0.83	47	393	373
TAS - DDF	0.76	13	359	354
TAS - DIF	0.83	15	382	347
TAS - EOT	0.63	16	376	335
MFLQ – moral	0.74	5.2	375	359

MFLQ – sacred	0.78	3.5	364	384
MFLQ – health	0.68	5.7	335	377
HTAS – general health interest	0.79	37	387	383
HTAS – natural health interest	0.74	26	374	378
HTAS – light product interest	0.82	22	385	365
HTAS – food as reward	0.78	26	367	388

DS: sensitivity to disgust, FN: food neophobia, PBC: private body consciousness, SP: sensitivity to punishment, SR: sensitivity to reward, SS: sensation seeking, SS – BS: boredom sensitivity, SS – ES: experience seeking, SS – TAS: thrill and adventure seeking, SS – D: disinhibition, STAI-S: state anxiety, STAI-T: trait anxiety, TAS: alexithymia, TAS – DDF: Difficulty Describing Feelings, TAS – DIF: Difficulty Identifying Feeling, TAS – EOT: Externally-Oriented Thinking, MFLQ: Meaning of Food in Life Questionnaire, HTAS: Health and Taste Scale

Pearson's correlation coefficient within psychological traits and PROP responsiveness are shown in Table 20. Psychological traits were strongly correlated. Food neophobia, sensitivity to punishment, and alexithymia were strongly associated with anxiety. Sensation seeking and sensitivity to reward were strongly correlated with each other.

PROP responsiveness was weakly correlated only with sensitivity to disgust and state anxiety.

Table 20. Pearson correlation coefficients within psychological traits and PROP responsiveness. Significant correlations are emboldened (p<0.028).

Variables	DS	FN	PBC	SP	SR	SS	STAI-T	STAI-S	TAS	PROP
DS	**1.00**	**0.31**	**0.15**	**0.18**	**-0.13**	**-0.36**	**0.08**	0.07	0.01	**0.09**
FN	**0.31**	**1.00**	-0.03	**0.13**	**-0.08**	**-0.32**	0.04	**0.11**	**0.19**	0.03
PBC	**0.15**	-0.03	**1.00**	**0.13**	**0.08**	0.03	**0.09**	0.01	-0.05	0.02
SP	**0.18**	**0.13**	**0.13**	**1.00**	**0.09**	**-0.15**	**0.54**	**0.34**	**0.45**	0.02
SR	**-0.13**	**-0.08**	**0.08**	**0.09**	**1.00**	**0.33**	**0.13**	0.05	**0.16**	0.02
SS	**-0.36**	**-0.32**	0.03	**-0.15**	**0.33**	**1.00**	0.02	-0.01	0.04	-0.01
STAI-T	**0.08**	0.04	**0.09**	**0.54**	**0.13**	0.02	**1.00**	**0.53**	**0.38**	0.04
STAI-S	0.07	**0.11**	0.01	**0.34**	0.05	-0.01	**0.53**	**1.00**	**0.29**	**0.10**
TAS	0.01	**0.19**	-0.05	**0.45**	**0.16**	0.04	**0.38**	**0.29**	**1.00**	0.01
PROP	**0.09**	0.03	0.02	0.02	0.02	-0.01	0.04	**0.10**	0.01	**1.00**

DS: sensitivity to disgust, FN: food neophobia, PBC: private body consciousness, SP: sensitivity to punishment, SR: sensitivity to reward, SS: sensation seeking, STAI-S: state anxiety, STAI-T: trait anxiety, TAS: alexithymia, PROP: PROP status

Pearson's correlation coefficients within food attitudes questionnaires are shown in Table 21. All MFLQ domains were strongly correlated. HTAS subscales were partially correlated. General health interest was positively correlated with natural product interest and negatively correlated with using food as reward. Light product interest was not correlated with general health interest and with natural product interest and was weakly correlated with using food as reward.

Table 21. Pearson correlation coefficients within food attitudes subscales (MFLQ and HTAS). Significant correlations are emboldened (p=0.045).

Variables	MFLQ - moral	MFLQ - sacred	MFLQ - health	HTAS - general health interest	HTAS - light product interest	HTAS - natural product interest	HTAS - using food as a reward
MFLQ - moral	**1.00**	**0.47**	**0.46**	**0.32**	**-0.10**	**0.37**	0.02
MFLQ - sacred	**0.47**	**1.00**	**0.12**	**0.20**	-0.05	**0.27**	**0.09**
MFLQ - health	**0.46**	**0.12**	**1.00**	**0.44**	0.04	**0.34**	**-0.12**
HTAS - general health interest	**0.32**	**0.20**	**0.44**	**1.00**	-0.01	**0.51**	**-0.20**
HTAS - light product interest	**-0.10**	-0.05	0.04	-0.01	**1.00**	-0.06	**0.10**
HTAS - natural product interest	**0.37**	**0.27**	**0.34**	**0.51**	-0.06	**1.00**	**-0.12**
HTAS - using food as a reward	0.02	**0.09**	**-0.12**	**-0.20**	**0.10**	**-0.12**	**1.00**

MFLQ: Meaning of Food in Life Questionnaire, HTAS: Health and Taste Scale

7.3.2 Effects of gender and age on psychological traits and PROP status

Both gender and age affected individual variation in the majority of psychological traits (Table 22). A significant gender effect was found for all psychological traits except for food neophobia, two sensation seeking subscales (boredom susceptibility and thrill and adventure seeking), and the difficulty in identifying feeling subscale of alexithymia. Females had significantly higher sensitivity to disgust, private body consciousness, sensitivity to punishment, and state and trait anxiety than males, while males were more sensitive to reward, sensation seeking, and alexithymia.

A significant age effect was found for all psychological traits except the private body consciousness and the externally oriented thinking subscale of alexithymia. Sensitivity to punishment, sensitivity to reward, sensation seeking, state and trait anxiety, and alexithymia decreased with age, while food neophobia and sensitivity to disgust increased with age.

Some effects were further characterised by an interaction between gender and age. A decrease in sensitivity to punishment with age was found in females, but not in males, and a decrease in sensitivity to reward, sensation seeking, and difficulty describing feelings with age was found in males, but not in females. Moreover, an increase in food neophobia with age was found in males, but not in females.

Table 22. Two-way ANOVA: gender, age and their interaction effect on psychological traits and PROP bitterness scores. F, p, and mean values. Significant differences are emboldened (p<0.05).

Psychological traits	**Gender**				**Age**					**Gender*Age**	
	F	**p-value**	**mean values**		**F**	**p-value**	**mean values**			**F**	**p-value**
			Males	**Females**			**18-30**	**31-45**	**46-60**		
DS	**61.3**	**<0.00**	**27.7**	**30.8**	**5.7**	**0.00**	**28.5 b**	**29.2 ab**	**30.1 a**	0.7	0.48
FN	0.2	0.67	27.8	27.4	**8.2**	**0.00**	**26.1 b**	**26.7 b**	**29.9 a**	**7.1**	**0.00**
PBC	**38.6**	**<0.00**	**16.5**	**18.3**	1.1	0.33	17.7 a	17.2 a	17.4 a	0.2	0.81
SP	**21.8**	**<0.00**	**8.1**	**9.7**	**17.6**	**<0.00**	**10.1 a**	**9.0 a**	**7.6 b**	**4.4**	**0.01**
SR	**48.8**	**<0.00**	**6.5**	**4.8**	**37.1**	**<0.00**	**6.9 a**	**5.6 b**	**4.4 c**	**4.1**	**0.02**
SS	**20.3**	**<0.00**	**95.7**	**90.7**	**22.4**	**<0.00**	**98.0 a**	**92.1 b**	**89.5 b**	**4.4**	**0.01**
SS – BS	0.8	0.36	18.5	18.2	**6.9**	**0.00**	**19.1 a**	**18.1 b**	**17.8 b**	**4.8**	**0.01**
SS – ES	0.1	0.75	27.9	28.0	**13.6**	**<0.00**	**29.2 a**	**27.7 b**	**27.0 b**	**2.9**	**0.06**
SS - TAS	**80.4**	**<0.00**	**24.5**	**21.0**	**14.1**	**<0.00**	**24.2 a**	**22.2 b**	**21.9 b**	1.2	0.30
SS - D	**14.0**	**0.00**	**24.8**	**23.6**	**25.4**	**<0.00**	**25.6 a**	**24.2 b**	**22.8 c**	**3.9**	**0.02**
STAI - S	**12.7**	**0.00**	**30.4**	**32.1**	**10.3**	**<0.00**	**32.5 a**	**31.4 ab**	**29.9 b**	2.5	0.09
STAI - T	**9.7**	**0.00**	**39.4**	**41.4**	**25.8**	**<0.00**	**43.0 a**	**40.4 b**	**37.8 c**	1.1	0.33
TAS	**11.9**	**0.00**	**48.2**	**45.4**	**4.3**	**0.01**	**48.4 a**	**46.0 b**	**46.0 b**	2.7	0.07
TAS - DDF	**10.4**	**0.00**	**13.4**	**12.4**	**4.5**	**0.01**	**13.5 a**	**12.8 ab**	**12.4 b**	**5.9**	**0.00**
TAS - DIF	0.0	0.85	15.3	15.4	**6.4**	**0.00**	**16.3 a**	**14.7 b**	**15.0 b**	1.3	0.27
TAS - EOT	**30.2**	**<0.00**	**16.9**	**15.2**	0.0	0.97	16.1 a	16.1 a	16.0 a	0.4	0.68
PROP	**14.6**	**0.00**	**48.6**	**56.1**	0.1	0.87	53.1 a	51.9 a	52.1 a	0.2	0.80

DS: sensitivity to disgust, FN: food neophobia, PBC: private body consciousness, SP: sensitivity to punishment, SR: sensitivity to reward, SS: sensation seeking, SS – BS: boredom sensitivity, SS – ES: experience seeking, SS – TAS: thrill and adventure seeking, SS – D: disinhibition, STAI-S: state anxiety, STAI-T: trait anxiety, TAS: alexithymia, TAS – DDF: Difficulty Describing Feelings, TAS – DIF: Difficulty Identifying Feeling, TAS – EOT: Externally-Oriented Thinking, PROP: PROP status

Gender affected responsiveness to PROP (Table 22) with females more responsive than males, while no effect of age and its interaction with gender on PROP bitterness scores was found.

7.3.3 Effects of gender and age on food attitudes

The effects of gender and age on food attitude are shown in Table 23.

The scores for the Moral and Health domains of the Meaning of Food in Life Questionnaire (MFLQ) were significantly affected by gender, with females having higher scores in both scales. Age did not affect any domain and no significant interaction between gender and age was detected.

Both gender and age affected individual variation in most Health and Taste subscales. A significant gender effect was found for general health interest, natural product interest, and using food as reward, with females having higher scores than males. A significant age effect was found for all the subscales. Light product interest and using food as reward decreased with age, while general health interest and natural product interest increased with age. None of these effects were affected by interactions between gender and age.

Table 23. Two-way ANOVA: effect of gender, age, and their interaction on food attitude. F, p, and mean values. Significant differences are emboldened (p<0.05).

Attitudes	Gender				Age					Gender*Age	
	F	p-value	mean values		F	p-value	mean values			F	p-value
			Males	Females			18-30	31-45	46-60		
MFLQ - moral	**7.4**	**0.0**	**4.9 b**	**5.1 a**	0.5	0.6	5.0 a	5.1 a	5.1 a	0.1	0.9
MFLQ - sacred	2.1	0.1	3.4 a	3.6 a	0.2	0.8	3.5 a	3.4 a	3.5 a	0.2	0.8
MFLQ - health	**16.1**	**< 0.0001**	**5.5 b**	**5.8 a**	2.8	0.1	5.6 a	5.7 a	5.7 a	0.0	1.0
HTAS - general health interest	**23.9**	**< 0.0001**	**35.4 b**	**38.3 a**	**5.2**	**0.0**	**35.7 b**	**36.9 ab**	**37.9 a**	0.1	0.9
HTAS - light product interest	2.4	0.1	21.3 a	20.5 a	**12.2**	**< 0.0001**	**22.0 a**	**21.4 a**	**19.2 b**	1.3	0.3
HTAS - natural product interest	**9.7**	**0.0**	**25.4 b**	**26.9 a**	**11.3**	**< 0.0001**	**24.8 b**	**26.3 a**	**27.5 a**	0.1	0.9
HTAS - using food as a reward	**8.4**	**0.0**	**25.5 b**	**26.9 a**	**13.0**	**< 0.0001**	**27.2 a**	**27.1 a**	**24.4 b**	0.6	0.6

MFLQ: Meaning of Food in Life Questionnaire, HTAS: Health and Taste Scale

7.3.4 Effects of psychological traits and PROP status on sensory evaluations and the role of state anxiety

Samples. Two-way ANOVA showed that bitterness (F=785.79, p>0.0001), astringency (F=109.86, p<0.0001), and overall flavour (F=440.85, p<0.0001) increased with increasing OMWW concentration (Figure 10).

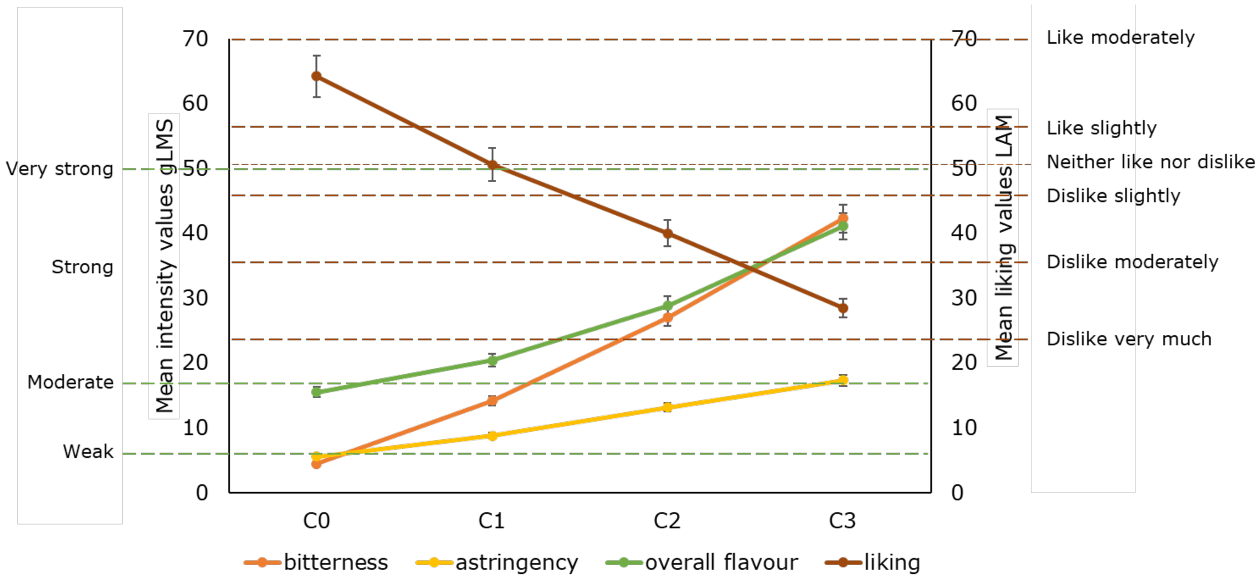


Figure 10. Mean intensity ratings for bitterness, astringency, overall flavour, and mean liking ratings by sample (C0, C1, C2, and C3). Error bars are standard errors.

Psychological traits. Food neophobia significantly affected the intensity of astringency (F=42.5, p<0.0001) and overall flavour (F=5.1, p=0.025). Sensitivity to disgust affected overall flavour (F=13.6, p=0.000). Sensitivity to punishment affected astringency (F=5.1, p=0.024) and sensitivity to reward significantly affected bitterness (F=4.4, p=0.036) and astringency (F=18.1, p=0.000).

State and trait anxiety significantly affected bitterness (F=4.1, p=0.043 and F=6.9, p=0.009) and astringency (F=25.5, p<0.0001 and F=14.1, p=0.000). State anxiety also affected overall flavour (F=5.2, P=0.022).

Alexithymia significantly affected astringency (F=10.9, p=0.001), similar to all its three subscales: difficulty describing feelings (F=15.5, p<0.0001), difficulty identifying feeling (F=16.7, p<0.0001), and externally oriented thinking (F=25.1, p<0.0001).

Subjects high in these traits perceived the target sensations as more intense than the others.

The thrill and adventure seeking subscale of sensation seeking significantly affected bitterness (F=6.3, p=0.012) and overall flavour (F=5.7, p=0.017), and experience seeking affected astringency (F=5.3, p=0.022). High sensation-seeking subjects perceived the target sensations as less intense than the other subjects.

Some effects were further characterised by interaction between the sample and trait. Subjects with high food neophobia perceived C2 and C3 as more astringent (F=3.9, p=0.008) and C3 as more intense in terms of overall flavour (F=3.4, p=0.017) than subjects with low food neophobia.

The most phenol-enriched sample was perceived as less bitter and less astringent by thrill- and adventure-seeking ($F=4.8$, $P=0.002$) and experience-seeking ($F=2.6$, $p=0.05$) subjects, respectively.

Further analysis revealed that the group with high state anxiety was also characterised by higher food neophobia ($F=10.8$, $p=0.001$), sensitivity to punishment ($F=70.5$, $p<0.0001$), trait anxiety ($F=160.4$, $p<0.0001$), and alexithymia ($F=54.7$, $p<0.0001$) scores than the group with low state anxiety. Subjects with low state anxiety had higher experience-seeking scores ($F=5.0$, $p=0.025$), showed greater natural product interest ($F=6.8$, $p=0.009$), and considered the health domain to be more important ($F=9.1$, $p=0.002$). No differences between groups were detected in terms of perceived bitterness intensity of PROP.

PROP status. PROP status significantly affected bitterness ($F=26.0$, $p<0.0001$), astringency ($F=20.3$, $p<0.0001$), and overall flavour ($F=17.0$, $p<0.0001$), with ST rating sensory properties as more intense than MT and NT. An effect of the interaction between the samples and the PROP status was observed. ST and MT perceived the bitterness of C1 as more intense than non-tasters ($F=3.5$, $p=0.002$).

7.3.5 Effects of psychological traits and PROP status on hedonic evaluations

The two-way ANOVA showed that liking significantly decreased with increasing OMWW concentration ($F=630.58$, $p<0.0001$) (Figure 10).

Sensation seeking ($F=6.3$, $p=0.012$), difficulty describing feelings ($F=4.6$, $p=0.03$), and difficulty identifying feeling ($F=5.6$, $p=0.018$) significantly affected liking. High sensation-seeking subjects, and subjects who had greater difficulty describing and identifying feelings liked these samples more than low sensation-seeking subjects, and subjects who had less difficulty describing and identifying feelings. Other psychological traits and PROP statuses did not affect the hedonic evaluation of the samples.

7.3.6 Effects of food attitudes on sensory and hedonic evaluations

The sacred ($F=7.4$, $p=0.007$) and health ($F=4.2$, $p=0.04$) domains of the MFLQ and the light product interest ($F=4.8$, $p=0.03$) and natural product interest ($F=4.9$, $p=0.03$) domains of the HTAS significantly affected bitterness. Subjects with high scores in the sacred, health, light product interest, and general product interest domains perceived the samples as more intense.

The scores in the general health interest ($F=8.0$, $p=0.005$), light product interest ($F=39.5$, $p<0.0001$), and natural product interest ($F=13.5$, $p=0.000$) domains of the HTAS significantly affected astringency. Subjects with high general health interest and natural product interest showed a reduced astringency perception compared to subjects with low general health and natural product interest.

The scores in the sacred (F=5.3, p=0.02) and health (5.8, p=0.02) domains of the MFLQ and the light product interest (F=15.2, p=0.000) and using food as reward (F=5.0, p=0.025) domains of the HTAS significantly affected overall flavour. Subjects with high scores in the aforementioned domains perceived the overall flavour of the samples as more intense.

The scores in the moral (F=17.6, p<0.0001), sacred (F=26.9, p<0.0001), and health (F=6.2, p=0.01) domains of the MFLQ significantly affected liking. Subjects with high scores in the moral and sacred domains liked the samples more while those with high scores in the health domain liked the samples less.

7.3.7 Consumer segmentation based on psychological traits

7.3.7.1. Consumer segmentation and characterization

As many factors affected sensory and hedonic evaluations of samples, principal component analysis was performed on the psychological traits that played a role in the evaluations to obtain a general and more comprehensive overview of the impact of these variables. The first two dimensions explained 56.45% of the variance and the first component allowed the separation of subjects into two clusters (Figure 11).

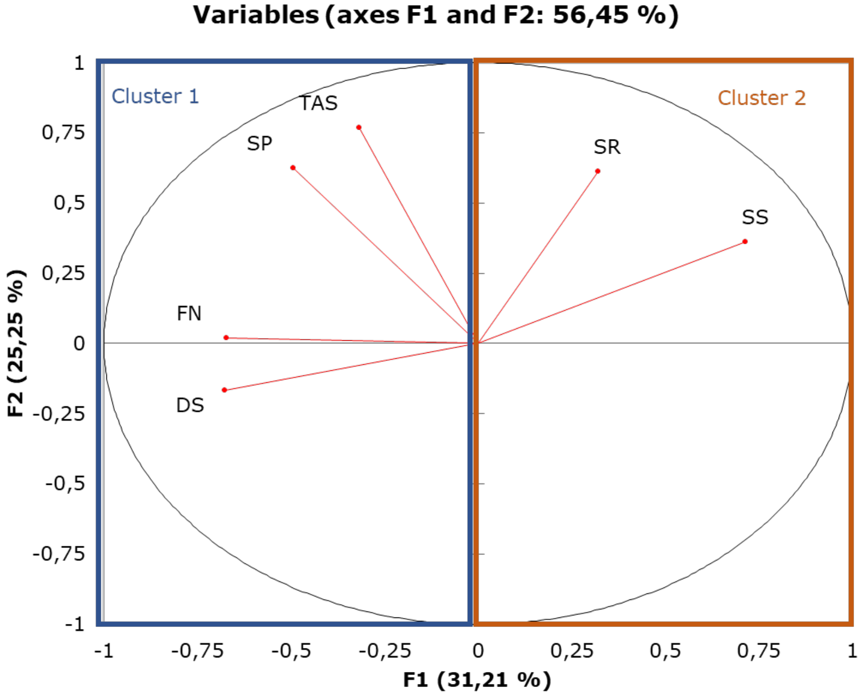


Figure 11. Principal component analysis of psychological traits that played a role in the sensory and hedonic evaluations of samples.

Cluster 1 was mainly composed of females (p<0.0001) and older people (F=10.4, p<0.001) with high alexithymia, sensitivity to disgust, food neophobia, sensitivity to punishment, and state and trait anxiety. Cluster 2 was composed mainly of males and high sensation-seeking individuals with high sensitivity to reward, who considered the moral and sacred domains to be important (Table 23).

Table 23. One-way ANOVA: effect of cluster on psychological traits, PROP bitterness scores, and food attitudes. F, p, and mean values. Significant differences are emboldened (p<0.05).

Variables	F	p value	Cluster 1	Cluster 2
PBC	0.0	0.959	17.5 a	17.5 a
SS - BS	**175.9**	**< 0.0001**	**16.6 b**	**20.1 a**
SS - ES	**232.8**	**< 0.0001**	**25.7 b**	**30.5 a**
SS - TAS	**189.2**	**< 0.0001**	**20.2 b**	**25.3 a**
SS - D	**234.1**	**< 0.0001**	**22.0 b**	**26.5 a**
STAI-S	**23.3**	**< 0.0001**	**32.6 a**	**30.2 b**
TAS - DDF	**25.4**	**< 0.0001**	**13.7 a**	**12.1 b**
TAS - DIF	**18.7**	**< 0.0001**	**16.3 a**	**14.5 b**
TAS - EOT	**54.2**	**< 0.0001**	**17.0 a**	**14.9 b**
PROP	0.2	0.674	53.3 a	52.4 a
HTAS - General health interest	1.6	0.203	37.3 a	36.5 a
HTAS - Light product interest	2.9	0.090	21.3 a	20.4 a
HTAS - Natural product interest	0.3	0.592	26.3 a	26.0 a
HTAS - Using food as a reward	0.0	0.851	26.2 a	26.3 a
MFLQ - Moral	**8.4**	**0.004**	**4.9 b**	**5.1 a**
MFLQ - Sacred	**8.2**	**0.004**	**3.3 b**	**3.6 a**
MFLQ - Health	1.6	0.211	5.7 a	5.6 a

PBC: private body consciousness, SS – BS: boredom sensitivity, SS – ES: experience seeking, SS – TAS: thrill and adventure seeking, SS – D: disinhibition, STAI-S: state anxiety, TAS – DDF: Difficulty Describing Feelings, TAS – DIF: Difficulty Identifying Feeling, TAS – EOT: Externally-Oriented Thinking, PROP: PROP status, MFLQ: Meaning of Food in Life Questionnaire, HTAS: Health and Taste Scale

7.3.5.2 Effect of consumer segmentation on sensory and hedonic evaluations

The cluster significantly affected bitterness (F=4.0. p=0.05), astringency (F=7.7. p=0.005), and overall flavour (F=10.9. p=0.001). Cluster 1 perceived the target sensations as more intense than Cluster 2. Even though the difference in liking did not reach significance, Cluster 1 tended to like the samples less. The effect of the interaction between cluster and sample on overall flavour was significant (F=2.6. p=0.05), with Cluster 1 perceiving the overall flavour of C3 as more intense than Cluster 2 (Figure 12 a-d).

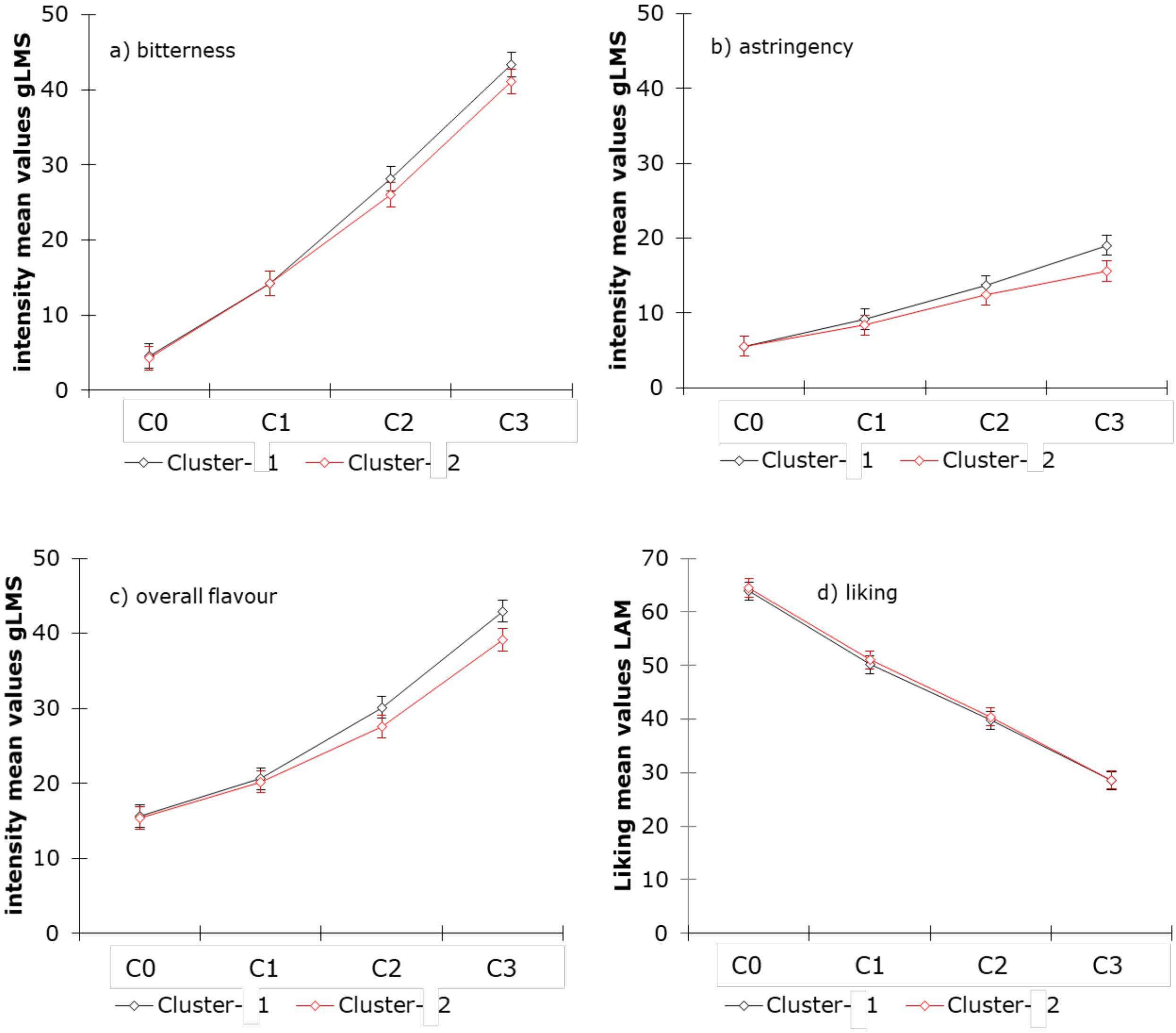


Figure 13. Mean intensity ratings for bitterness (a), astringency (b), overall flavour (c), and mean liking ratings (d) by sample and by Cluster. Error bars are standard errors.

7.3.6 Consumer segmentation based on liking for the first sample mixed with OMWW

Findings revealed a clear impact of previous consumer segmentation on the perceived intensity of target sensations; however, cluster did not affect the acceptability of these products. As the median of the liking for the first sample added with phenol extracts from OMWW (C1) was exactly 50 on LAM that corresponds to "Neither like nor dislike", the attention has been focused on this condition that may maximise any individual differences in order to highlight possible variations that can modulate the acceptability of this sample.

The population was grouped into Likers (above the median) and Dislikers (below the median) to verify if these groups differ according to each of the variables.

The cluster significantly affected the perception of sensory properties of C1. Likers perceived bitterness ($F=85.1$. $p<0.0001$), astringency ($F=9.5$. $P=0.002$), and overall flavour ($F=19.6$. $p<0.0001$) as less intense than Dislikers.

There were no differences in clusters according to the PROP responsiveness, psychological traits, and Health and Taste attitudes. Likers reported higher scores for the sacred domain ($F=7.5$. $p=0.006$) and lower scores for the health domain ($F=9.8$. $p=0.002$) of MFLQ compared to Dislikers.

7.4 Discussion

The characteristics of the population participating in the study confirmed existing data on gender and age effects on psychological traits and PROP status. We found no effect of gender on neophobia, in line with previous findings that reported no (De Toffoli et al., 2019; Knaapila et al., 2015) or little (Monteleone et al., 2017) effect. We also confirmed an increase in neophobia with age (Bäckström. Pirttilä-Backman. & Tuorila, 2003; De Toffoli et al., 2019; Meiselman et al., 2010; Siegrist et al., 2013; Tuorila et al., 2001). The effect of gender on the other traits was also consistent with the results of previous studies which showed that females were more sensitive to punishment than males, and males were more sensitive to reward than females (Caseras et al., 2003; De Toffoli et al., 2019; Torrubia et al., 2001). Females were more sensitive to disgust (De Toffoli et al., 2019; Spinelli et al., 2018) and males were significantly high sensation-seekers (Aluja, Kuhlman, & Zuckerman, 2010) and had high alexithymia (Parker et al.,1993; Spinelli et al., 2018). Anxiety was clearly affected by gender, with females having high state and trait anxiety. This confirms the high prevalence of anxiety disorders in females (Bruce et al., 2005).

For age, with some exceptions, comparison with previous studies was limited. This is because the available literature contains information on either younger individuals or a specific age range. In line with previous results, we found a decrease in alexithymia and sensitivity to punishment and reward with age (De Toffoli et al., 2019; Spinelli et al., 2018). Additionally, sensation seeking and state and trait anxiety decreased with age, confirming previous results (Roberti, 2004; Spielberger, 2008).

Results from this study confirmed previous findings on the gender effect on PROP responsiveness. In the present study, females rated PROP bitterness higher than males. This confirms the results of previous studies which showed that females are more sensitive to PROP than males (Bartoshuk, 2000; De Toffoli et al., 2019; Monteleone et al., 2017; Zhao & Tepper, 2007). In our sample, we found no effect of age on PROP responsiveness, in contrast to the findings of other studies (Bartoshuk, 2000; De Toffoli et al., 2019; Monteleone et al., 2017; Zhao & Tepper, 2007).

Females showed higher scores in general health interest, natural product interest, and using food as reward subscales of Health and Taste Scale and in moral and health domains of Meaning of Food in Life Questionnaire. Light product interest and using food as reward decreased with age, while general health interest and natural product interest increased with age. Age did not affect any domain of the Meaning of Food in Life Questionnaire. Our findings on food attitudes confirmed that females have higher general health interest and natural product interest, and assigned higher scores to the using food as reward subscale of the Health and Taste Attitude Scale and that individuals are more concerned about consuming healthy foods as they age (Monteleone et al., 2017; Roininen et al., 1999, 2001; Saba et al., 2019). Meaning of Food in Life Questionnaire is a relatively recent tool and to our knowledge no study on the effects of gender and age on this scale has been conducted thus impairing the comparison with pre-existing data.

In line with previous results, phenols positively affected the perceived intensity of bitterness, astringency, and overall flavour, and negatively affected liking that ranged from 'Likely moderately' of the sample without OMWW extract (C0) to 'Dislike very much' of the most enriched sample (C3) (Dinnella et al. 2011; Drewnowski & Gomez-Carneros 2000; Lesschaeve & Noble. 2005; Vitaglione et al. 2015). Taste is one of the most important choice factors when choosing functional foods (Urala & Liisa, 2003) and Tuorila & Cardello (2002) demonstrated that bitter and salty off-flavours decreased the liking and likelihood of consumption of juice samples that were reported to be healthy. These results confirmed the innate dislike and aversion to bitterness and astringency, as they represent potential sources of toxic compounds and rotten and/or unripe food (Laureati, Pagliarini, Toschi, Monteleone, 2015), which may have anti-nutritional effects in animals and humans by reducing the digestibility of dietary proteins (Dinnella et al., 2011; Melis et al., 2017). Therefore, despite the binding effect of endogenous proteins, the warning properties were still clearly perceptible, compromising the acceptability of the phenol-enriched product. However, phenol extracts were added to a plain vegetable matrix and a large margin of improvement with adequate culinary preparations may be conceivable.

PROP status and psychological traits and PROP status significantly affected the perception of target sensations, confirming the impact of these factors on the perceived intensity of warning sensations. However, no significant correlations between PROP status and psychological traits, except weak correlations between PROP status and sensitivity to disgust and state anxiety, were found. These results lead us to suggest that the differences in perception noted for the traits may be not associated with a differential taste responsiveness, but rather with the anxiety associated with food experience in those high in these traits. This also confirms the hypothesis that the reason for these different responses to warning sensations is not only due to a differential taste function but also to the meaning associated with the stimulus.

Responsiveness to PROP significantly increased the perception of bitterness, astringency, and overall flavour, similar to results of previous studies (Bartoshuk et al. 1988; Dinnella et al. 2018; Laureati et al. 2018; Spinelli, De Toffoli, Dinnella, Laureati, Pagliarini, Bendini, Braghieri, Gallina, et al. 2018; Tepper et al. 2009). However, it did not affect liking, confirming that how these differences in perception are related to food acceptance is unclear.

Some studies have shown that PROP tasters give lower acceptance ratings to bitter foods, including coffee, cheddar cheese, tofu, and Japanese green tea (Akella, Henderson, & Drewnowski, 1997; Drewnowski, Henderson, Levine, & Hann, 1999; Ly & Drewnowski, 2001) and some studies (Intranuovo & Powers. 1998), but not others (Mela. 1990) have shown that liked more dark beer and ales than non-tasters. To our knowledge, the influence of PROP status on preferences for functional foods characterised by warning sensations has not been investigated in other studies.

Subjects high in psychological traits related to anxiety, such as food neophobia, sensitivity to disgust, sensitivity to punishment, and alexithymia, perceived the warning sensations as more intense than subjects low in these traits. We may hypothesise that anxiety and its related traits may affect the perception of target sensations attributing to them a 'warning and dangerous' meaning. This makes people more vigilant when approaching and eating these foods. This meaning attribution may put individuals in a more anxious state, leading to them perceiving the warning sensations with a heightened intensity. This explanation is in line with previous studies that reported that healthy individuals with mild anxiety were more sensitive to sensory inputs, such as pain (Thompson. Keogh. French. & Davis. 2008), tone loudness (Dess & Edelheit. 1998), and bitter, sweet, and salty tastes (Ileri-Gurel, Pehlivanoglu, & Dogan. 2013; Platte, Herbert, Pauli, & Breslin, 2013).

In addition, neophobics exhibited higher physiological arousal (pulse, GSR, respirations) than neophilics when presented with food stimuli (Raudenbush & Capiola. 2012) and were also found to be more sensitive to threatening information, which may be due to a generalised enhanced vigilance in this subject group (Mogg & Marden, 1990). As such, eating might be expected to generate a relatively low level of pleasure or reward compared to that experienced by those with lesser degrees of food neophobia. Thus, within this group, the probability of being 'pleasantly surprised' by food is low (Jaeger et al., 2017).

Additionally, subjects high in sensation seeking perceived warning sensations as more intense than subjects low in this trait. We may hypothesise that sensation seeking, which was negatively correlated with food neophobia (Pliner & Hobden, 1992), could affect the perception of target sensations by attributing to them a ‘novelty and curious’ meaning. This makes individuals more relaxed when approaching and eating phenol-enriched foods. High sensation-seeking individuals look for new sensations, may experience less stress, and may be more resilient, fearless, and calm in the face of danger than low sensation-seeking individuals (Ravert et al., 2013).

Warning sensations were not expected in the bean purée samples and their perception may support their search for new sensations and put individuals high in sensation seeking in a lower arousal state. This can make individuals perceive the sensations with reduced ease and with a diminished intensity, in line with Zuckerman's individual difference approach to optimal levels of arousal (Zuckerman. 1979). This explanation is supported by the definition for sensation seekers: individuals who are willing to seek out novel, complex, and intense stimuli and are willing to take risks in order to gain such experiences (Zuckerman. 1979). In fact, sensation seeking is associated with increased attraction to and consumption of foods that are hot (spicy) and contain unusual spices and foods that are highly flavoured or unusually textured (Byrnes & Hayes, 2013; Kish & Donnenwerth, 1972; Zuckerman. 1979).

Sensitivity to reward was strongly correlated with sensation seeking (Byrnes & Hayes, 2013). However, a reverse pattern was observed. Individuals highly sensitive to reward reported increased perception of sensory properties. These individuals probably considered the sensory properties as indicators of the healthiness of the food products. In line with a previous hypothesis, this enhanced perception was probably due to individuals focusing on the rewarding aspects (healthiness) of the stimuli (Spinelli et al., 2018).

Few psychological traits affected liking of bean purée samples mixed with OMWW. High sensation-seeking individuals preferred the samples more than low sensation-seeking individuals. This confirms the increased attraction to and consumption of novel and unconventional foods (Byrnes & Hayes. 2013; Kish & Donnenwerth. 1972; Zuckerman. 1979). In the present study, a clear, negative relationship was detected among individuals who perceived the sensory properties as more intense and liked the samples less.

Two subscales of alexithymia, difficulty identifying feeling and difficulty describing feeling, also played a role in liking. Surprisingly, in the present study, an increased perception of warning sensations was correlated with an increased liking, even though we expected a lower liking for such warning foods (Robino et al., 2016). These findings are controversial and did not confirm the results from Berenbaum (1994) and McDonald and Prkachin (1990) who have revealed that individuals with high alexithymia showed higher disgust compared to subjects with low alexithymia.

As psychological traits and PROP status effects were fragmentary, cluster analysis based on PCA of psychological traits relevant to sensory and hedonic ratings enabled us to investigate the interaction between psychological traits, reinforcing the effect of each trait. Individuals are characterised simultaneously by multiple traits and PCA approach seems to account for the complex human nature (Mojet et al. 2016). The clusters confirmed the results of previous studies which reported that psychological traits related to anxiety enhanced the perception of warning sensations, putting individuals in an alert state that may cause an increased perception of warning sensations (Laureati et al., 2018; Pliner & Melo, 1997; Spinelli et al., 2018).

We expected to find more differences in liking associated with the different meaning attributions. One explanation may be that when acceptability is very low, the modulatory effect of psychological traits and PROP status is difficult to detect. This means that for each trait both groups (Low and High) tend to reject the food product, and thus, psychological trait/PROP status-related differences are not observed. In fact, studies that demonstrated the effect of psychological traits on liking used food products in the acceptability range (Laureati., 2018; Spinelli et al., 2018).

The relationship between perceived intensity of warning sensations and liking was modulated by few psychological traits. One explanation may be that acceptability of functionalised foods is more complex and involves several additional variables such as personal motivation, health consciousness, attitude towards functionalised foods, and costs (Vecchio, Van Loo, & Annunziata, 2016). Therefore, taste responsiveness and psychological traits are not the only barriers to functional food consumption, as confirmed by Stratton et al. (2015).

In fact, our sample demonstrated that attitude may modulate the perceived intensity of target sensations and liking. However, the effects were controversial. Domains of the MFLQ indicated that the intrinsic meaning we associate with food and to eating behaviours can modulate our food choices (Arbit et al., 2017).

Individuals with low general health and natural product interests perceived the samples as more intense. Since these subjects are less familiar with healthy foods and less responsive to general messages promoting healthy diet (Saba et al., 2019), they may have attributed a negative meaning to the sensations and may have judged the sensations as alarming. The using food as reward subscale followed the same pattern of sensitivity to reward; subjects who considered food as highly rewarding perceived the sensations as more intense than the other subjects, by probably attributing a rewarding value to the overall flavour (Spinelli et al., 2018). This rewarding feeling from consuming functional products may reflect the generally accepted notion in western countries that individuals are increasingly becoming responsible for their own health and well-being (Urala & Liisa, 2003). These attitudes did not affected liking of functionalised foods and these findings are in contrast to expectations and previous results (Roininen et al., 1999). As functional foods differ from conventionally healthy foods, general health interest was expected to correlate positively with attitudes towards functional foods.

Individuals who attributed a low sacred and health meaning to food perceived the samples as more intense. This increased unpleasant reaction is reflected in an increased liking for the samples in subjects low in sacred domains, while subjects low in health domains liked less the samples. The moral domain did not play any role in the perception of warning sensations, but it affected liking among subjects who assigned high scores to the moral aspect of food and liked the samples more, confirming that morality is a stable driver of vegetable consumption (Cliceri, Spinelli, Dinnella, Prescott, & Monteleone, 2018; Rozin, Markwith, & Stoess, 1997).

In the present study, we mainly found effects on sensory properties or on liking and in few cases sensory and hedonic ratings were strongly related. These findings suggest that these effects are very complex and multidimensional and may partly be related to the meaning attributed to the stimulus. Individuals were divided into two groups based on the liking of the first sample mixed with phenol extracts from OMWW for further analysis. Despite the wide variability, subjects did not differ in terms of psychological traits or PROP status, suggesting that several other factors play crucial roles as determinants of functionalised food acceptance. Multiple conceptualisations of beliefs in the context of functional foods were used previously. These beliefs range from belief in one's own impact on personal health (Hilliam, 2009), health benefit belief (Childs & Poryzees, 1998), perception of health claims (Bech-Larsen & Grunert, 2003), belief in the food-disease prevention concept, belief in the disease-preventative nature of natural foods (Childs & Poryzees, 1998), and opinions of the relationship between food and health (Ares, Giménez, & Gámbaro, 2008).

This is one reason why the development and marketing of functional foods is expensive and exceptionally risky. These data suggest that further investigation of the combined effects of psychological traits and food attitudes on sensory and hedonic responses is needed in order to better understand the underlying mechanism of functionalised food acceptability.

The attempt to profile people according to their socio-demographics, psychological traits, and attitudes towards healthy foods could be useful for developing food prototypes that fit the preference of consumer clusters identified on the basis of their individual differences.

8. General discussion and conclusion

The selection, the adoption and the validation of the psychological questionnaires in the Italian population allowed to obtain and to provide quantifiable and comparable data and to highlight possible barriers to the consumption of healthy foods.

The present thesis confirms that food choice is influenced by many interacting factors in humans and the acceptability of a certain food depends on the interplay between its intrinsic and extrinsic characteristics and person-related dimensions that are biological, physiological, psychological, and socio-cultural (Köster, 2009; Mela, 2006; Rozin, 2006; Sobal, Bisogni, Devine, & Jastran, 2006; Sobal, Bisogni, & Jastran, 2014).

The understanding of the factors involved in eating behaviour and food choice and how they are interrelated is increasingly relevant. This is particularly important in the modern society where food consumption is attributed several meanings including healthy lifestyle, environmental sustainability, and mental and physical well-being (Menrad, 2003; Roberfroid, 2000). Moreover, knowledge of the possible drivers of food acceptability can help to promote and facilitate the consumption of healthy foods and the development of prevention programs for nutrition-related diseases, such as obesity and eating disorders (Haines & Neumark-Sztainer, 2006).

This multicomplex and multidimensional process appears particularly relevant in the choice of phenol-rich foods and functionalised foods that are also characterised by health benefits and warning sensations, such as bitterness and astringency, two sensory properties which humans innate dislike and consider aversive (Abuajah et al., 2015; Dinnella et al., 2011; Shahidi & Ambigaipalan, 2015).

Taste is one of the most important factors. Sensory properties drive liking for vegetables (Appleton et al., 2019) and unpalatable sensations may act as a barrier to vegetable acceptance (Drewnowski & Gomez-Carneros, 2000; Shimada, 2006). However, tastes alone cannot explain the enormous individual variability in the choice and acceptability of phenol-rich foods and functionalised foods.

In the present study, PROP status affected the perceived intensity of warning sensations, but no differences were detected between groups in terms of familiarity with and choice of phenol-rich foods and in terms of liking for phenol-enriched foods. These results were consistent with those of previous studies that demonstrated a lack of association between the preference of bitter vegetables and responsiveness to PROP bitterness (Catanzaro et al., 2013; M Laureati et al., 2018; Shen et al., 2016), mainly because demographics, genetics, and other environmental factors may influence both phenotypic responses to oral stimulation and affective response to food (Fischer et al., 2013; Piochi et al., 2018; Tepper et al., 2017). These results confirmed the initial hypothesis that sensory and especially hedonic responses to foods characterized by warning sensations are modulated by several factors and liking may vary across individuals regardless the strict functionality of the peripheral system.

The systematic investigation of the effects of psychological traits highlighted their key role in familiarity with, choice of, and sensory and hedonic evaluations of phenol-rich and functionalised foods. The present results confirm that the same stimuli can elicit different reactions, in terms of perceived intensity of warning sensations, in different clusters of individuals, suggesting that the modulatory effects of psychological traits are predominantly related to the meaning that individuals attributed to them.

Individual expectations of the taste of food can have a significant impact on the sensory evaluation of that food (Schifferstein et al., 1999). Additionally, food products in which critical sensations are perceived plays a fundamental role. Vegetables rich in phenols and coffee and tea characterized by warning sensations are familiar on average and the effect of psychological traits on familiarity with and choice of phenol-rich foods was rather clear and systematic. Subjects high in traits related to anxiety choose less the most bitter and astringent option of the pairs and are less familiar with vegetables and coffee and tea strongly connoted with bitterness and astringency. Functionalised foods are less familiar, and the acceptability process was more complex as the product itself and its related sensations were associated with several meanings and the effects of psychological traits appeared more labile and disorganised.

The effect of food neophobia is pervasive among food products and behaviours. Subjects higher in food neophobia choose less the most bitter/astringent option of the pairs, showed a lower familiarity for vegetables and coffee/tea characterized by warning sensations and perceived bitterness, astringency and overall flavour in the phenol-enriched bean cream samples as more intense than subjects low in this trait.

In line with these results, subjects high in sensitivity to disgust reported significantly lower choice indices for phenol-rich foods, significantly lower familiarity with coffee and tea characterized by warning sensations and perceived overall flavour in the phenol-enriched bean cream samples as more intense than subjects low in this trait.

Subjects high in sensitivity to punishment reported significantly lower choice indices for phenol-rich foods, significantly lower familiarity with vegetables characterized by warning sensations and reported higher astringency intensity in the phenol-enriched bean cream samples than subjects low in this trait.

Finally, subjects with high alexithymia were less familiar with vegetables and coffee and tea characterized by warning sensations and perceived astringency of bean cream samples as more intense that subjects with low alexithymia.

In this context, food attitudes may be important and may modulate the rewarding value of foods, increasing the acceptability.

Considering individual differences helps to obtain a more complete picture of the complex relationships that determine the acceptability of a certain food category and enables the identification of the barriers to and the facilitators of healthy eating.

Moreover, the identification of psychological barriers to the consumption of phenol-rich and functional foods may enable the development and planning of targeted preventive programs for children and adults. On one hand, psychological traits related to food, such as food neophobia and sensitivity to disgust, could be modulated and reduced with repeated taste and culinary practice experience education. By so doing, phenol-rich foods may be perceived as less unfamiliar and alarming and rejective reactions may be inhibited. On the other hand, specialists must be aware that some psychological traits not related to food, such as anxiety, alexithymia, sensation seeking, and sensitivity to reward and punishment, could play a key role in the acceptability of phenol-rich foods. Clinical and support interventions to reduce and manage these traits may indirectly have positive effects on food behaviours and healthy food consumption.

Additionally, the recognition that individual differences can lead to different sensory and hedonic evaluations paves the way for the development of personalised food products.

Personalised nutrition is very challenging and offers a new approach towards eating behaviours by providing advice on healthy food choices and eating patterns to fit an individual's needs and personal preferences. This approach is complex but promising and the essential goal is to achieve lasting improvements in dietary behaviour and health.

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Attachments: Preliminary studies on the pre-existent database – the Italian Taste Project (Spinelli et al., 2018 and Laureati et al., 2018)

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Personality traits and gender influence liking and choice of food pungency

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ABSTRACT

The study, part of the larger Italian Taste project, was aimed at exploring the role of personality traits and taste responsiveness on liking and choice of pungent foods. Data of 1146 subjects (61% females, aged 18–60) were analysed. Subjects were characterised for demographics, taste functions (responsiveness to PROP and fungiform papillae density), and personality traits: sensitivity to reward (SR), to punishment (SP) and to disgust (SD), private body consciousness (PBC), alexithymia (TAS) and food neophobia (FN). They evaluated capsaicin and other tastants in solutions, then evaluated liking and perceived intensity (burning, acid, sweet and overall flavour) in a series of four samples of tomato juice, each spiked with capsaicin at a different concentration (0.3; 0.68; 1.01; 1.52 mg/kg). A choice index for pungent food was calculated as a sum of the choices of the spicy option using a questionnaire developed to evaluate preferences within a pair of food items (pungent vs non pungent option).

Males and females differed for frequency of chili consumption and were studied separately. Age was not associated with frequency of chili consumption. Responsiveness to PROP was found to be positively correlated to perceived burn intensity. Results from ANOVA models showed that High SR, Low FN, Low DS (both males and females) and Low SP (males) liked significantly more the burning samples. Low FN and DS (in both genders), low SP (in females) perceived lower burning, and overall flavour intensities, while this was not observed in High SR. PLS regression models were used to gain a deeper understanding of the factors that affect pungent food choice. Choice was positively correlated with liking, and negatively with burning intensity, FN and DS. In addition, choice was negatively correlated with SP in females and positively with SR in males.

Our results confirmed that many factors interplay in spicy food liking and choice and highlighted the role played by different personality traits in females and males. It was also reported that for same traits an effect on liking of pungency is associated with a lower perceived intensity of burning and overall flavour, while for other traits only an effect on liking was observed.

Abbreviations: FPD, fungiform papillae density; FN, food neophobia; HCP, hot chili pepper; PBC, private body consciousness; SD, sensitivity to disgust; SP, sensitivity to punishment; SR, sensitivity to reward; TAS, alexithymia

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1. Introduction

The preferred level of pungency in food – sensations of burning, bite, tingling and so on – varies considerably worldwide. How individuals come to like and enjoy foods characterised by pungency, in particular the intense and often aversive sensations produced by chilies, has been the subject of several studies since the 1980s. Rozin and Schiller (1980), in their seminal study aimed at better understanding the mechanism related to the acquisition of a preference for chili, noted the fundamental role of exposure. They hypothesised that because a hedonic shift is produced by exposure, pungent sensations might become associated with positive events, including enhancement of the taste of bland foods, postingestional effects, or social rewards. Rozin and Schiller (1980) also reported an association between preference for chili and the personality trait of sensation seeking: for some individuals, the initial mouth burn produced by the chili may become pleasant as the person realizes that it is not really harmful (see the concept of "constrained risk", Rozin & Schiller, 1980).

Increasingly, research has also addressed the question of whether personality factors might influence preference development for pungent foods. Significant positive correlations have been reported between preference for spicy and chili-containing foods and measures of sensation seeking (Brown, Ruder, Ruder, & Young, 1974; Logue & Smith, 1986; Terasaki & Imada, 1988; Byrnes & Hayes, 2013), as well as with measures of sensitivity to reward (Byrnes & Hayes, 2013), a trait associated with the responsivity to BAS (Behavioural Activation System), a conceptual system responsible for approach behaviour in response to incentive (signals of reward or non-punishment). Interestingly, a further study of Byrnes and Hayes (2015) highlighted gender differences in these relationships, with spicy food liking and intake associated with sensitivity to reward in men and with sensation seeking in women. A recent study by Byrnes and Hayes (2016) confirmed the association between sensation seeking and both liking and intake of spicy foods, while finding an association of sensitivity to reward and the trait of risk taking only with spicy foods intake.

Another personality trait, sensitivity to punishment describes individual differences in reactivity and responsivity to the Behavioural Inhibition System (BIS), hypothesized to control behaviour in response to signals of punishment, frustrating non-reward and novel stimuli. While an association with spicy food intake has not been reported for sensitivity to punishment (Byrnes & Hayes, 2013, 2015, 2016), a weak association was found with liking of spicy foods (Byrnes & Hayes, 2013). In a further study, Nolden and Hayes (2017) did not see any effect of food adventurousness (variety seeking, measured using the VARSEEK scale) on burn perception, while a significant effect was found on liking ratings for samples spiked with different concentrations of capsaicin, and on reported liking for spicy foods, and a trend was reported on frequency of chili intake. Törnwall et al. (2014) reported that the individuals who preferred spicy foods and a strawberry flavoured jelly spiked with capsaicin to one without it were less neophobic, but they did not report differences in the intensity of pungency.

There are also some limited data (Stevens, 1990) that have suggested that individuals with high Private Body Consciousness (PBC) – reflecting awareness of internal sensations – rate the burn of capsaicin as more intense than those with low PBC, hypothesising that this might be linked to a higher intake, but further studies did not support these findings (Byrnes & Hayes, 2013).

Genetic factors have major influence on liking of oral pungency and spicy foods, accounting for 18–58% of the variation in a study on adults Finnish twins (Törnwall, Silventoinen, Kaprio, & Tuorila, 2012). Some of this relationship appears to be mediated by PROP tasting, which is strongly genetically determined. However, the role of sensitivity to PROP is not clear, with several studies reporting a positive association with pungency (Karrer & Bartoshuk, 1991; Prescott & Swain-Campbell, 2000; Tepper & Nurse, 1997) while other studies did not find a significant association (Törnwall et al., 2012). Tepper et al. (2009) found liking of chili to be a function of PROP status, with non-tasters liking the chili more than did supertasters in an Italian but not in a US sample, while Bajec and Pickering (2010) reported no effect of PROP responsiveness on liking of hot spices (including hot peppers, and curry, wasabi and horseradish) in a Canadian sample. Ullrich, Touger-Decker, O'Sullivan-Maillet, and Tepper (2004) reported that those PROP tasters who were also more food adventurous liked chili and hot sauce more than PROP tasters who were less food adventurous; in addition, the authors reported that, in non-tasters, food adventurousness had little influence on liking of chili and other spicy foods.

The complexity of these influences on liking of spicy foods and in the perception of pungency suggest that an understanding of the development of liking for chili is far from complete. It is likely that there are multiple routes to liking, variously linked to the interactions of the different factors that play a role (see also Dalton & Byrnes, 2016). The conflicting research findings may be due to the low number of subjects participating in the studies and to the different measures used, encouraging further investigation of these issues on larger samples. In addition, liking for burning has been explored primarily in water solutions or in flavoured jelly (Byrnes & Hayes, 2016; Törnwall et al., 2012), but seldom in a food matrix (Ludy & Mattes, 2012) and in this case on a very limited number of subjects (n = 25).

Investigating the factors that influence pungent food liking is of interest not only to fully understand food choice and preference, but also for the beneficial consequences for health that the consumption of foods rich in capsaicin and capsiate might have in augmenting energy expenditure (Ludy, Moore, & Mattes, 2012; Mattes & Ludy, 2016). In addition, a recent study reported that the consumption of hot red chili pepper was associated with reduced mortality in a large population sample (Chopan et al., 2017).

The present study was aimed at further exploring the role of personality traits and taste responsiveness on liking and choice of chili and other pungent foods. The rationale behind this study is the adoption of a multidisciplinary and multidimensional approach to food choices and preferences (Köster, 2009; Monteleone et al., 2017) to better understand the complexity of preferences for pungent foods. Based on previous research (Byrnes & Hayes, 2015) that suggested that personality variables influence the intake of spicy foods differently in men and women, and that the relationship between the variables of personality, perceived burning/stinging of capsaicin, liking of spicy foods, and consumption of spicy foods may differ between men and women, we aimed to assess in two larger samples, one of females and one of males, whether (1) personality and taste responsiveness were associated with sensory perception and liking of burning in a food; (2) personality and taste responsiveness were associated with pungent food choice; (3) personality variables influence the intake of spicy foods differently in females and males.

2. Material and methods

2.1. Overview

The present data were collected as part of the larger, ongoing "Italian Taste Project" which aims to investigate influences on food choice and preferences in a large population sample (Monteleone et al., 2017). This multisession study involved an online questionnaire session (at home) and a one-on-one testing in a sensory laboratory across 2 days. Only a selection of these tests will be presented here. For a complete overview of the testing and further details on the definition of the procedures, see Monteleone et al. (2017).

2.2. Participants

Data were collected on 1225 subjects during the first year of the Italian Taste project. Three subjects were excluded because they did not complete the sensory test and 76 subjects due to problems in the use of the generalized Label Magnitude Scale (gLMS). Data were collected in 19 sensory labs (IT units) in Italy (Monteleone et al., 2017). The distributions of PROP ratings of two units differed from the others in showing a higher frequency of ratings close to the maximum of the scale, due the lack of compliance with the procedure for training subjects to the gLMS use. Thus, data from these units were excluded. The final sample (n = 1146) was 61.1% female with a mean age of 36.5 years (SD 12.8; 18–60 years old range: 18–30: 42.5%; 31–45: 27.1%; 46–60: 30.5%).

2.3. Procedure

2.3.1. Measuring sensation intensity and liking for pungency

On day 1, before starting the hedonic evaluation of food samples, participants were introduced to the use of the Labelled Affective Magnitude scale (LAM; Schutz & Cardello, 2001; Cardello & Schutz, 2004) and familiarised with it. The scale anchors were spaced according to the values of Cardello and Schutz (2004), from *greatest imaginable dislike* (0) to *greatest imaginable like* (100), with neither liked nor disliked set at 50. Numerical labels were not reported on the scale.

Prior to the evaluations, participants were asked to rate their appetite (from "not at all" to "very" hungry) and were then presented with a series of four samples of tomato juice, each spiked with capsaicin at a different concentration (0.3; 0.68; 1.01; 1.52 mg/kg). The presentation order of the tomato juice samples within each set was randomised across subjects. Participants were instructed to make a mark on the vertical line to indicate their degree of liking or disliking after tasting each sample and to rate the sample relative to the greatest imaginable like/dislike for foods (see Lawless et al., 2010). After the evaluation of each sample, participants rinsed their mouths with water, had a cracker and rinsed again their mouths with water for a total of at least 180 s before passing to the following sample.

On day 2, participants were trained to the use of gLMS (0: no sensation; 100: the strongest imaginable sensation of any kind) consistent with standard procedures (Bartoshuk, 2000; Green et al., 1996; Green, Shaffer, & Gilmore, 1993). The gLMS consisted of a 100 unit vertical line with labels placed at *no sensation*, 0; *barely detectable*, 1.4; *weak*, 6; *moderate*, 17; *strong*, 34.7; *very strong*, 52.5; and *strongest imaginable sensation of any kind*, 100. Numerical labels were not reported on the scale. Subjects were instructed to think to the "strongest imaginable sensation" as the most intense sensation they could imagine that involves remembered/imagined sensations in any sensory modality. This included such varied sensations as the cold of a cube of ice in the mouth, the deafening noise of a plane that is flying low, the strong pain felt when shutting a finger in a door. Participants were invited to ask questions about how to use the scale, and a practice trial was given in which they were asked to evaluate the intensity of the most intense light they have ever experienced using a paper version of the scale.

Participants were then presented with seven water solutions, corresponding to five basic tastes (sweet, sour, salty, bitter, umami), astringent and burning sensations, which were rated for intensity using the gLMS. The concentration of the tastants were decided based on published psychophysical data (Feeney & Hayes, 2014; Hayes, Sullivan, & Duffy, 2010; Masi, Dinnella, Monteleone, & Prescott, 2015) and previous preliminary trials conducted with one hundred untrained subjects recruited in five Italian sensory laboratories (unpublished data), in order to select solutions equivalent to moderate/strong on a gLMS (sourness: citric acid 4 g/kg; bitterness: caffeine 3 g/kg; sweetness: sucrose 200 g/kg; saltiness: sodium cloride 15 g/kg; umami: monosodium glutamic acid salt 10 g/kg; astringency: K Aluminum Sulfate 0.8 g/kg; pungency: capsaicin 1.5 mg/kg). Participants were presented with each sample (10 ml) in a 80 ml plastic cup identified with a random three digit code. The presentation order of the samples was randomised, with the exception of the capsaicin solution which was always presented last, to minimise carry-over effects. Participants were instructed to hold the sample in their mouth for 3 s, then expectorate, wait 3 s (5 s in the case of bitterness, umami, astringency and burning) and evaluate the intensity of the sensation on the gLMS. After each sample, participants rinsed their mouths with water and waited 60 s before evaluating the following sample. After the capsaicin solution, participants rinsed their mouth with water, had a cracker and rinsed again with water for at least 180 s before proceeding to the following test.

Subsequently, participants were again presented with the series of 4 samples of tomato juice, each spiked with capsaicin at a different concentration (0.3; 0.68; 1.01; 1.52 mg/kg) and they evaluated the intensity of burning, sourness, sweetness and overall flavour of these samples using the gLMS. The presentation order of the tomato juice samples within each set was randomised across subjects. The presentation order of the attributes for each sample was randomised across subjects, with the exception of overall flavour, which was always presented last. Participants were instructed to hold the sample in their mouth for 7 s, then swallow, wait 5 s and evaluate the intensity of the attributes. After the evaluation of each sample, participants rinsed their mouth with water, had a cracker and rinsed again with water for a total of at least 180 s before proceeding to the next sample.

2.3.2. Measuring intake, familiarity and preferences (stated liking) for chili pepper and pungent foods

To assess participants' usual intake of chili and pungent food, we adapted to the Italian culture the question used previously by Lawless, Rozin, and Shenker (1985) and adapted by Byrnes and Hayes (2013). We asked participants "How often do you consume chili pepper and pungent foods?". Responses were recorded on an 8-point category scale (never, < 1/month, 1–3/month, 1–2/week, 3–4/week, 5–6/week, 1/day, 2+/day). These values were re-coded as a yearly frequency (e.g., 1–3/month = 24, 3–4/week = 182, 1/day = 365, etc.) and log transformed prior to analysis to reduce skew, as suggested by Byrnes and Hayes (2015). Subjects were grouped as users (consuming chili pepper and pungent foods at least 1–2 times per week), medium users (1–3 times per month) and non-users (less than once per month) of chili pepper).

Familiarity with chili and pungent foods (see Table 1, column Pungent option) was measured using the IT-Food Familiarity Questionnaire (IT-FFQ), developed within the Italian Taste project to collect information about familiarity with foods among Italians. The IT-FFQ included 184 items, assessed using a 5-point labelled scale (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) developed by (Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001).

Table 1
Non-pungent vs pungent options included in the IT-FPQ, IT-FFQ and IT-FCQ, selected for the Pungent Food Index.

Context	Non-pungent option	Pungent option
Lunch/dinner	Spaghetti with tomato sauce	Spaghetti with hot tomato sauce
Lunch/dinner	Spaghetti with garlic and olive oil	Spaghetti with garlic, olive oil and hot chili pepper
Lunch/dinner	Risotto with saffron	Risotto with curry
Lunch/dinner	Sweet provolone cheese	Hot provolone cheese
Aperitif	Chips	Chips with paprika

The presentation order of the items within each product category, as well as the product category order, were randomised across participants.

Liking for chili and pungent food (see Table 1, column Pungent option) was measured using the IT-Food Preference Questionnaire (IT-FPQ), which consists of same 184 items as the IT-FFQ, assessed using the 9-point hedonic labelled scale (Peryam & Pilgrim, 1957) with the addition of the option "never tasted it". As for the IT-FFQ, the presentation order of the items within each product category, as well as the product category order, were randomised across participants.

The IT-Food Choice Questionnaire was developed in order to evaluate preferences within a pair of items selected among the 184 items of the IT-FFQ/FPQ. For each pair, respondents were asked to indicate which food they would choose in a specific eating situation: breakfast (13 pairs), snack/light-meal (13 pairs), main meal (either lunch or dinner, 43 pairs) and aperitif (10 pairs). The presentation order of the food items within each pair, and of the pairs within each eating context, was randomised across participants, while the presentation order of the eating situations was the same for all participants (breakfast, snack/light-meal, main meal, aperitif). Only the results related to the pairs that represented variations in pungency are presented here (Table 1). A choice index for pungent food was calculated as a sum of the choices of the pungent option assigning to each a value of 1 (pungent index range = 0–5), with higher scores reflecting higher choice of the pungent option.

2.3.3. *Measuring personality traits*

Participants completed questionnaires to assess six psychological or personality related traits: food neophobia; private body consciousness; sensitivity to punishment and reward; sensitivity to core disgust and alexithymia.

Food Neophobia (FN), defined as the reluctance to try and eat unfamiliar foods, was quantified using the 10-item instrument developed by Pliner and Hobden (1992). The individual FN scores were computed as the sum of ratings given to the ten statements (using a 7-point Likert scale: *disagree strongly/agree strongly*), after the neophilic items had been reversed. The scores thus ranges from 10 to 70, with higher scores reflecting higher food neophobia levels.

Private Body Consciousness (PBC), defined as the disposition to focus on internal bodily sensations (awareness of internal sensations), was quantified using the 5-item instrument developed by (Miller, Murphy, & Buss, 1981). The individual scores were computed as the sum of the ratings given to the five statements (using a 5-point scale: *extremely uncharacteristic/extremely characteristic*). The scores range from 5 to 25, with higher scores reflecting higher PBC levels.

Sensitivity to Punishment and Sensitivity to Reward (SP and SR). According to Gray's neuropsychological theory of personality (Gray & McNaughton, 2003), two basic brain systems control behaviour and emotions: the Behavioural Inhibition System (BIS) and the Behavioural Activation System (BAS). The responsiveness of these systems has been measured using the Sensitivity to punishment and sensitivity to reward questionnaire (SPSRQ, Torrubia, Ávila, Moltó, & Caseras, 2001). The SP scale is formed by a set of items reflecting situations which describe individual differences in reactivity and responsivity to BIS. The SR scale was conceived as a single measure of the functioning of the BAS dealing with specific rewards (i.e. money, gender, social power and approval, and praising). The SP and SR scales were scored with a *yes/no* format. For each subject, scores for each scale were obtained by adding all the *yes* answers. In the original version, the score for each scale ranges form 0 to 24. Based on Exploratory and Confirmatory Factor Analysis we removed 7 items from the Italian version (see details in Supplementary data 1); thus the scores range from 0 to 23 for SP and from 0 to 18 in SR, with higher scores reflecting, respectively, higher sensitivity to punishment and to reward.

Sensitivity to core disgust (DS). The responsivity to core-visceral disgust (rotten food, vermin, body fluids) was measured using the 8-item short form of the Disgust Sensitivity Scale (Disgust Scale-Short form, Inbar, Pizarro, & Bloom, 2009; Haidt, 2004; see also DS-R Haidt, McCauley, & Rozin, 1994; modified by Olatunji et al., 2007). The scale includes two subscales, each presented with a specific scale ranging from 1 = strongly disagree (very untrue about me), to 5 = *strongly agree (very true about me)* (subscale 1) and from 1 = *not at all disgusting*, to 5 = *extremely disgusting* (subscale 2). The scores range from 8 to 80, with higher scores reflecting higher sensitivity to disgust. The rating scale was modified compared to the original adopting a 5-point Likert scale to improve its psychometric properties as suggested by Olatunji et al. (2007).

Alexithymia (TAS) is a multifaceted construct encompassing difficulty identifying subjective emotional feelings and distinguishing between feelings and the bodily sensations of emotional arousal, difficulty describing feelings to other people, an impoverished fantasy life, and a stimulus-bound, externally oriented cognitive style (Nemiah, Freyberger, & Sifneos, 1976). This construct was operationalised using the Toronto Alexithymia Scale (TAS-20) developed by Bagby et al. (1994) and already validated in Italian (Bressi et al., 1996). The TAS-20 includes 20 items rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (*strongly agree*). The questionnaire provides a total alexithymia score (TAS Total), and three subscale scores, which reflect the three main factors of the alexithymia construct: Difficulty identifying feelings; Difficulty describing feelings; Externally oriented thinking. The TAS Total score range from 20 to 100, with a higher score indicating a greater level of alexithymia.

When available, a validated Italian translation of the questionnaires was used (TAS-20, Bressi et al., 1996). In the other cases, the items were translated in Italian by two different bilingual Italian native-speakers and then back translated into the source language. Back translations were reviewed by an expert in semantics and adjustments were made when necessary to select the most appropriate translation. A set of analysis was conducted to evaluate the factor structure, reliability, stability over time, and validity of the Italian version of the SPSRQ, DS and PBC. Our findings provided support for the use of the Italian version of the Disgust Scale-Short form, the Private Body Consciousness scale and a 41-item version of the Sensitivity to punishment and sensitivity to reward questionnaire with improved psychometric properties compared to the original 48-item version. Material and methods, results and discussion are reported in the Supplementary data 1, while the questionnaires and their translation in Italian are available in Supplementary data 2. The validation of the Italian version of the neophobia scale is reported elsewhere (Laureati et al., submitted). However, the scale, which has been already used in the Italian translation (Demattè, Endrizzi, & Gasperi, 2014) displayed high internal consistency and test–retest reliability.

Based on the total score for each personality trait, subjects were divided into sub-groups representing low and high scores, based on the median (see Table 2). Participants with a median score were not considered.

2.3.4. *Taste functions*

PROP taster status was assessed using a 3.2 mM PROP solution, prepared by dissolving 0.545 g/L of 6-n-propyl-2-thiouracil (European Pharmacopoeia Reference Standard, Sigma Aldrich, Milano, IT) into deionized water (for example, see Prescott, Soo, Campbell, & Roberts, 2004). Subjects were presented with two identical 10 ml samples, each coded with a three-digit code. Subjects were instructed to hold each sample in their mouth for 10 s, then expectorate, wait 20 s and evaluate the intensity of bitterness using the gLMS (Bartoshuk et al., 2004). Subjects had a 90 s break in order to control for carry-over effects after the first sample evaluation. During the break, subjects rinsed their mouth with distilled water for 30 s, ate some plain crackers for 30 s, and finally rinsed with water for a further 30 s. PROP taster status was based on the average rating of the two replicates, and groupings were based on arbitrary cut-offs (Fischer et al., 2013; Hayes et al., 2010): PROP

Table 2
Rated personality traits (sensitivity to reward, SR; sensitivity to punishment, SP; sensitivity to disgust, DS; food neophobia, FN; alexithymia, TAS; private body consciousness, PBC). For each personality trait the range, mean, standard deviation (SD), median and number of subjects included in the analysis are reported and the effect of gender (with mean values for females and males), age (with mean value for age class) and interaction (F, p value) are shown in ANOVA model (significant differences are bolded) and are reported.

Personality trait	Range	Mean	SD	Median	n	Gender		Mean value		Age		Mean value			Gender × Age	
						F	p-value	Females	Males	F	p-value	18–30	31–45	46–65	F	p-value
FN	10–69	27.11	11.71	25	1146	**5.66**	**0.018**	26.62^{b}	28.34^{a}	5.30	**0.005**	26.02^{b}	27.76^{ab}	28.65^{a}	0.58	0.557
DS	10–40	28.85	5.60	29	1146	**114.26**	**< 0.0001**	30.30^{a}	26.80^{b}	8.02	**0.000**	27.73^{b}	28.7^{a}	29.20^{a}	**4.54**	**0.011**
SP	0–23	9.34	5.19	9	1146	**29.15**	**< 0.0001**	9.73^{a}	8.07^{b}	37.08	**< 0.0001**	10.65^{a}	7.87^{b}	8.19^{b}	0.37	0.691
SR	0–17	5.64	3.56	5	1146	**113.91**	**< 0.0001**	4.61^{b}	6.66^{a}	112.67	**< 0.0001**	7.47^{a}	5.11^{b}	4.3^{c}	2.30	0.100
TAS	20–80	45.59	11.30	45	1141	**6.12**	**0.014**	44.42^{b}	46.10^{a}	32.01	**< 0.0001**	48.84^{a}	43.43^{b}	43.51^{b}	2.22	0.109
PBC	6–25	18.28	3.61	18	1138	**15.32**	**< 0.0001**	18.58^{a}	17.71^{b}	4.52	**0.011**	18.52^{a}	18.16^{ab}	17.75^{b}	**3.61**	**0.027**

^{a,b}Different letter in a row indicate a significant difference between gender or age groups, respectively.

non-tasters (NT) ≤ 17; PROP medium tasters (MT), 17–53; and PROP supertasters (ST) > 53 on the gLMS.

Fungiform Papillae (FP) density was determined by swabbing the anterior portion of the dorsal surface of the tongue with blue food coloring, using a cotton-tipped applicator. This made the FP easily visible as red structures against the blue background of the stained tongue. Digital pictures of the tongue were recorded (Shahbake, Hutchinson, Laing, & Jinks, 2005) using a digital microscope (Micro-Capture, version 2.0 for 20×–400×) (Masi et al., 2015). For each participant, the clearest image was selected, and the number of FP was counted in two 0.6 cm diameter circles, one on right side and one on left side of tongue, 0.5 cm from the tip and 0.5 cm from the tongue midline. The number of FP was manually counted by two researchers independently according to Denver Papillae Protocol (Nuessle, Garneau, Sloan, & Santorico, 2015). The average of these values was used for each subject.

2.4. Data analysis

2.4.1. Effect of gender and age on personality traits

Two-way analysis of variance was used to determine the main effects of gender (M, F) and age (18–30; 31–45; 46–60), and their interaction, on each personality trait.

2.4.2. Relationships among personality traits, taste functions, burning intensity, liking and choice of pungent foods

Pearson's correlation coefficients were computed for an overall view of the relationships between personality traits, taste functions (PROP responsiveness, FPD, responsiveness to capsaicin in water solution), age and yearly intake and stated preference for pungent foods. Raw (non-normalized) data were used for the intensity and affective ratings. Yearly intake of chili pepper was log transformed. Significance criteria was set at alpha = 0.05. Given the high number of possible comparisons (12*11/2 = 66), Bonferroni corrections were applied, and the critical value for each test was calculated as 0.05/66 = 0.000758. To reduce the risk of false positives, the Benjamini–Hochberg procedure was also applied (alpha = 0.05).

One-way analysis of variance was used to determine the main effect of the user status (the trichotomized form, see above) on age, PROP responsiveness, basic tastes, burning and astringency in water solutions, number of fungiform papillae and each personality trait. The association between gender and user status was investigated using Chi-Square tests. Two-way analysis of variance was used to determine the main effects of personality traits (the dichotomized form, see above) and the samples, and their interaction, on the liking, pungency, acid, sweet and overall flavour for the tomato juices spiked with capsaicin. When appropriate, a Bonferroni adjustment was applied for multiple comparisons.

A Partial Least Square (PLS) regression model was computed separately for each gender assuming the pungent index (see above) as response variable (Y) and 13 explanatory variables (X): age; five personality traits (FN, SR, SP, DS and TAS); three taste functions (PROP responsiveness and fungiform papillae density, responsiveness to capsaicin in water solution); familiarity with hot chili pepper, yearly intake of chili pepper; stated liking for hot chili pepper; liking for the tomato sample with the highest concentration in capsaicin (1.52 mg/kg). Familiarity was coded using dummy variables where 0 represents the levels 1, 2 and 3, and 1 represents the levels 4 and 5, on the familiarity scale. All PLS regressions models were run on standardized mean centered input variables, using cross-validation on 20 random segments and performing a jack-knife uncertainty test with 95% confidence interval for the detection of significant variables (Martens & Martens, 2000). Due to the large amount of information collected, a two-step procedure was used (Asioli, Almli, & Næs, 2016). In the first step, all the individual attributes were included in the model. Then, in the second step, a new model was run only including as active variables those that were found to be significant in at least one gender in the first step. The other variables were included in the model as downweighted. This resulted in a better suited and more parsimonious model.

All data were analysed using XLSTAT 19.02, with the exception of the PLS, which was conducted using Unscrambler®X 10.5, and CFA (Confirmatory Factor Analysis), which was conducted using AMOS 19 (Arbuckle, 2010) and, for robust Diagonally Weighted Least Squares, using RStudio Version 1.1.383 – package: lavaan 0.5-23.1097.

3. Results

3.1. Effect of age and gender on personality traits

Age and gender effects were found for each personality trait, and interaction between age and gender was found in sensitivity to disgust and private body consciousness (see Table 2). Females were significantly higher in private body consciousness, and more sensitive to disgust and to punishment than males, while males were more neophobic, more sensitive to reward and higher in alexithymia. Sensitivity to reward, sensitivity to punishment, alexithymia and, to a lower extent, private body consciousness decreased with age, while food neophobia and sensitivity to disgust increased with age.

3.2. Chili pepper user, medium user and non-user differ in gender, personality traits and perceived burning intensity

Results from the ANOVA showed that chili non-users rated the burning intensity of the capsaicin solution significantly higher, and

Table 3
User, medium user and non-user of chili pepper by physiological characteristics, personality traits and socio-demographics (significant differences $p < 0.05$ are emboldened).

Variable	User (n = 365)	Medium-user (n = 322)	Non-users (n = 459)	p-value
Age	36.61	35.97	36.79	0.673
Fungiform papillae density (cm^2)	21.08	22.83	22.40	0.160
PROP	39.20	38.41	40.22	0.651
Intensity of sourness	34.03	33.62	34.47	0.849
Intensity of bitterness	31.64	30.76	32.50	0.513
Intensity of sweetness	38.73	40.89	40.00	0.313
Intensity of saltiness	36.15	37.19	37.81	0.505
Intensity of umami	26.58	26.30	27.10	0.834
Intensity of astringency	19.33	19.04	18.50	0.775
Intensity of burning	**41.49[c]**	**47.28[b]**	**55.80[a]**	**< 0.0001**
Sensitivity to reward	**6.05[b]**	**5.77[ab]**	**5.23[b]**	**0.003**
Sensitivity to punishment	**8.78[b]**	**9.07[ab]**	**9.97[a]**	**0.003**
Sensitivity to disgust	**27.87[b]**	**28.75[ab]**	**29.69[a]**	**< 0.0001**
Food neophobia	**25.22[b]**	**26.02[b]**	**29.39[a]**	**< 0.0001**
Alexithymia	46.02	45.17	45.54	0.618
Private Body consciousness	18.40	17.98	18.38	0.217

[a,b]Different letter in a row indicate a significant difference.

were significantly more sensitive to disgust, more neophobic, more sensitive to punishment and less sensitive to reward than chili users (Table 3). No effect of user status was found on age, intensity of basic tastes or astringency, PROP responsiveness, or FP density. A relationship between gender and user status was found, with females more likely to be non-users than males (percentage of females among users = 52.60%; medium users = 58.25%; non users = 69.93%; Chi-square = 27.26, $p < 0.0001$).

Given the fact that gender was associated with user status and that an effect of gender was found on each personality trait, males and females were analysed as separate cohorts, as suggested by Byrnes and Hayes (2015).

3.3. Associations between personality traits, intensity of burning, liking and intake of pungent foods

3.3.1. Burning intensity: responsiveness to capsaicin in water solution

A negative relationship was found between the burning intensity of capsaicin in solution and liking and yearly intake of chili and pungent food both in females (from -0.28 to -0.35) and males (from -0.24 to -0.29). Both in males and females, the intensity of capsaicin was positively related to food neophobia (M: r = 0.13; F: r = 0.10) and sensitivity to disgust (M: r = 0.18; F: r = 0.16), but not to sensitivity to reward, sensitivity to punishment, alexithymia nor private body consciousness (see Tables 4 and 5).

Table 4
Pearson correlation coefficients within the personality traits, taste functions and measures of liking and choice of hot chili pepper (HCP) and pungent foods in females (n = 676). Significant correlations with correction for false positive with the Benjamini–Hochberg procedure are emboldened.

Variables	Personality traits						Taste function			Age	Hot chili pepper and pungent foods	
	FN	DS	SP	SR	TAS	PBC	FPD	PROP	Burning intensity	Age	HCP yearly intake	HCP liking
FN	**1.00**											
DS	**0.24***	**1.00**										
SP	**0.13***	**0.18***	**1.00**									
SR	−0.08	−0.08	0.05	**1.00**								
TAS	**0.20***	0.10	**0.50***	**0.17***	**1.00**							
PBC	−0.02	0.05	**0.11**	**0.09**	−0.02	**1.00**						
FPD	−0.06	−0.04	**0.13***	**0.13**	**0.11**	0.02	**1.00**					
PROP	0.06	0.06	−0.01	0.04	**0.10**	−0.02	0.00	**1.00**				
Burning intensity	**0.10**	**0.16***	0.05	−0.04	0.02	0.02	0.00	**0.16***	**1.00**			
Age	0.06	0.03	**−0.21***	**−0.35***	**−0.26***	−0.01	**−0.34***	**−0.11**	0.04	**1.00**		
HCP yearly intake	**−0.19***	**−0.11**	−0.09	0.05	0.00	0.01	−0.08	0.00	**−0.28***	0.03	**1.00**	
HCP liking	**−0.18***	**−0.10**	−0.09	0.03	−0.05	−0.01	−0.07	0.01	**−0.35***	0.07	**0.73***	**1.00**

* Indicates a significant correlation after Bonferroni correction for multiple comparisons ($p < 0.0008$).

Table 5
Pearson correlation coefficients within the personality traits, taste functions and measures of liking and choice of hot chili pepper (HCP) and pungent foods in males (n = 419). Significant correlations with correction for false positive with the Benjamini–Hochberg procedure are emboldened.

Variables	Personality traits						Taste function			Age	Hot Chili Pepper and pungent foods	
	FN	DS	SP	SR	TAS	PBC	FPD	PROP	Burning intensity	Age	HCP yearly intake	HCP liking
FN	**1.00**											
DS	**0.27***	**1.00**										
SP	**0.19***	**0.12**	**1.00**									
SR	0.00	−0.01	0.11	**1.00**								
TAS	**0.24***	**0.14**	**0.52***	**0.18***	**1.00**							
PBC	0.00	0.06	**0.16**	**0.16**	−0.01	**1.00**						
FPD	−0.10	−0.06	0.10	**0.26***	0.06	0.04	**1.00**					
PROP	0.02	0.06	−0.02	**0.12**	−0.02	0.01	0.00	**1.00**				
Burning intensity	**0.13**	**0.18***	0.02	0.06	−0.04	0.09	0.00	**0.20***	**1.00**			
Age	**0.12**	**0.18***	**−0.19***	**−0.44***	**−0.15**	**−0.15**	**−0.35***	−0.08	0.06	**1.00**		
HCP yearly intake	**−0.13**	**−0.12**	−0.03	0.06	0.05	0.03	0.02	−0.04	**−0.24***	−0.01	**1.00**	
HCP liking	**−0.18***	−0.08	−0.02	0.00	0.04	0.05	−0.03	−0.03	**−0.29***	0.02	**0.64***	**1.00**

* Indicates a significant correlation after Bonferroni correction for multiple comparisons ($p < 0.0008$).

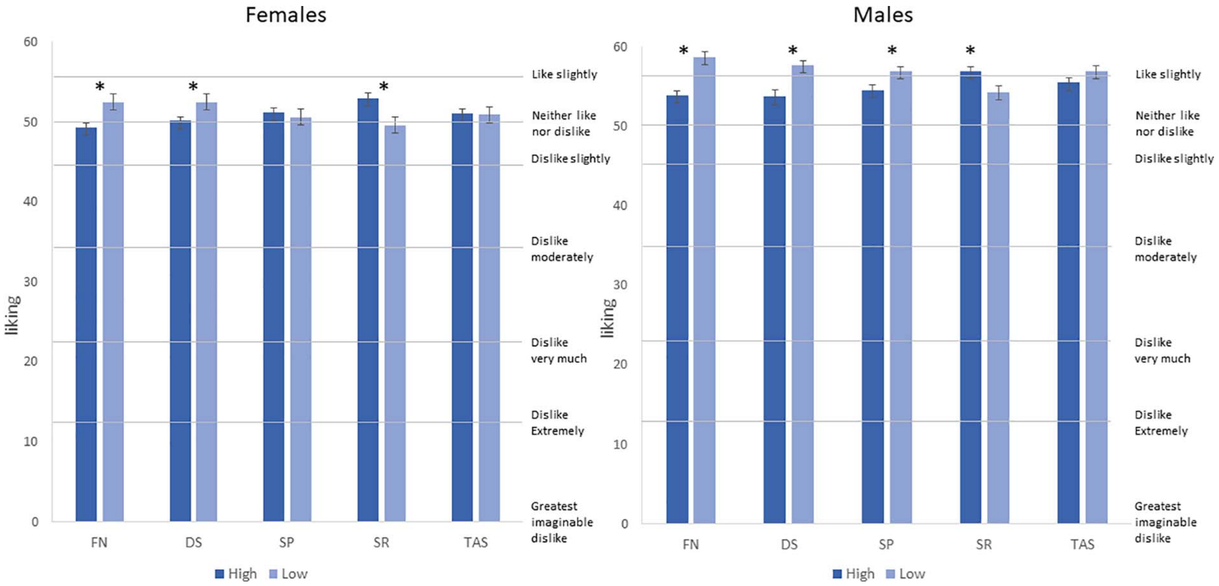

Fig. 1. Liking ratings (Least Squares means) for the tomato juice samples spiked with capsaicin for females and males for low and high in food neophobia (FN), sensitivity to disgust (DS), sensitivity to punishment (SP), sensitivity to reward (SR) alexithymia (TAS). * indicates a significant difference $p < 0.05$.

3.3.2. *Personality traits*

Weak negative correlations were found between the personality traits and liking and intake of pungent foods. Neophobia was negatively associated with chili stated liking (F and M: r = -0.18) and with yearly intake (M: -0.13; F: r = -0.19) in both males and females. Sensitivity to disgust was weakly negatively associated with chili stated liking (-0.10) and yearly intake (-0.11) in females and with yearly intake (-0.12) in males.

3.3.3. *Age*

Age was not significantly associated with any measure of liking nor yearly intake of hot chili pepper or to burning intensity (Tables 4 and 5).

3.3.4. *PROP responsiveness*

Both in females and in males, a significant positive relationship was found between PROP responsiveness and intensity of a capsaicin stimulus (F: r = 0.16; M: r = 0.20, Tables 4 and 5), but not with stated liking nor yearly intake of chili. No significant correlation was found either in females nor males between fungiform papillae density and burn of capsaicin, yearly intake and liking for chili.

3.4. *Effect of personality traits on liking for capsaicin in tomato juice*

A significant main effect of the sample was found in each ANOVA model. A significant main effect of food neophobia, sensitivity to disgust and sensitivity to reward on liking of the tomato juices spiked with capsaicin was found in both males and females: individuals low in food neophobia and disgust sensitivity and individuals high in sensitivity to reward liked these samples more. A significant main effect of sensitivity to punishment on liking was found only in males, with individuals low in sensitivity to punishment expressing higher liking (Fig. 1). Post-hoc tests with Bonferroni adjustment revealed a significant difference between the two groups (High and Low) on the samples with the concentration of capsaicin of 1.01 mg/kg in females and 1.52 mg/kg in males, for both food neophobia and sensitivity to reward (Table 6). No significant effect of alexithymia or private body consciousness on liking was observed, either in males nor females.

None of these effects were further qualified by interactions between the personality traits and the samples, with the exception of food neophobia in females and sensitivity to reward in males where a trend for significance was observed (respectively, p = 0.069; p = 0.068).

3.5. *Effect of personality traits on intensity of sensory properties of tomato juice plus capsaicin*

A significant main effect of the sample was found in each ANOVA model with the exception of acid in some cases (Table 6). Food neophobia and sensitivity to disgust had significant main effects on the intensity of burning and overall flavour in both males and females, with individuals high in food neophobia and sensitivity to disgust giving higher ratings and, in males only, also for acid (Fig. 2).

Sensitivity to punishment and alexithymia had a significant main effect, but only in females, on intensity of pungency and overall flavour, with high sensitivity to punishment and high alexithymia reporting higher intensities. Females higher in alexithymia also reported higher intensities for acid and sweet, while males higher in alexithymia only for acid. Sensitivity to reward had a significant main effect on sweetness in both males and females, with higher SR rating higher intensities of sweet (Fig. 2). None of these effects were further qualified by interactions between each personality trait and the samples.

Post hoc tests with Bonferroni adjustment revealed that a significant difference between the two groups (High and Low) was reported on the samples with the higher concentration of capsaicin (1.52 mg/kg) in females for burning sensation in food neophobia and sensitivity to punishment and in males for overall flavour in food neophobia.

3.6. *Effect of PROP status on intensity and liking for capsaicin in tomato juice*

An effect of PROP status on the intensity of all sensory properties measured in the tomato juice spiked with capsaicin series was found, with supertasters scoring significantly higher for burning, acid, sweetness and overall flavour in both males ($p < 0.0001$) and females ($p < 0.0001$) (Fig. 3). An interaction between PROP status and sample for burning in both males (p = 0.007) and females (p = 0.059) was found. Post-hoc tests with Bonferroni adjustment revealed significant differences between the groups for the high capsaicin sample (1.52 mg/kg) in females for burning sensation and overall flavour, and in burning sensation and sweetness in males. Significant differences were also found for the 1.1 mg/kg capsaicin sample for overall flavour in females and burning sensation in males.

Table 6
Associations of food neophobia (FN), sensitivity to disgust (DS), sensitivity to punishment (SP), sensitivity to reward (SR) alexithymia (TAS) and private body consciousness (PBC) groups (low/high) and samples (TOM 1, 2, 3 4) on liking and perceived intensities of burning, acid, sweet and overall flavour, 2-way analysis of variance, F ratios (df for each personality trait = 1; for samples = 3). Significant differences $p < 0.05$ are emboldened.

Personality trait	Variable	FEMALES				MALES			
		Personality trait		Sample		Personality trait		Sample	
		F	p-value	F	p-value	F	p-value	F	p-value
FN	Liking	**16.68**	**< 0.0001**	**54.79**	**< 0.0001**	**28.39**	**< 0.0001**	**7.96**	**< 0.0001**
	Burning	**13.72**	**0.000**	**397.50**	**< 0.0001**	**12.69**	**0.000**	**215.48**	**< 0.0001**
	Acid	3.39	0.066	**2.80**	**0.038**	0.48	0.488	0.73	0.537
	Sweet	1.40	0.237	**8.28**	**< 0.0001**	1.39	0.239	**5.12**	**0.002**
	Flavour	**6.17**	**0.013**	**178.06**	**< 0.0001**	**10.54**	**0.001**	**56.85**	**< 0.0001**
DS	Liking	**8.32**	**0.004**	**47.51**	**< 0.0001**	**16.53**	**< 0.0001**	**8.08**	**< 0.0001**
	Burning	**15.42**	**< 0.0001**	**368.38**	**< 0.0001**	**8.08**	**0.005**	**193.76**	**< 0.0001**
	Acid	2.11	0.146	1.97	0.117	**8.02**	**0.005**	0.93	0.427
	Sweet	0.68	0.410	**7.67**	**< 0.0001**	2.37	0.124	**4.22**	**0.006**
	Flavour	**9.08**	**0.003**	**160.14**	**< 0.0001**	**10.12**	**0.001**	**52.17**	**< 0.0001**
SP	Liking	0.49	0.484	**51.71**	**< 0.0001**	**6.71**	**0.010**	**7.85**	**< 0.0001**
	Burning	**15.61**	**< 0.0001**	**388.29**	**< 0.0001**	0.02	0.879	**204.14**	**< 0.0001**
	Acid	0.29	0.593	**3.05**	**0.027**	0.07	0.796	0.73	0.533
	Sweet	1.82	0.177	**7.86**	**< 0.0001**	0.00	0.956	**4.01**	**0.007**
	Flavour	**4.30**	**0.038**	**167.73**	**< 0.0001**	0.98	0.323	**57.39**	**< 0.0001**
SR	Liking	**17.67**	**< 0.0001**	**46.58**	**< 0.0001**	**7.02**	**0.008**	**10.51**	**< 0.0001**
	Burning	3.03	0.082	**367.75**	**< 0.0001**	0.18	0.669	**189.33**	**< 0.0001**
	Acid	2.33	0.127	2.39	0.067	0.16	0.689	0.68	0.566
	Sweet	**4.48**	**0.034**	**7.23**	**< 0.0001**	**4.59**	**0.032**	**2.78**	**0.040**
	Flavour	0.61	0.435	**165.63**	**< 0.0001**	0.00	0.957	**51.68**	**< 0.0001**
TAS	Liking	0.04	0.847	**57.77**	**< 0.0001**	2.59	0.108	**8.81**	**< 0.0001**
	Burning	**11.28**	**0.001**	**403.54**	**< 0.0001**	3.26	0.071	**218.01**	**< 0.0001**
	Acid	**7.58**	**0.006**	**3.11**	**0.025**	**4.65**	**0.031**	0.59	0.618
	Sweet	**7.21**	**0.007**	**8.41**	**< 0.0001**	3.75	0.053	**4.80**	**0.002**
	Flavour	**7.27**	**0.007**	**181.50**	**< 0.0001**	0.33	0.564	**58.11**	**< 0.0001**
PBC	Liking	1.19	0.276	**52.90**	**< 0.0001**	0.99	0.321	**8.49**	**< 0.0001**
	Burning	0.33	0.563	**345.93**	**< 0.0001**	0.87	0.352	**203.64**	**< 0.0001**
	Acid	0.02	0.881	**3.00**	**0.030**	1.45	0.229	0.76	0.517
	Sweet	0.57	0.450	**8.78**	**< 0.0001**	2.38	0.123	**3.68**	**0.012**
	Flavour	0.00	0.983	**146.74**	**< 0.0001**	0.37	0.542	**51.32**	**< 0.0001**

However, no effect of PROP status on liking scores was found in males ($p = 0.997$), and in females only a weak effect was found, with NT having lower liking scores compared to ST and MT ($p = 0.039$). There were no further significant differences between groups for each sample.

3.7. Associations between personality traits and the pungent food choice

In both PLS models, on females and males, the cross-validation indicated that only one component had a significant prediction ability and therefore only one component was used in the jack-knife test for estimating the uncertainty of the model parameters. In females, the explained variances for the first two components were 31% and 9% for X and 47% and 3% for Y (Fig. 4), while in males these were 27% and 11% for X and 39% and 1% for Y (Fig. 5).

Age and sensitivity to reward were not significant in females, while sensitivity to punishment was found to be not significant in males. In both genders, the variables most positively associated with the pungent food index were the stated liking, the yearly intake and the familiarity of chili, and the liking for the tomato sample with the highest capsaicin concentration (1.52 mg/kg). The variables most negatively correlated with the pungency index were the intensity of burning, food neophobia and sensitivity to disgust. In females, sensitivity to punishment was also negatively correlated with the pungency index, while in males, age was negatively, and sensitivity to reward positively, correlated with the pungency index. Alexithymia, PROP responsiveness and FP density were found to be not significant, in either males or females, and thus were included in the model as downweighted variables for illustrative purposes.

4. Discussion

4.1. Yearly intake of chili and intensity of capsaicin

Consistent with Lawless et al. (1985), but in contrast to more recent studies (Byrnes & Hayes, 2013, 2015, 2016), we found a significant negative relationship between intensity of capsaicin solutions and yearly intake of chili and pungent food, both in females and males. We can hypothesise that these different results are due to a different level of concentration chosen for the capsaicin solutions, from moderate to strong (1.5 mg/kg) in our case, higher (7.5 mg/kg, between 'strong' and 'very strong' on the gLMS) in Byrnes and Hayes (2013, 2015) and lower and higher (0.9 and 3.6 mg/kg) in Byrnes and Hayes (2016). However, Nolden and Hayes (2017) have recently reported an association of yearly intake of chili pepper with capsaicin perception using a range of different concentrations (0.11, 0.275, 0.55, 1.1, 2.75, 5.5, 11 and 22 mg/kg).

We found that users and non-users of chili in a large adult sample of Italians significantly differed in responsiveness to pungency, personality traits and gender, but did not differ either in age or in responsiveness to basic tastes, astringency, PROP nor in fungiform papillae density.

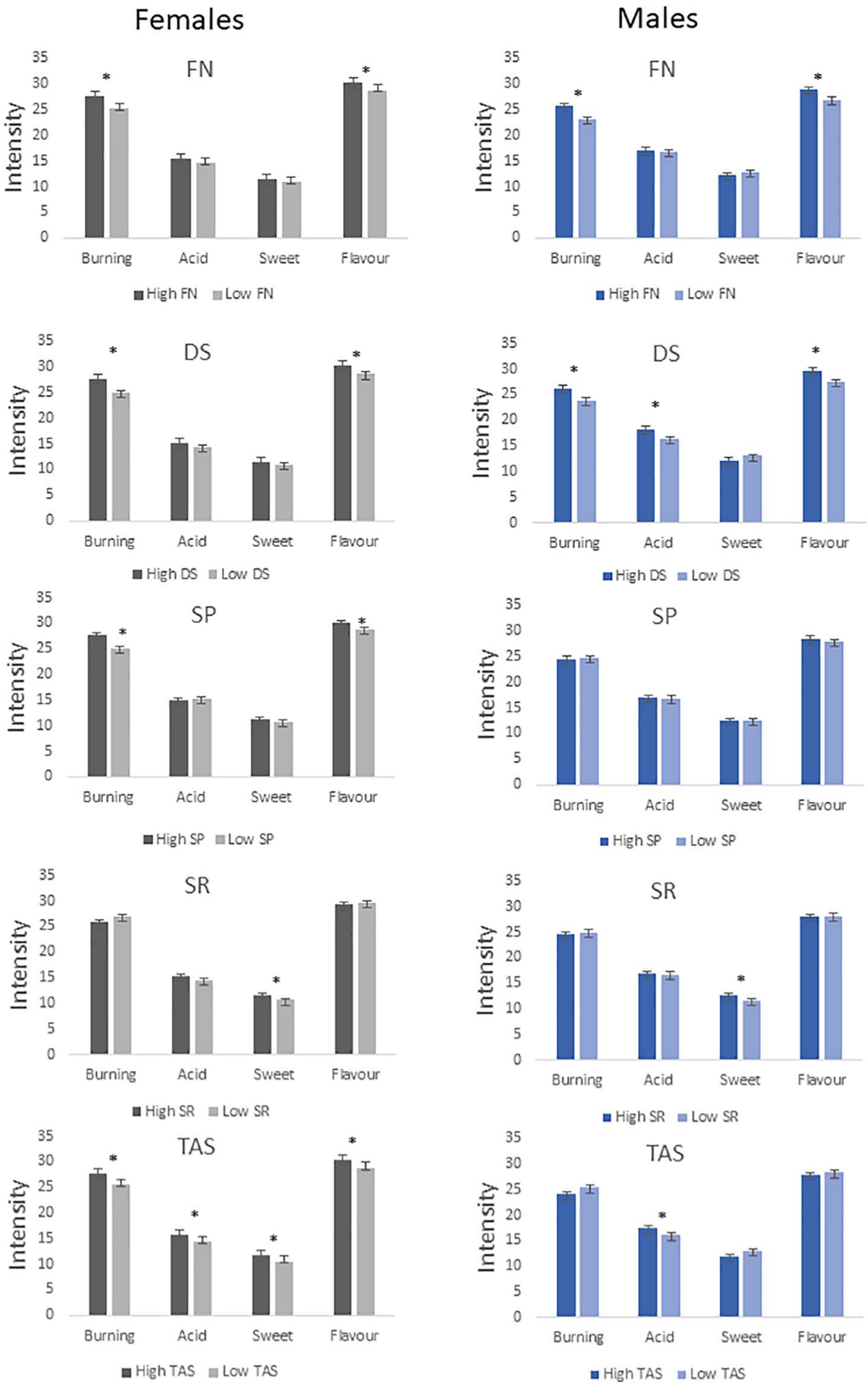

Fig. 2. Perceived intensities of burning, acid, sweet and overall flavour (Least Squares means) for the tomato juice samples spiked with capsaicin for females and males for low and high in food neophobia (FNì), sensitivity to disgust (DS), sensitivity to punishment (SP), sensitivity to reward (SR) alexithymia (TAS). * indicates a significant difference $p < 0.05$.

4.2. Personality traits affect liking and perception of burning differently

In line with previous results (Byrnes & Hayes, 2013), we did not find a relationship between private body consciousness, sensitivity to reward or sensitivity to punishment, and intensity of capsaicin solutions. However, we found a weak, but significant, positive relationship between food neophobia and sensitivity to disgust and the perceived intensity of capsaicin solution.

Our findings highlight a significant role for personality traits in chili and pungent foods choice and liking, both in a test in a laboratory setting with a series of tomato juices with different concentration of capsaicin and on self-reported choice of pungent foods. Interestingly, we observed that not only some traits have a differing importance in their links to chili and pungent food preferences, but also that some traits are associated with burn intensity. We observed three patterns:

a. *Personality traits influence liking and perception of burning sensation.*

In both females and males, more neophobic individuals and those more sensitive to disgust had lower liking scores for tomato juice spiked

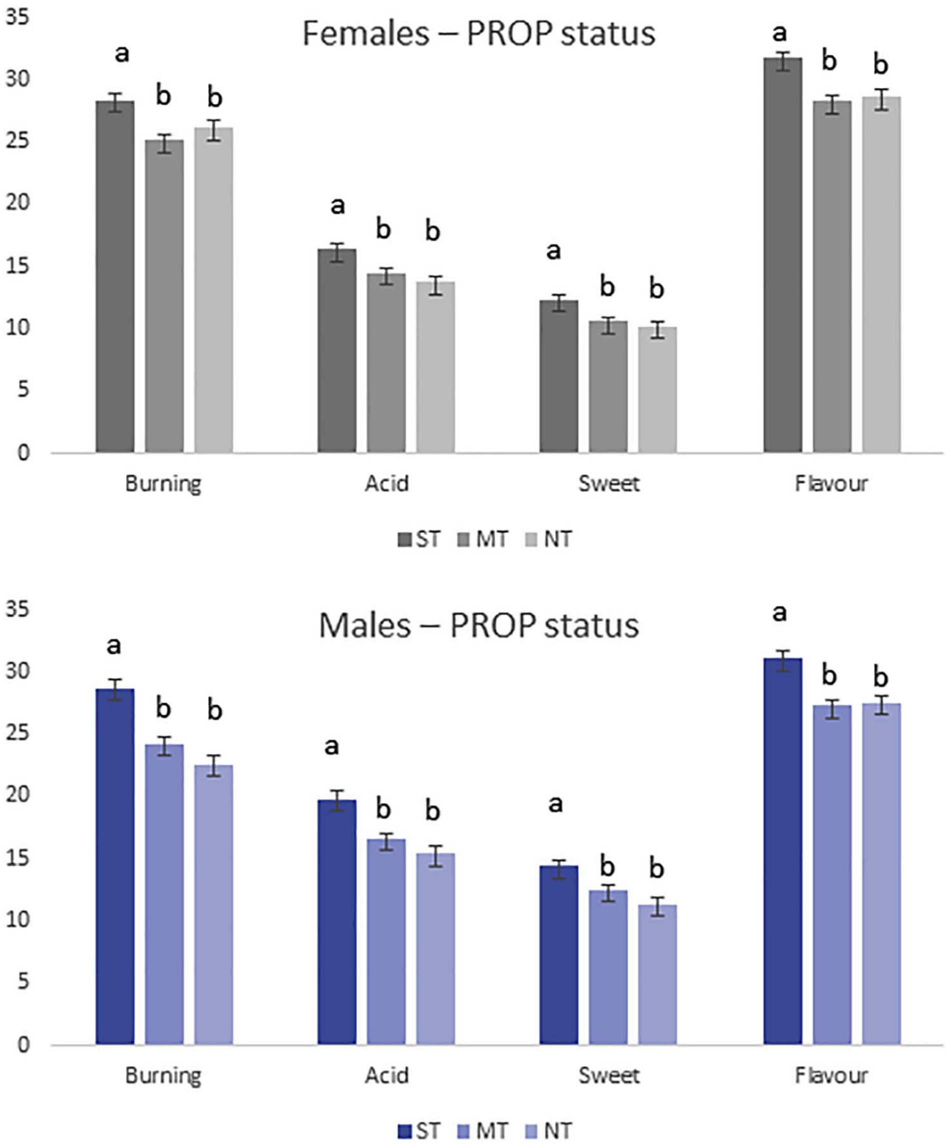

Fig. 3. Perceived intensities of burning, acid, sweet and overall flavour (Least Squares means) for the tomato juice samples spiked with capsaicin for females and males PROP non-taster (NT), medium taster (MT) and super taster (ST). * different letters indicate significant differences.

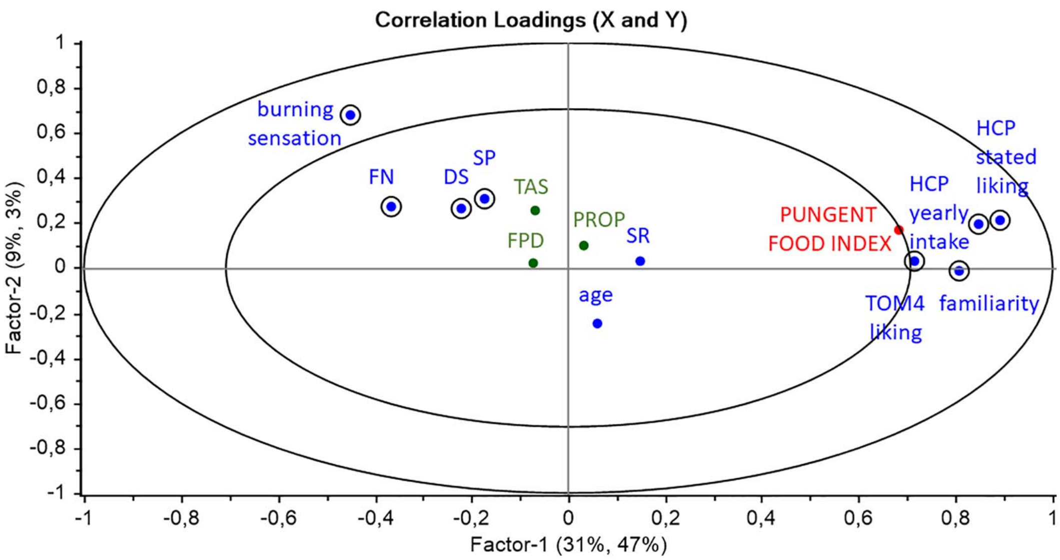

Fig. 4. Correlation loadings from PLS model in females. Variance accounted for X and Y for PC 1 and PC2 are reported in brackets. Important variables (uncertainty test) are circled. In green the downweighted variables. FN = food neophobia; DS = sensitivity to disgust; SP = sensitivity to punishment; SR = sensitivity to reward; TAS = alexithymia; PROP = PROP responsiveness; FPD = fungiform papillae density.

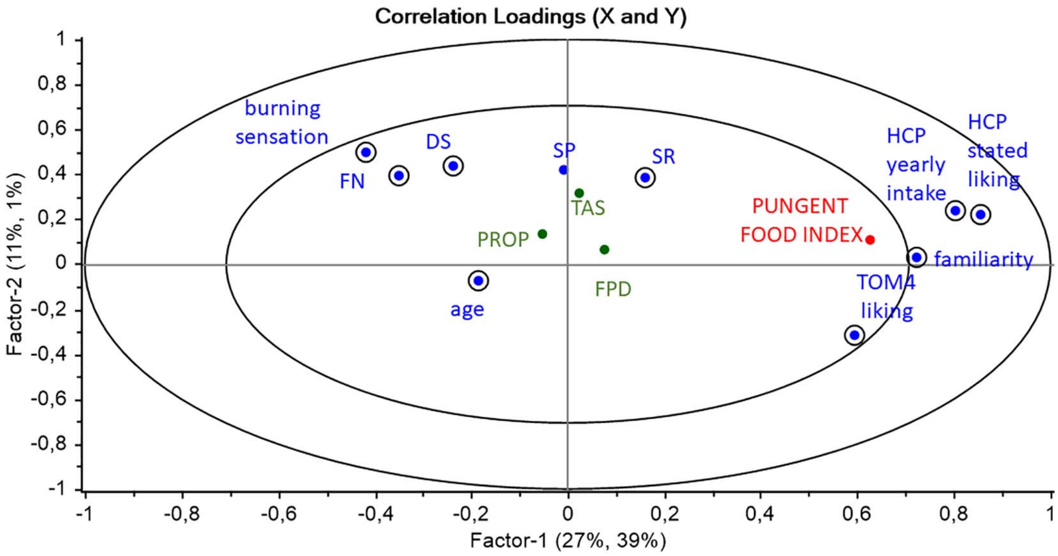

Fig. 5. Correlation loadings from PLS model in males. Variance accounted for X and Y for PC 1 and PC2 are reported in brackets. Important variables (uncertainty test) are circled. In green the downweighted variables. FN = food neophobia; DS = sensitivity to disgust; SP = sensitivity to punishment; SR = sensitivity to reward; TAS = alexithymia; PROP = PROP responsiveness; FPD = fungiform papillae density.

with capsaicin, and rated the intensity of pungency and overall flavour higher. Thus, the personality traits were associated with a different perception of the key sensation and the "hedonic" meaning assigned to the sensory stimuli is probably modulated by the intensity of these sensations (burning, overall flavour). This finding is consistent with previous studies that reported infrequent chili users rated the capsaicin burn as more intense than did the frequent users (Prescott & Stevenson, 1995), confirmed also here by our findings on capsaicin solutions.

b. *A personality trait is linked to liking for, but not perception of, burning sensations.*

For both females and males, those more sensitive to reward gave higher liking scores for tomato juice spiked with capsaicin, but did not differ in intensities of pungency and overall flavour compared to individuals less sensitive to reward.

c *Personality traits influence perception of burning sensations but not liking.*

In these cases, the personality traits of alexithymia and sensitivity to punishment play a role in perception but do not influence liking in females.

Both in the case in which we observed an effect of personality on liking and on intensity (food neophobia and sensitivity to disgust), and in the case in which we observe an effect only on liking but not on intensity (sensitivity to reward), we may hypothesise that the reason behind these different responses is not associated with a differential taste function but with the meaning associated with the stimulus. Food neophobia, sensitivity to punishment and sensitivity to disgust have all been found to be associated with anxiety (FNS: Pliner, Eng, & Krishnan, 1995; Pliner, Pelchat, & Grabski, 1993; Pliner & Hobden, 1992; Pliner & Loewen, 1997; Raudenbush & Capiola, 2012; DS: Viar-Paxton & Olatunji, 2016; SP: Torrubia et al., 2001). Recent studies have reported that healthy individuals with mild anxiety were more sensitive to sensory inputs, such as pain (Thompson, Keogh, French, & Davis, 2008), tone loudness (Dess & Edelheit, 1998), and bitter, sweet and salty tastes (Ileri-Gurel, Pehlivanoglu, & Dogan, 2013; Platte, Herbert, Pauli, & Breslin, 2013; Wilson, Kumari, Gray, & Corr, 2000). They were also found to be more sensitive to threatening information, which is explained by a generalized enhanced vigilance in this subject group (Mogg & Marden, 1990).

Capsaicin induces a chemosensory response that is associated with burning and, at higher concentrations, to pain. Individuals that are higher in the traits of food neophobia, sensitivity to disgust and sensitivity to punishment may be in a more anxious state during a pungent stimulus, and thus perceive the key sensations (burning-overall flavour) with a heightened intensity. Several studies have reported that individuals who perceive a higher intensity of pungency tend to like the stimulus less, and this may explain the effect of these traits on liking (Stevenson & Yeomans, 1993). In other words, we hypothesise that these personality traits may modulate the sensory response to a stimulus, and consequently affect liking. The fact that we did not find significant correlations of these traits with PROP status either in males nor in females, and only a weak relationship between fungiform papillae density and sensitivity to punishment only in females, lead us to suggest that the differences in perception noted for the traits of food neophobia, sensitivity to disgust and sensitivity to punishment may be not associated with a differential taste responsiveness, but rather with the anxiety associated with food experience in those high in these traits. This idea is coherent with recent findings that show that food neophobia is pervasive in terms of both preferences and intake, and is not limited to unfamiliar foods (Jaeger, Rasmussen, & Prescott, 2017; Laureati et al., submitted). Further studies are needed to confirm this hypothesis, investigating more in depth the relationship between these traits, anxiety and taste responsiveness.

Previous studies found a connection between taste responsiveness to PROP and reactivity to visceral disgust elicitors (Herz, 2011, 2014), and explained this with the concept that greater responsivity to visceral disgust develops through a lifetime of intense activation of the anterior insula by oral sensations. Thus, as a result of continuously greater stimulation among individuals who are highly taste sensitive, their anterior insula become more sensitized to other stimuli that activate the insula as well (e.g., disgust elicitors), compared with individuals who are less taste sensitive. However, we did not find a significant correlation between PROP responsiveness and sensitivity to disgust either in males nor in females.

Robino et al. (2016) reported that alexithymia, the inability of individuals to identify and name their emotional states, differed between PROP non-taster and taster individuals, with non-tasters showing higher total alexithymia scores. This higher alexithymia scores were associated with liking of alcohol, sweets and fats/meats whereas lower alexithymia scores were related to liking of vegetables, condiments and strong cheeses. We report only a weak but significant positive correlation between PROP responsiveness and alexithymia in females, and we found that females higher in alexithymia perceived higher burning in the tomato juices samples spiked with capsaicin, but we did not find an influence of both PROP responsiveness nor alexithymia on liking of pungent and pungent foods. Further investigation on the relationships between PROP responsiveness and personality traits are needed to gain a deeper insight in this issue.

The fact that we found an effect of sensitivity to reward on pungency liking, but not on the sensory response, suggests that this effect is uniquely related to the meaning associated with the burning sensation and/or the pungent food – that it, its reward value. The contributions of culture, social environment on one hand (Rozin & Schiller, 1980), and the neurobiological (the dopamine reward system) and genetic systems on the other, in the construction of this meaning are not clear at present, and thus require further investigation. The mesolimbic dopamine "reward" pathways have been proposed as the key biological basis of the trait of sensitivity to reward (Gray & McNaughton, 2003), but the connection between this trait and the food reward system (Rolls, 2015) requires further exploration. Prescott and Stevenson (1995) reported that sweetness was suppressed by the presence of capsaicin, and this effect was confirmed in our data. However, for individuals more sensitive to reward we reported a higher perception of sweetness intensity for the series of tomato juices spiked with capsaicin. Again, this is probably consistent with a focus on the rewarding aspects of the stimulus for these individuals. Further investigations are needed to understand this issue more in depth. Males higher in sensitivity to punishment expressed higher liking scores for capsaicin added samples, but did not score differently the intensities of burning nor overall flavour. It is possible that, in males only, this trait operates in a similar, but inverse, way as reward.

4.3. Personality traits affect pungent food choice differently in males and females

The PLS regression models allowed examination of the relationships between personality traits and pungent food choice with a more global perspective. Although we found no effect on pungent food choice of PROP responsiveness, fungiform papillae density and alexithymia, our findings indicate that personality traits play an important role in pungent food choice. Sensitivity to disgust and food neophobia (in both genders) and sensitivity to punishment (in females) were negatively associated with the choice of pungent foods. Such traits, which are also associated with the dimension of anxiety, may act as a barrier, for their alerting effect, in the choice of chili and pungent foods and thus also in the hedonic shift that guides the development of liking for chili.

Conversely, in males, sensitivity to reward, associated with impulsivity (Torrubia et al., 2001), might promote this hedonic shift, favouring the preference for chili and pungent food. In fact, in males, sensitivity to reward was positively associated with the choice of pungent foods. Previous studies have showed the association of sensitivity to reward to unhealthy food choices, such as higher fat intake, higher alcohol consumption, smoking frequency (Morris, Treloar, Tsai, McCarty, & McCarthy, 2016; Tapper, Baker, Jiga-Boy, Haddock, & Maio, 2015), and disliking for bitter vegetables such as rocket and radish (Monteleone et al., 2017). Interestingly, in this study, we report a positive effect of sensitivity to reward on food behaviour, considering the possible benefits for health of chili, e.g. in terms of weight management or in treating dysphagia (Ludy, Tucker, & Tan, 2015). However, it has to be noted that pungent foods can vary dramatically in energy density: while in a Mediterranean food culture such as the Italian one, chili is usually associated with tomato sauce, in other food culture it is often associated with high fat culinary preparations.

Our results on sensitivity to reward are consistent with previous findings of Byrnes and Hayes (2015), who found a stronger relationship in males between sensitivity to reward and pungent food liking and with intake as well. In a further study, Byrnes and Hayes (2016) did not find an effect of sensitivity to reward on liking, but only on intake. This result might be due to the fact that the cohort was not large enough, as the authors suggested, but also to the fact that the sample was highly unbalanced in terms of gender, with more females, who are less sensitive to reward. We did not find a correlation between sensitivity to reward and intake, but we did find an effect of intake (as user status) on sensitivity to reward and a correlation between sensitivity to reward and pungent food choice in males.

For food neophobia, sensitivity to disgust and sensitivity to reward, we report similar results both on liking for tomato juices added with capsaicin and on pungent food choice. On the other hand, with sensitivity to punishment we observed different results: in males, we reported an association with liking, but not with pungent food choice. In females, we reported an association with pungent food choice, but not an effect on liking. In females we found an effect on perception of sensitivity to punishment as well, with individuals higher in sensitivity to punishment perceiving higher intensities of burning and overall flavour. These results suggest that further investigation of this trait and its association with sensory and hedonic responses is needed in order to better understand its role in each gender.

Interestingly, some traits seem to play a role in pungent food liking only for males or females. This might be explained by the fact that males are more sensitive to reward than females, while females are more sensitive to punishment than males.

5. Conclusions

The identification of personality traits as sources of individual differences in sensory and hedonic responses is not new (Stevens, 1996; Stone & Pangborn, 1990) and has been recently gaining new interest with recent findings suggesting a link between specific personality traits and sensory thresholds (Croy, Springborn, Lötsch, Johnston, & Hummel, 2011). Further studies are needed to investigate in a large sample the connection between sensory, hedonic and personality traits, taking into account gender differences. However, the current study has expanded the existing knowledge about the effects of variations in personality traits on food preferences in two major ways.

Firstly, the impact of personality traits on burning sensation and pungent food liking and choice differ in males and females. This may signal that food neophobia and sensitivity to disgust in both genders, and sensitivity to punishment for females, actually are an important barrier to the hedonic shift for liking of hot chili pepper and pungent foods. Conversely, sensitivity to reward may promote this hedonic shift, stronger in males, impacting not only liking but choice as well. These findings may have important implication for health intervention, considering the beneficial effect for health associated with hot chili pepper.

Secondly, some personality traits are associated with both liking and perception of burning sensation, some not. Food neophobia and sensitivity to disgust in both genders, and sensitivity to punishment in females, are associated with both perception and liking of burning and choice of pungent foods, while sensitivity to reward is associated with liking but not with a different perception of burning in both genders and with pungent food choice in males. Sensitivity to punishment is associated in females with the perception of burning and choice of pungent foods, but not with liking.

This signals that what we identify under the umbrella term of "personality traits" may actually be different phenomena: on one hand, personality may reflect individual differences in sensitivity to taste and to chemestetic sensations and, in combination with these, influence food liking. We do not know which of these is the cause or the consequence; further studies will possibly clarify this fundamental issue, but we may hypothesise that our oral sensitivity influences our personality, being the means through which individuals interact with the world. Notwithstanding this, it is apparent that in this case, the meaning assigned to the sensory stimuli, such as pungent food, is modulated by how intense these sensations (burning, overall flavour) are felt. On the other hand, we have a personality trait that directly influence liking of hot chili pepper, sensitivity to reward. In this case liking does not seem to be dependent on how intense is perceived the burning sensation, but uniquely related to the meaning associated to it and/or to the pungent food, namely its rewarding value, being it social or neurobiological.

Author contributions

SS undertook the analyses and wrote the manuscript; SS and EM contributed to plan the analyses; SS, EM, JP, ADT, CD, ML discussed the interpretation of the results; EM, AB, CD, IE, TGT, FG, ML, EP, FS, SS, LT collaborated in the design of the project Italian Taste; all authors helped with data collection, reviewed and offered critical comments on the manuscript. ADT undertook the analyses for the validation of the questionnaires and wrote the relative paragraphs as part of her PhD thesis.

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Supplementary data

Supplementary data associated with this article (validation of the Italian version of the personality trait questionnaires and their translation) can be found, in the online version, at http://dx.doi.org/10.1016/j.foodqual.2018.01.014.

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Associations between food neophobia and responsiveness to “warning” chemosensory sensations in food products in a large population sample

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ABSTRACT

The aim of the present study is to explore the association between food neophobia and chemosensory responsiveness and to determine whether this association translates into different food liking and preference patterns. Data were collected on 1225 respondents (61% females, age 20–60 years) as part of the Italian Taste project. Respondents completed the *Food Neophobia Scale* (FNS) as well as a food preference and familiarity questionnaire for a number of foods and beverages categorized as mild or strong tasting. Moreover, they evaluated attribute intensity and liking of an actual food (dark chocolate pudding) varying in the level of sweetness, bitterness and astringency. Taste function was evaluated by measuring fungiform papillae density (FPD), responsiveness to PROP (6-n-propylthiouracil) and to water solutions representing various oro-sensory qualities.

High, medium and low neophobic subjects did not differ for FPD and chemosensory responsiveness. Reported liking was significantly lower for high neophobics than low neophobics mainly for those vegetables and beverages characterized by high levels of warning stimuli (i.e. bitterness, sourness, astringency and alcohol), whereas almost no differences were found for the bland versions of food items. High and medium neophobics rated astringency and, to a lesser extent, bitterness of the dark chocolate pudding, as more intense than low neophobics and liked the most bitter and astringent variants significantly less than low neophobics.

Differences in liking, however, do not seem to be mediated by high food neophobics’ superior taste functioning but rather by higher levels of arousal when eating food and/or drinking beverages that are perceived as unpleasant and potentially dangerous. Finally, the effect of food neophobia was evident not only for unusual items in the Italian food context, but even for items that might be considered highly familiar.

1. Introduction

Food neophobia, defined as the reluctance to eat unfamiliar foods, is a characteristic that all omnivores, including humans, share (Pliner & Hobden, 1992). This food behavior is a heritable trait (Knaapila et al., 2007) which has been preserved from one generation to another making some individuals extremely selective about food, presumably as a means to avoid the potential toxicity of an unknown food source. Even in modern society, where food safety is generally guaranteed and the protective purpose of food neophobia has lost importance, up to

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35% of individuals show a selective attitude toward food (Kauer, Pelchat, Rozin, & Zickgraf, 2015; Zickgraf & Schepps, 2016). Similar percentages have been reported in two large-scale studies on USA (Meiselman, King, & Gillette, 2010) and New Zealand (Jaeger, Rasmussen, & Prescott, 2017) population samples, with high neophobic individuals accounting, respectively, for 40–45% and 30% of the total population.

Food neophobia (FN) and food selectivity are considered maladaptive behaviors as they decrease diet variety, thus having potentially important nutritional consequences. Recent evidence suggests that, in adults, FN is negatively related to daily fruit and vegetables intake and to diet variety in general (Jaeger et al., 2017; Zickgraf & Schepps, 2016). Moreover, an association between FN and increased body mass index has been observed (Proserpio, Laureati, Invitti, & Pagliarini, 2018) as neophobic individuals may choose to eat familiar food which is more energy dense than fruit and vegetables (Knaapila et al., 2011) or may be less willing to try healthy alternative versions of familiar products (Monteleone et al., 2017; Schickenberg, van Assema, Brug, & de Vries, 2008).

Although FN has been studied extensively, especially in children, relatively little information is available on its causal origins and relationship to eating behavior in adults. Knaapila et al. (2011) reported high neophobic reactions for fruit and vegetables, fish and meat but no effect of FN was observed on frequency of use of energy dense foods in a large sample of young adults. Similar findings have been reported in children (Cooke, Wardle, & Gibson, 2003), but it remains unclear why FN is particularly high for certain food categories. Some authors suggested that this behavior may be due topersonality traits (Dovey, Staples, Gibson, & Halford, 2008), whereas others reported perceptual (Coulthard & Blissett, 2009) or genetic reasons (Knaapila et al., 2007, 2011). More likely, the specificity of FN is due to the concurrence of all these factors.

An important aspect for novel food refusal is the expectation that the sensory properties of food may be unpleasant (Pliner, Pelchat, & Grabski, 1993). In this context, individual difference in taste responsiveness may play an essential role in moderating this effect. Polymorphisms in the TAS2R38 gene may lead to variation in the perception of the bitterness of 6-n-propylthiouracil (PROP), with individuals classed as ‘supertasters’ (STs), ‘medium tasters’ (MTs) or ‘nontasters’ (NTs) (Bartoshuk, Duffy, & Miller, 1994). Despite some contradictory data in the literature, higher taste responsiveness to PROP has been associated with greater perception of a variety of oro-sensory stimuli including sensations from bitter/astringent fruits and vegetables, fruit juices, and alcoholic beverages (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006; Lanier, Hayes, & Duffy, 2005; Melis et al., 2017; Tepper et al., 2009). Moreover, when compared with PROP non-tasters, PROP tasters perceive sourness (Prescott, Soo, Campbell, & Roberts, 2004) and the burning sensations from ethanol and spices (Prescott et al., 2000) more intensely. In general, STs also express greater dislike and more frequent rejection of astringent, bitter and sour fruits and vegetables compared to NTs (Hayes, Feeney, & Allen, 2013; Monteleone et al., 2017; Sandell et al., 2015). Moreover, a greater PROP responsiveness seems to be associated with diets rich in saturated fatty acid and added sugars, in contrast to plant-based diets (Stevenson et al., 2016). Since FN is considered an adaptive, evolutionary response, which prevents from the ingestion of poisonous substances more commonly found in fruits and vegetables (i.e., bitter, sour, and astringent compounds) (Pliner & Salvy, 2006), it is reasonable to hypothesize that food neophobics might be more sensitive to such “warning” chemosensory signals, detecting even subtle changes of these stimuli in food.

Quite surprisingly, there has been very little research carried out to ascertain whether taste responsiveness varies according to the degree of FN, and whether individual differences in perception may contribute to influence food preference and choice among neophobics and neophilics. Törnwall et al. (2014), in a large-scale study on twins, showed large differences in liking of foods with specific flavor qualities (e.g. sour fruits, berries, spicy foods and spices), but showed no differences in the liking of bland foods (salty-and-fatty foods, sweet-and-fatty foods, and fish), as a function of FN. The food neophilic group (food adventurous group), expressed higher liking for sour and spicy foods compared to the less neophilic group (basic group) and had more tolerance for capsaicin burn when tasted in model food. Interestingly, the two groups did not differ in their PROP responsiveness, or in their ratings of the intensity of sour and pungent stimuli.

Ullrich, Touger-Decker, O’Sullivan-Maillet, and Tepper (2004) reported a more complex association between taste responsiveness, rejection of novel food and food preference. They classified subjects according to their frequency of trying new foods as food adventurous or non-adventurous and found that food adventurousness was strongly associated with greater liking of bitter, hot, and pungent foods in PROP tasters, but not in PROP NTs. Only PROP tasters that were less adventurous showed a dislike of bitter, hot, and pungent foods. However, a comparison in PROP responsiveness between the two groups was not explicitly reported.

Although these findings suggest an association between FN, taste responsiveness and food preference, it is unclear whether the food rejection shown by food neophobics is mediated by a physiological predisposition to taste hypersensitivity or instead by higher levels of arousal when approaching new foods. With the possible exception of Törnwall et al. (2014), in which a model food (strawberry jelly) was used, to our knowledge, there have been no studies of FN in large population samples that have evaluated real foods varying in their sensory properties. Indeed, one of the limits of the existing literature on FN is that conclusions are drawn on small datasets thus limiting the explanatory power of FN in relation to other factors associated to food choice and health (Jaeger et al., 2017). Therefore, there is a need for further exploration of FN in larger population samples in order to examine its causal origins and its impact on food preferences and choices and its potential consequences on human health.

The present paper is part of the *Italian Taste* project, a large-scale study aimed at exploring the associations among biological, genetic, physiological, sociocultural, psychological and personality-related factors, describing the dimensions of food liking, preference, behavior and choice, and their relevance in determining individual differences within a given food culture framework (Monteleone et al., 2017).

Assuming that people high in FN tend to reject foods, in particular vegetables that are often characterized by “alarm” sensations such as sourness, bitterness and astringency, we wanted to explore whether the reluctance to consume such foods might reflect greater chemosensory responsiveness. The hypothesis is that food neophobics show higher taste responsiveness, which lead them to perceive “warning” chemosensory sensations as more intense than do neophilics. The increased responsiveness in food neophobics might justify the reduced liking for a variety of foods with high levels of “warning” sensations often experienced in many vegetables and healthy products. To test this hypothesis, we studied a sample of 1225 individuals who were assessed for taste functioning by measuring fungiform papillae density (FPD) and PROP responsiveness as well as the intensity of solutions representing the basic tastes and astringency. Respondents also completed the Food Neophobia Scale (FNS) and a food preference and familiarity questionnaire for a number of foods and beverages that could be categorized as mild or strong tasting. Food preference for warning stimuli was also tested using a real product (i.e., chocolate pudding) which was evaluated for liking and intensity of sweetness, bitterness and astringency.

2. Material and methods

2.1. Participants

Data were collected on 1225 Italian consumers (61% female; age range 20–60 years). Male and female mean ages were 37.0 years (SD = 13.1) and 36.8 years (SD = 12.7), respectively. The age distributions of males and females were not significantly different. In order to explore possible age-related differences, respondents were divided in three age groups: 18–30 years (41%), 31–45 years (27%), 46–60 years (32%). Participant recruitment details for the project are detailed in Monteleone et al. (2017).

Data on PROP responsiveness, attribute intensities and liking for the real product (chocolate puddings) were collected on 1149 respondents (61% females; age range 20–60 years, males mean age 36.6 years ± SD 13.1, females mean age 36.4 years ± SD 12.7). This reduced data set was due to the fact that two of the 19 research units involved in the project differed from the others for these measurements, showing a higher frequency of ratings close to the maximum of the scale, probably due to the lack of compliance with the procedure for training subjects to the gLMS and LAM scale use (Monteleone et al., 2017).

The study was conducted in agreement with the Italian ethical requirements on research activities and personal data protection (D.L. 30.6.03 n. 196). The study protocol was approved by the Ethics Committee of Trieste University where the genetics unit of the project is based. The respondents gave their written informed consent at the beginning of the test according to the principles of the Declaration of Helsinki.

2.2. Measurements

A detailed description of the *Italian Taste* project data collection is provided in Monteleone et al. (2017). In the present study, we limited the description to the measurements of interest. Briefly, respondents were invited to the laboratory to participate to several activities throughout two separate days. Prior to the laboratory sessions, participants completed at home an online questionnaire about their familiarity with a series of food items. During the first day, respondents were introduced to the general aim of the study and received instructions on the use of the hedonic and intensity rating scales as well as on the administration of the questionnaires. Then, they were asked to perform the hedonic test on four chocolate pudding samples. The hedonic test was followed by the administration of the food preference questionnaire, the FNS questionnaire and the evaluation of PROP solutions. During the second day, respondents were reminded of the general aim of the study and asked to rate the intensity of the water solutions (i.e., sweet, bitter, salty, sour, umami, astringent) and, after a short rest, the intensity of sweetness, bitterness and astringency of the chocolate pudding samples. The second session ended with the assessment of fungiform papillae density.

2.2.1. Questionnaires

2.2.1.1. Food familiarity and preference. The food familiarity and food preference questionnaires were developed to measure, respectively, familiarity with, and liking for, a series of food items including vegetables, beverages and sweets/desserts. The item selection reflected variations in familiarity (more/less familiar foods) and taste (mild/strong). Taste classification was based on previous literature data and published sensory databases (Dinnella, Recchia, Tuorila, & Monteleone, 2011; Lease, Hendrie, Poelman, Delahunty, & Cox, 2016; Rouseff, 1990; Wiener, Shudler, Levit, & Niv, 2012). The rationale for choosing these three specific food categories was that vegetables and beverages include items that can be easily categorized as mild or strong tasting, whereas sweets/desserts are clearly recognizable as mild items. This categorization would have been difficult with foods such as meat, fish or bakery products that, on their own, vary little in flavor intensity.

Food familiarity was assessed using a 5-point labeled 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". In order to minimize possible influences of familiarity on the association between food neophobia and reported liking of mild/strong tasting food products, within each food category, only items with mean familiarity score > 3.5 were retained, for a total of 16 vegetables, 13 beverages and 15 sweets/desserts.

Reported liking was assessed using the 9-point hedonic scale (Peryam & Pilgrim, 1957) anchored at the extremes: 1 = "extremely disliked" and 9 = "extremely liked" using as middle point of the scale 5 = "neither liked nor disliked". If the participant had never tasted the food in question, they could choose the answer "I have never tasted it". The presentation order of the items within each product category as well as the product category order were randomized across participants.

2.2.1.2. Food neophobia assessment. Food neophobia was quantified using the Food Neophobia Scale (FNS) developed by Pliner & Hobden (1992). The FNS consists of ten statements evaluated with a 7-point agreement scale ranging from 1 = "I strongly disagree" to 7 = "I strongly agree". The individual FNS scores were computed as the sum of ratings given to the ten statements, after the neophilic items had been reversed; thus, the scores theoretically ranged from 10 to 70, with higher scores reflecting higher FN levels. The FNS frequency distribution was calculated and respondents were divided into 3 groups according to their FN level: low, medium and high (see results section 3.2 for details).

The original FNS was translated to Italian by two independent bilingual Italian native-speakers and, then, back translated into English (Supplementary material). The two versions were compared to identify discrepancies and reach consensus for an updated version, which was reviewed by an expert in semantics and adjustments were made when necessary to select the most appropriate translation. The final version of the Italian FNS was pilot tested with a small sample of subjects to confirm the clarity of the items and instructions for completion of the instrument. In order to assess temporal stability of the Italian version of FNS, the scale was administered twice on a sub-sample of 117 respondents (48.5% females, age range 21–60 years, mean age = 39.4 years, SD = 11.6) with a minimum and maximum time interval of 8 and 14 months, respectively, between the two administrations.

2.2.2. Liking and intensity ratings of a real food product

A dark chocolate pudding (prepared by dissolving in water a pudding mix: Budino da zuccherare, Cameo S.p.A., Italy with added cocoa powder: Cacao Amaro Perugina, Nestlè, Italy) was selected for the study according to the following criteria: i) being widely consumed and distributed in Italy; ii) being simple and reproducible to prepare (e.g. ready-made product), to handle (e.g. to be consumed at room temperature) and homogeneous in composition and to be easily portioned (e.g. semi-solid). Four samples varying in sucrose concentration were produced by adding different amounts of sucrose (C1 = 38 g/kg; C2 = 83 g/kg; C3 = 119 g/kg; C4 = 233 g/kg) to the base dark chocolate pudding. The addition of sucrose was expected to increase sweetness, while decreasing bitterness and astringency. The choice of sugar concentrations was based on published psychophysical data, preliminary tests (unpublished data) and a pilot study performed in 10 sensory laboratories with an average number of 5 subjects per lab to ascertain that all four prototypes were clearly discriminated according to the target sensations (i.e., sweetness, bitterness, astringency).

Liking and intensity of the target sensations were evaluated in separate days. During the first session, respondents were asked to rate their liking for each of the chocolate pudding samples using the Labeled Affective Magnitude Scale, LAM (0–100) (Schutz & Cardello, 2001). During the second session, respondents evaluated the intensity of three sensations, namely sweetness, bitterness and astringency for each of the samples using the Generalized Labeled Magnitude Scale, gLMS (0–100) (Bartoshuk et al., 2004). The experimenters provided instructions for the use of both scales prior to tasting.

In each session, the samples were served at room temperature and presented simultaneously in plastic cups coded with 3-digit numbers. Each sample consisted of 15 g of chocolate pudding. The respondents were instructed to eat the entire amount provided prior to rating liking/intensity. An interval of 90 s was imposed between tastings, during which water (tap or mineral water) was provided for palate cleansing. The sample presentation order was systematically varied according to a William's Latin square.

2.2.3. Responsiveness to PROP and water solutions

A supra-threshold 3.2 mM PROP solution was prepared by dissolving 0.5447 g/L of 6-n-propyl-2-thiouracil (European Pharmacopoeia Reference Standard, Sigma Aldrich, Milano, IT) into deionized water (Prescott et al., 2004). Subjects were presented with two identical samples (10 ml) in plastic cups, coded with three-digit numbers. Subjects were instructed to hold each sample (10 ml) in their mouth for 10 s, then expectorate, wait 20 s and evaluate the intensity of bitterness using the gLMS (Bartoshuk et al., 2004). Subjects had a 90 s break in order to control for carry-over effect after the first sample evaluation. During the break, subjects rinsed their mouth with water for 30 s, had some plain crackers for 30 s, and finally rinsed with water for a further 30 s. The average bitterness score was used for each subject.

Respondents were grouped according to their PROP status based on arbitrary cut-offs (Fischer et al., 2013; Hayes, Sullivan, & Duffy, 2010). Non-tasters (NTs) were 25.6% of total sample (arbitrary cut-off gLMS ≤ 17, moderate), whereas Super-tasters (STs) were 29.3% (arbitrary cut-off gLMS ≥ 53, very strong). The rest of the respondents were considered as Medium-tasters (MTs).

Six water solutions, corresponding to the five basic tastes and astringency were rated for intensity using the gLMS. The concentration of the solutions were decided based on published psychophysical data (Feeney & Hayes, 2014; Hayes et al., 2010; Masi, Dinnella, Monteleone, & Prescott, 2015) and previous preliminary trials conducted with one hundred untrained subjects (unpublished data) in order to select solutions equivalent to moderate/strong on a gLMS (sourness: citric acid 4 g/kg; bitterness: caffeine 3 g/kg; sweetness: sucrose 200 g/kg; saltiness: sodium chloride 15 g/kg; umami: monosodium glutamic acid salt 10 g/kg; astringency: potassium aluminum sulfate 0.8 g/kg). Respondents were informed about the sensory quality that they were tasting.

2.2.4. Fungiform papillae density

The anterior portion of the dorsal surface of the tongue was swabbed with household blue food coloring, using a cotton-tipped applicator. This made the fungiform papillae (FP) easily visible as red structures against the blue background of the stained tongue. Digital pictures of the tongue were recorded (Shahbake, Hutchinson, Laing, & Jinks, 2005) using a digital microscope (MicroCapture, version 2.0 for 20×-400×) (Masi et al., 2015). For each participant, the clearest image was selected, and the number of FP was counted in two 0.6 cm diameter circles, one on right side and one on left side of tongue, 0.5 cm from the tip and 0.5 cm from the tongue midline. The number of FP was manually counted by two researchers independently according to the Denver Papillae Protocol (Nuessle, Garneau, Sloan, & Santorico, 2015). The average of these two scores was used for each subject. The individual FPD was then calculated by reporting the number of FP to a common unit area of 1 cm^2. The FPD frequency distribution was calculated and respondents were divided into 3 groups: Low FPD (LFP; respondents in the lowest quartile: FPD ≤ 12.37, 25.7%), Medium FPD (MFP; respondents in the second and third quartiles, 12.37 < FPD < 29.16, 49.5%) and High FPD (HFP; respondents in the highest quartile: FPD ≥ 29.16, 24.8%).

2.3. Data analysis

2.3.1. Validation of the Italian version of the FNS

Reliability of the scale was assessed by calculating internal consistency (Cronbach's α) and temporal stability by test–retest evaluation. Correlations between items, item total correlation with FNS score and the relationship between mean values for each item and for total FNS score in the test–retest evaluation were measured using Pearson's correlation coefficients. Analysis of Cronbach's α with deleted variables was performed in order to investigate whether all the items contributed in the same way to the construct.

Consistent with previous studies (Fernandez-Ruiz et al., 2013; Laureati, Bergamaschi et al., 2015), the relationship between each item was further evaluated with Principal Component Analysis (PCA). Data were standardized (i.e., scaled to unit variance) prior to modeling and cross validation was chosen as validation method. A correlation loadings plot was used to find significant variables (> 50% explained variance) (Westad, Hersleth, Lea, & Martens, 2003). The external validity of FNS was evaluated analyzing the relationship between FNS scores and mean vegetables reported liking and familiarity through Pearson's correlation coefficients.

2.3.2. Association among food neophobia, chemosensory responsiveness, liking and attribute intensities

The association between FN, chemosensory responsiveness and reported liking (vegetables, beverages and sweets) was explored through 3-way ANOVAs considering FN level (Low, Medium, High), Gender and Age (18–30 years, 31–45 years, 46–60 years) and their 2-way interactions as factors. When a significant effect of Age and/or Gender was found, data were further analyzed separately for males and females and for the three age groups through 2-way ANOVA considering FN level, either Gender or Age and the respective interactions as independent variables in order to have better insights on the relative contribution of these factors on dependent variables. Post-hoc comparisons using the Bonferroni test adjusted for multiple comparison were used. Familiarity data were analyzed through Friedman's test. The association between FN, liking and attribute intensities of the real food (chocolate pudding) was investigated through 2-way ANOVA considering FN level (Low, Medium, High), Samples (C1-C4) and their interaction as factors. A p-value of 0.05 was considered as threshold for statistical significance. The SAS/STAT statistical software package version 9.3.1 (SAS Institute Inc., Cary, USA) and The Unscrambler X software (CAMO Software AS, Oslo, Norway) were used for the data analysis.

3. Results

3.1. Validation of the Italian version of the FNS

The reader is referred to Appendix A for the presentation of the results about internal reliability and external validity of FNS Italian version. Briefly, the scale displayed high internal consistency (Cronbach's $\alpha = 0.87$) and test–retest reliability. The correlation between the first and second administration of the whole scale was 0.77 ($p < 0.01$). PCA results showed that the second principal component separated reversed from unreversed items, indicating the ability of the instrument to measure two distinctive dimensions that describe opposite reactions to food, namely food neophobia and food neophilia. The FNS score was significantly and negatively related to reported vegetables liking ($r = -0.19$, $p < 0.0001$) and familiarity ($r = -0.15$, $p < 0.0001$) indicating satisfactory predictive validity.

3.2. Food neophobia scores segmentation

The FNS frequency distribution was calculated and respondents were divided into three groups according to their FN level. The group with Low FN (the neophilic group), corresponded to 26.9% of the total sample and had a FNS score within the lowest quartile (FNS score ≤ 18, mean FNS score = 14.2). The medium FN group accounted for 46.9% of the total sample and included respondents within the second and third quartiles (18 < FNS score < 36, mean FNS score = 26.1). The group with high FN (the neophobic group) corresponded to 26.2% of the total sample and had a FNS score within the highest quartile (FNS

Table 1
Effect of food neophobia level on fungiform papillae density (FPD) and chemosensory responsiveness. Values are reported as mean (standard error).

Variable	Food neophobia level			Fisher's F	p-value
	Low (n = 329)	Medium (n = 575)	High (n = 321)		
FPD	21.6 (0.8)	21.8 (0.5)	20.0 (0.7)	$F_{(2,1105)} = 2.26$	p = 0.10
Responsiveness to:					
PROP	38.6 (1.7)	37.3 (1.2)	40.4 (1.6)	$F_{(2,1135)} = 1.21$	p = 0.30
Sweetness	41.1 (1.2)	39.8 (0.8)	39.2 (1.1)	$F_{(2,1134)} = 0.68$	p = 0.51
Bitterness	29.9 (1.3)	32.3 (0.9)	32.1 (1.3)	$F_{(2,1134)} = 1.17$	p = 0.31
Saltiness	37.4 (1.3)	37.1 (0.9)	38.6 (1.2)	$F_{(2,1134)} = 0.48$	p = 0.62
Sourness	33.5 (1.3)	33.4 (0.9)	34.7 (1.2)	$F_{(2,1134)} = 0.38$	p = 0.68
Umami	25.4 (1.2)	27.5 (0.8)	27.0 (1.1)	$F_{(2,1134)} = 1.14$	p = 0.32
Astringency	17.5 (1.1)	20.0 (0.8)	19.0 (1.0)	$F_{(2,1122)} = 1.84$	p = 0.16

score ≥ 36, mean FNS score = 43.3).

3.3. Chemosensory responsiveness is not affected by food neophobia level

Mean values of FPD and responsiveness to PROP, basic tastes and astringency as a function of FN are reported in Table 1. Three-way ANOVA showed no effect of FN level on any of the oro-sensory variables considered. An effect of the main factors Age and Gender was found for FPD (Gender: $F_{(1,1105)} = 5.44$, $p < 0.05$; Age: $F_{(2,1105)} = 60.71$, $p < 0.0001$), responsiveness to PROP (Gender: $F_{(1,1135)} = 14.70$, $p < 0.0001$; Age: $F_{(2,1135)} = 3.19p < 0.05$), umami (Gender: $F_{(1,1134)} = 4.64$, $p < 0.05$; Age: $F_{(2,1134)} = 5.74$, $p < 0.01$) and astringency (Gender: $F_{(1,1134)} = 5.47$, $p < 0.05$; Age: $F_{(2,1134)} = 3.78$, $p < 0.05$). Post-hoc tests with Bonferroni adjustment revealed that females had higher FPD and were more responsive to PROP but scored lower for umami and astringency than did males. FPD decreased considerably with increasing age. Accordingly, younger subjects perceived PROP, umami and astringency as more intense than the older ones. None of the 2-way interactions were significant.

3.4. Food neophobia level influences liking of strong but not mild tasting food and beverages

3.4.1. Vegetables

Results from 3-way ANOVA with interactions showed that the main factors Age and Gender were significant for most vegetables independently of taste categorization (mild/strong). In all cases, females and older subjects liked vegetables more than did males and younger people (only sweet corn showed a significant, negative relationship with age), probably due to the increased awareness of healthy eating with age and in females (Margetts et al., 1997). The FN × Gender interaction was significant only in one case (Cucumber: $F_{(4,\ 1197)} = 3.24$, $p < 0.05$), and the FN × Age interaction was significant in two cases (Broccoli: $F_{(4,\ 1201)} = 3.21$, $p < 0.05$; Eggplant: $F_{(4,\ 1201)} = 2.45$, $p < 0.05$). In general, ANOVA conducted on females and males separately produced comparable results, as did the analysis performed on the three age groups, suggesting that Gender and Age are not confounding effects of FN on reported liking of mild/strong tasting vegetables. The results on the effect of FN on vegetables liking and familiarity are reported in Table 2 averaged across gender and age. Food neophobia had a significant effect on liking of all vegetables with a strong taste, while the effect on mild vegetables was observed only for one (i.e. green beans) out of eight items. Post-hoc comparisons showed that, in general, low food neophobics (neophilics) liked vegetables significantly more than did medium and high food neophobics. The analysis of familiarity data showed that, with the exception of three strong tasting items (i.e., asparagus, broccoli and radish), all vegetable items were well known and commonly used by subjects with different levels of FN. Overall, results indicate a strong association, independent of age and gender, between FN and liking for those vegetables characterized by "warning" chemosensory sensations such as bitterness and/or astringency.

3.4.2. Beverages

Results from 3-way ANOVA with interactions showed that the main factor Age was often significant. When the association between age and liking was negative and a concomitant FN effect was observed, the relative contribution of age and FN on beverages reported liking cannot be established unequivocally. This was only the case for one item, namely alcoholic aperitifs. To analyze further the relative contribution of FN and age on reported beverage liking, the analysis was performed separately for the three age categories (18–30 y, 31–45 y, 46–60 y), confirming that Age was not a confounding effect of FN. In other words, if a beverage was significantly more or less liked according to age, the trend was the same in all the three FN groups (low, medium, high). The FN × Age interaction was significant only for red wine ($F_{(4,1189)} = 2.39$, $p = 0.05$); red wine was equally liked by the three age categories in low and medium neophobic people, whereas liking for red wine increased significantly according to age in the high neophobic group.

Gender was often a significant effect for liking, with males providing higher liking ratings for beverages than females, except for non-alcoholic aperitif. In order to better understand the relative contribution of gender and FN on beverages liking, a separate analysis was performed for males and females, which provided a very similar outcome for both genders. No FN × Gender and FN × Age interactions were significant.

Mean beverage liking and familiarity ratings by taste categorization (mild/strong) and FN, averaged across gender and age, are reported in Table 3. FN had a significant effect on liking for all beverages with a strong taste. Post-hoc comparisons indicated that, overall, low neophobics liked these beverages significantly more than did high neophobics, whereas medium neophobics lay in between. The effect of FN on beverages with a mild taste was significant for sweetened tea and soft drinks. In this case, the trend of reported liking was in the opposite direction, in that high food neophobics liked these beverages significantly more than low neophobics. The analysis of the familiarity data provided similar results with mild beverages being either equally familiar or more familiar to food neophobics than to neophilics and strong beverages being in general less familiar to neophobics than neophilics. Overall, these results indicate that, for beverages, a strong taste, which comprised warning sensations such as bitterness, astringency and alcohol bite plays an important role in modulating liking in food neophobic individuals. Moreover, this behavior is independent of age and gender.

3.4.3. Sweets and desserts

Results from 3-way ANOVA with interactions showed that Age and Gender were significant for most items. As expected, the association between age and liking of sweets and desserts was always negative, probably due to increased health concerns with increasing age and/or decreased liking for sweetness with age. Moreover, post hoc comparisons showed that females gave higher liking scores than males for all items, with the exception of honey. Although women are reported to have high food health awareness, there is also evidence of higher cravings for sweets in females than males (Roininen et al., 2001; Tuorila, Keskitalo-Vuokko, Perolac, Spectord, & Kapriob, 2017). To analyze further the relative contribution of FN, age and gender on liking for sweets and desserts, separate analyses were performed for females and males and for the three age classes. These analyses returned very similar outcomes for females and males as well as for the three age groups, confirming that age and gender were not confounding effects of FN in reported liking of sweets and desserts.

Mean liking and familiarity ratings for sweets and desserts mean by taste categorization (mild/strong) and FN averaged across gender and

Table 2
Mean values of reported liking (range 1–9) and mean familiarity ranks (1–5) for vegetables grouped according to taste classification (mild/strong) by food neophobia level (Low: n = 329, Medium: n = 575, High: n = 321). $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, n.s. non-significant difference.

Items	Taste	Reported Liking				Familiarity			
		p-value(1)	Food neophobia level			p-value(2)	Food neophobia level		
			Low	Medium	High		Low	Medium	High
Carrot	Mild	n.s.	7.2	7.1	7.0	n.s.	4.4	4.4	4.3
Cucumber	Mild	n.s.	6.0	5.9	5.7	n.s.	4.0	4.0	3.9
Fennel	Mild	n.s.	7.0	7.0	6.9	n.s.	4.3	4.4	4.4
Green bean	Mild	*	7.5^{a}	7.2^{b}	7.1^{b}	n.s.	4.5	4.5	4.5
Green pea	Mild	n.s.	7.5	7.4	7.3	n.s.	4.4	4.5	4.5
Lettuce	Mild	n.s.	7.4	7.1	7.1	n.s.	4.4	4.4	4.2
Sweet corn	Mild	n.s.	6.6	6.2	6.2	n.s.	3.9	3.9	3.8
Tomato	Mild	n.s.	8.0	7.7	7.8	n.s.	4.8	4.8	4.8
Artichoke	Strong	**	7.5^{a}	7.1^{b}	7.0^{b}	n.s.	4.2	4.2	4.2
Asparagus	Strong	**	7.4^{a}	7.1^{ab}	6.8^{b}	*	4.1^{a}	4.1^{a}	4.0^{b}
Broccoli	Strong	***	7.3^{a}	6.8^{b}	6.4^{c}	**	4.4^{a}	4.3^{ab}	4.2^{b}
Cauliflower	Strong	**	6.5^{a}	6.1^{ab}	5.8^{b}	n.s.	4.0	3.9	3.8
Chicory	Strong	**	6.4^{a}	6.2^{a}	5.8^{b}	n.s.	3.8	3.8	3.7
Eggplant	Strong	***	7.9^{a}	7.4^{b}	7.2^{b}	n.s.	4.4	4.3	4.3
Rocket	Strong	*	6.8^{a}	6.4^{b}	6.4^{b}	n.s.	4.1	4.1	4.0
Radish	Strong	***	5.8^{a}	5.5^{ab}	5.0^{b}	**	3.6^{a}	3.6^{a}	3.5^{b}

(1) According to 3-way ANOVA model with interactions. Mean values marked with different superscript letters by row indicate significant differences ($p < 0.05$) according to post hoc test with Bonferroni adjustment.
(2) According to Friedman test. Mean ranks marked with different superscript letters by row indicate significant differences ($p < 0.05$) according to post hoc test with Bonferroni adjustment.

age are reported in Table 4. Obviously, for this food category, all sweets and desserts are considered to have a mild taste, with few exceptions (i.e. dark chocolate, dark chocolate pudding, lemon sorbet, strawberries with sugar and lemon). Food neophobia did not have any effect on reported liking of sweets and desserts, with the exception of honey ($F_{(2, 1097)} = 4.12$, $p < 0.05$), dark chocolate ($F_{(2, 1209)} = 7.95$, $p < 0.0001$) and dark chocolate pudding ($F_{(2, 1196)} = 3.20$, $p < 0.05$), which were liked less by high and medium neophobics than low neophobics. Moreover, FN affected liking for milk chocolate ($F_{(2, 1204)} = 3.79$, $p < 0.05$), however, in this case high food neophobics provided significantly higher liking ratings than subjects with low FN. Familiarity data analysis provided similar results with sweets and desserts being either equally familiar or more familiar to food neophobics than neophilics with the exception of honey, which was less familiar among neophobics than neophilics. Overall, the present results are a confirmation that when a food is not perceived as a "warning" stimulus, FN plays a marginal role on liking, independently of age and gender.

3.5. Food neophobia level influences the perception and liking of warning sensations in real food

Mean intensity ratings for sensory attributes and mean liking for each FN level are depicted in Fig. 1 a–d. Two-way ANOVA with interaction showed that sweetness (Fig. 1 a) increased with sugar concentration (main Sample effect: $F_{(3, 4564)} = 1067.47$; $p < 0.0001$), with no significant differences among the three FN groups (main FN level effect: $F_{(2; 4564)} = 0.92$; $p = 0.39$; Sample × FN level interaction: $F_{(6; 4564)} = 0.75$; $p = 0.61$). Accordingly, bitterness (Fig. 1 b) decreased

Table 3
Mean values of beverages reported liking (range 1–9) and mean familiarity ranks (range 1–5) grouped according to taste category by food neophobia level (Low: n = 329, Medium: n = 575, High: n = 321). $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, n.s. non-significant.

Items	Taste	Reported liking				Familiarity			
		p-value(1)	Food neophobia			p-value(2)	Food neophobia		
			Low	Medium	High		Low	Medium	High
Sweetened coffee	Mild	n.s.	5.7	6.0	6.2	**	3.9^{b}	4.1^{ab}	4.2^{a}
Sweetened tea	Mild	*	5.9^{b}	6.2^{ab}	6.4^{a}	n.s.	3.8	3.8	3.9
Ananas juice	Mild	n.s.	6.6	6.5	6.5	**	3.7^{b}	3.8^{ab}	3.9^{a}
Soft-drinks	Mild	*	5.8^{b}	5.8^{b}	6.1^{a}	**	3.7^{b}	3.8^{ab}	3.9^{a}
Non-alcoholic aperitif	Mild	n.s.	6.5	6.2	6.3	n.s.	3.6	3.6	3.6
Sweet spumante	Mild	n.s.	5.9	5.9	5.8	n.s.	3.6	3.6	3.6
Unsweetened coffee	Strong	***	5.2^{a}	4.9^{a}	4.2^{b}	***	3.8^{a}	3.7^{a}	3.4^{b}
Unsweetened tea	Strong	***	6.0^{a}	5.3^{b}	4.4^{c}	***	3.9^{a}	3.7^{b}	3.4^{c}
Grapefruit juice	Strong	***	5.8^{a}	5.4^{b}	5.0^{b}	n.s.	3.5	3.5	3.5
Alcoholic aperitif	Strong	***	6.5^{a}	6.2^{a}	5.4^{b}	***	3.8^{a}	3.8^{a}	3.5^{b}
Dry spumante	Strong	***	6.2^{a}	5.9^{b}	5.3^{c}	***	3.8^{a}	3.7^{a}	3.5^{b}
Red wine	Strong	***	7.1^{a}	6.8^{a}	6.1^{b}	***	4.0^{a}	4.0^{a}	3.7^{b}
Beer	Strong	***	7.1^{a}	6.6^{b}	6.2^{c}	***	4.0^{a}	4.0^{a}	3.7^{b}

(1) According to 3-way ANOVA model with interactions. Mean values marked with different superscript letters by row indicate significant differences ($p < 0.05$) according to post hoc test with Bonferroni adjustment.
(2) According to Friedman test. Mean ranks marked with different superscript letters by row indicate significant differences ($p < 0.05$) according to post hoc test with Bonferroni adjustment.

Table 4
Mean values of sweets and desserts reported liking (range 1–9) and familiarity ranks (range 1–5) grouped according to taste category by food neophobia level (Low: n = 329, Medium: n = 575, High: n = 321). $^{*}p < 0.05$, $^{***}p < 0.001$, n.s. non-significant.

Items	Taste	Reported liking				Familiarity			
		p-value	Food neophobia			p-value	Food neophobia		
			Low	Medium	High		Low	Medium	High
Biscuits	Mild	n.s.	6.7	6.6	6.7	n.s.	4.0	4.0	4.0
Cereals bar	Mild	n.s.	6.1	6.2	6.2	n.s.	3.6	3.6	3.6
Chocolate ice cream	Mild	n.s.	7.0	6.8	6.8	n.s.	3.9	3.9	3.9
Corn flakes	Mild	n.s.	6.3	6.2	6.1	n.s.	3.8	3.8	3.8
Croissant	Mild	n.s.	6.6	6.4	6.5	n.s.	3.9	3.8	3.8
Fruit tart	Mild	n.s.	7.5	7.5	7.6	*	3.9^{b}	4.0^{a}	4.1^{a}
Honey	Mild	*	6.7^{a}	6.7^{a}	6.2^{b}	***	3.8^{b}	3.7^{b}	3.4^{a}
Melba toast with jam	Mild	n.s.	6.8	6.9	6.8	n.s.	4.0	4.1	4.1
Milk chocolate	Mild	*	6.6^{b}	6.8^{ab}	7.1^{a}	*	3.8^{b}	3.9^{ab}	4.0^{a}
Peach jam	Mild	n.s.	6.7	6.6	6.2	n.s.	3.8	3.8	3.7
Strawberries with cream	Mild	n.s.	7.2	7.2	7.3	n.s.	3.7	3.7	3.7
Tiramisù	Mild	n.s.	7.7	7.7	7.7	*	3.8^{b}	3.9^{a}	3.9^{a}
Dark chocolate	Strong	***	7.7^{a}	7.1^{b}	6.8^{b}	*	4.0^{b}	4.2^{a}	4.2^{a}
Dark chocolate pudding	Strong	*	6.5^{a}	6.3^{ab}	6.1^{b}	n.s.	3.5	3.5	3.5
Lemon sorbet	Strong	n.s.	7.0	7.1	7.1	n.s.	3.7	3.8	3.7
Strawberries, sugar and lemon	Strong	n.s.	7.6	7.5	7.6	n.s.	4.0	4.0	4.0

(1) According to 3-way ANOVA model with interactions. Mean values marked with different superscript letters by row indicate significant differences ($p < 0.05$) according to post hoc test with Bonferroni adjustment.
(2) According to Friedman test. Mean ranks marked with different superscript letters by row indicate significant differences ($p < 0.05$) according to post hoc test with Bonferroni adjustment.

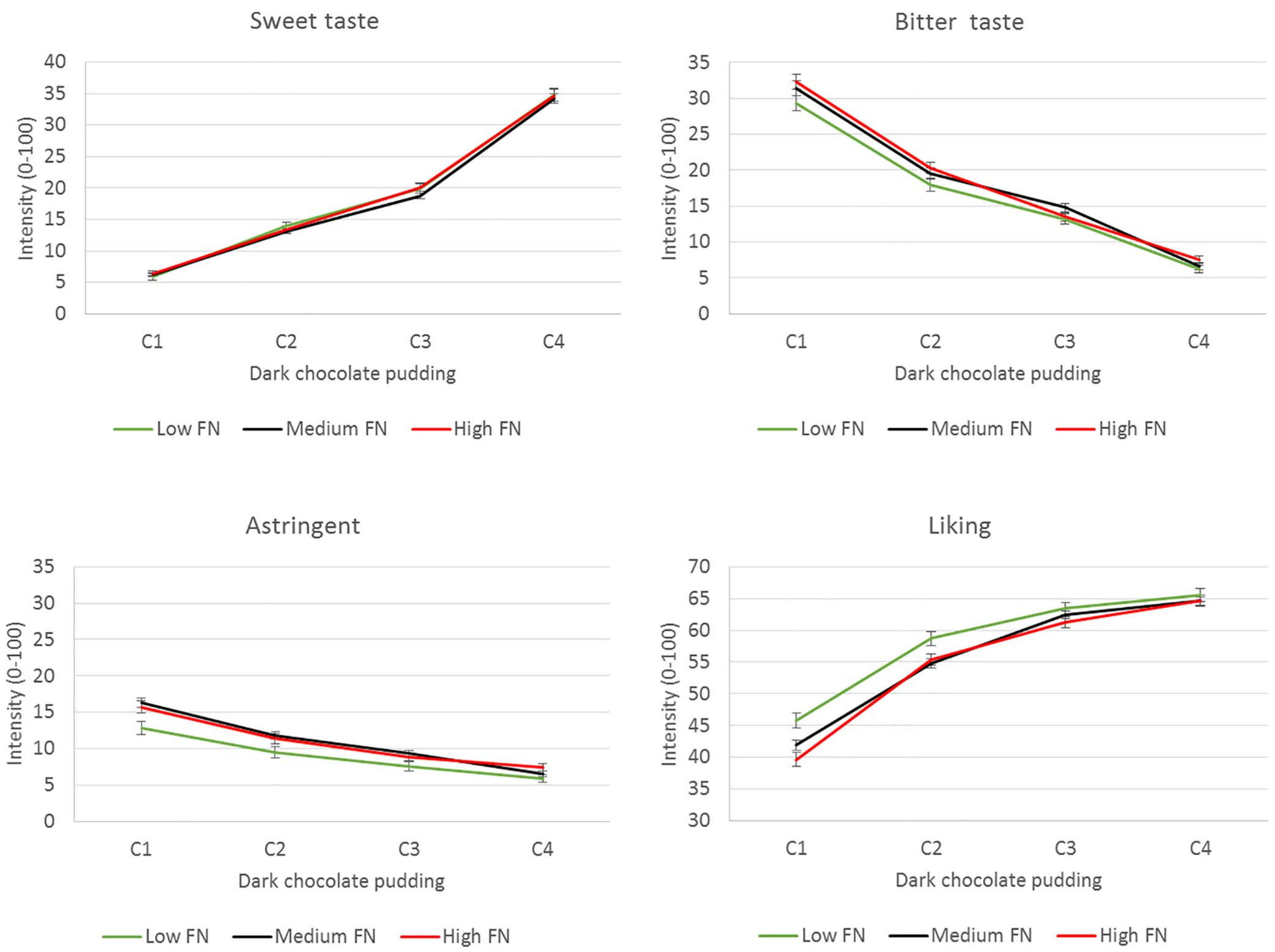

Fig. 1. Mean intensity ratings for sweet taste (a), bitter taste (b), astringency (c) and mean liking ratings (d) by sample (C1 less sweet sample, C4 sweetest sample) and by FN level. Error bars are standard errors.

with increased sugar concentration (main Sample effect: $F_{(3, 4564)} = 666.68$; $p < 0.0001$), with the low food neophobic group providing lower intensity ratings than the medium and the high FN groups, although the main factor FN just failed to reach significance ($F_{(2; 4564)} = 2.30$; $p = 0.09$). The interaction Sample × FN level was not significant ($F_{(6; 4564)} = 0.56$; $p = 0.76$).

Astringency (Fig. 1 c) decreased with increasing sugar concentration (main Sample effect: $F_{(3, 4564)} = 109.46$; $p < 0.0001$). The neophilic group provided intensity ratings which were systematically lower than the other two groups (main Neophobia level effect: $F_{(2; 4564)} = 6.61$; $p < 0.01$). The interaction was not significant. This reduced perception of bitterness and astringency by low food neophobics was reflected in an increased liking (Fig. 1 d) for the most bitter and astringent samples compared to high and medium food neophobics (main Sample effect: $F_{(3, 4564)} = 384.86p < 0.0001$; main Neophobia level effect: $F_{(2; 4564)} = 8.06$; $p < 0.001$), although the 2-way interaction was not significant. Separate analyses performed on females and males and on the three age classes produced a similar outcome, confirming that gender and age are not confounding effects of FN in the perception of warning sensations and liking of chocolate pudding.

4. Discussion

4.1. Validation of the Italian version of the food neophobia scale

The original version of the FNS, developed and validated on a representative sample of Canadian students, has been widely used to assess willingness to try new foods in studies conducted around the world after translation in different languages. Although the FNS has been already used in the Italian translation (Demattè et al., 2013) with good internal consistency, this is the first study to validate the instrument on a large sample of the Italian population (n = 1225). Internal consistency of the FNS scores in the present study was comparable to that reported in previous research involving large population samples of Finns (Knaapila et al., 2015; Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001), Swiss (Siegrist, Hartmann, & Keller, 2013), Spanish (Fernández-Ruiz, Claret, & Chaya, 2013), Swedish (Hursti & Sjödén, 1997) and New Zealand (Jaeger et al., 2017). Altogether, these results confirm that FNS is a robust and efficient tool even when translated in other languages (Ritchey, Frank, Hursti, & Tuorila, 2003).

4.2. Characteristics of food neophobia

We found a somewhat high proportion of neophobic people, in that a quarter of this sample had a food neophobia score higher than 36. Considering that we studied a population sample of adults, in which FN is expected to be low compared with childhood, a proportion of this magnitude has significant implications for food choices. As already observed in previous studies, we found an effect of both age (Meiselman et al., 2010; Siegrist et al., 2013; Tuorila et al., 2001) and gender (Hursti & Sjödén, 1997; Siegrist et al., 2013; Tuorila et al., 2001) on FN. Although these two factors did not seem to be confounding effects of FN on perception and liking of mild/strong tasting foods and beverages, we recommend considering both age- and gender-related differences when exploring the association between personality traits, food perception and preference. Other studies have indeed found that sociodemographic factors, especially gender, mediate the effect of personality traits on food liking and choice of spicy food (Spinelli et al., 2018).

4.3. Association between food neophobia, perception and liking of warning sensations in real food

The present large-scale study aimed to better understand the association between FN and chemosensory responsiveness and to determine whether this association translated in different food liking and preference patterns. We hypothesized that the rejection of specific food categories such as fruits and vegetables could be in part due to food neophobics' increased perception of strong and disliked oro-sensory stimuli, which often characterize plant food. Most fruits and vegetables are indeed rich in phenolic compounds and other substances that impart bitterness, astringency and sourness to the food (Drewnoski & Gomez-Carneros, 2000). Such oro-sensory qualities are considered biologically important "warning' signals. Bitterness and sourness are notoriously two sensory properties for which humans have an innate dislike and aversion, as they represent potential sources of toxic compounds and rotten and/or unripe food, respectively (Laureati, Pagliarini et al., 2015). Astringency also elicits negative consumer reactions when perceived at high intensities (Dinnella et al., 2011), probably because tannins may have anti-nutritional effects in animals and humans by reducing the digestibility of dietary proteins (Melis et al., 2017). Since FN is a conservative behavior, which keeps the organism's feeding behavior 'locked in on a safe track' (Schulze & Watson, 1995, p. 230), it can be reasonably hypothesized that food neophobics may have developed a hypersensitivity to warning sensations that makes them extremely cautious when approaching unfamiliar food, especially if it tastes bitter, astringent or sour.

We found that reported liking was significantly lower for high and medium food neophobics than low food neophobics especially for those vegetables and beverages which were characterized by higher levels of alarm stimuli (i.e. bitterness, sourness, astringency and alcohol), whereas almost no differences were found for the bland versions of vegetables and beverages and for sweets and desserts. This pattern was confirmed when tasting an actual food, as high and medium food neophobics liked the most bitter and astringent versions of a dark chocolate pudding significantly less than did low food neophobics. The clear hedonic-related differences between individuals with low and high neophobia levels for warning signals were substantiated by differences in perception, as high and medium food neophobics systematically rated astringency and, to a lesser extent, bitterness, as more intense than low food neophobics. The fact that the astringency of the chocolate pudding was clearly better discriminated by high and medium food neophobics than low food neophobics, whereas a tendency was found for bitterness is interesting and merits further explanation. Our data indicated that samples C1 and C2 of chocolate puddings were rated as "strong-moderate" for bitterness on the gLMS (mean intensity ratings: C1 = 31.3; C2 = 19.3), while as "moderate-weak" for astringency (mean intensity rating: C1 = 15.0; C2 = 11.0). Thus, we would have expected to find a more robust effect of food neophobia level on bitterness rather than on astringency. One explanation may be that when a critical sensation is clearly perceptible (i.e. bitterness), the higher arousal of neophobic subjects is difficult to detect. In other words, both neophilics and neophobics could be in an aroused state, thus neophobia-related differences could not be seen. By contrast, when the concentration of the sensation is subtle, the difference between neophobics and neophilics becomes evident. In line with this assumption, previous research has shown that food neophobics are characterized by a higher arousal level and a generalized enhanced vigilance than food neophilics when confronted with food stimuli (Pliner & Melo, 1997), which could lead them to detect minimal changes in sensory qualities of food. Interestingly, we did not find any difference between subjects with different FN levels for markers of chemosensory responsiveness (PROP sensitivity and FPD) and response to oro-sensory stimuli (i.e., astringency, sweetness, sourness, umami, saltiness and bitterness by caffeine). The fact that water solutions of chemosensory stimuli were all clearly perceptible (they were chosen to represent a "moderate/strong" intensity on the gLMS) is a further confirmation that differences in oro-sensory perception between food neophobics and food neophilics may be evident only at low concentrations. In other words, our data seem to suggest that higher arousal in food neophobics could increase perceptual sensitivity via increased alertness when approaching food and that arousal could be unpleasant, therefore producing dislike of stimulus.

Recently, a few studies have investigated the relationship between sensory responsiveness and FN, reporting a significant correlation between childhood FN and taste/smell sensitivity using parental report data (Coulthard & Blissett, 2009) and a significant and positive association between smell (but not taste) reactivity and FN in toddlers using behavioral measurements (Monnery-Patris et al. 2015). Interestingly, Farrow & Coulthard (2012) found that children's sensory sensitivity mediated the relationship between anxiety and selective/neophobic eating, suggesting that greater sensitivity to sensory information may explain why more anxious children are more likely to be selective eaters. A role for anxiety mediation in food neophobia has also been pointed out in adults (Pliner and Hobden, 1992; Pliner et al., 1993, 1995), and neophilics were found to exhibit lower physiological arousal (pulse, GSR, respirations) than neophobics when presented with food stimuli (Raudenbush & Capiola, 2012). Platte, Herbert, Pauli & Breslin (2013) demonstrated also that healthy individuals with moderate levels of anxiety were more sensitive to bitter and sweet. We may thus hypothesize that reduced liking of stronger sensory qualities (i.e., in our study the most astringent and bitter chocolate pudding samples) expressed by food neophobics does not depend on individual taste functioning but rather on a psychological mechanism of anxiety triggered by the perception of warning sensations. A similar hypothesis was proposed by Spinelli et al. (2018) to explain the effect of anxiety related traits such as neophobia, sensitivity to disgust and to punishment on pungency liking and sensory response. From this perspective, differences observed within FN levels may be associated with a different arousal intensity, influenced by the trait of food neophobia, which can modulate sensory and hedonic responses. In other words, food neophobics would not be hypersensitive to alarm signals but the perception of such signals would put them in an arousal state that could be thought to heighten the sensory responses to the stimuli. This is consistent with the assumption that the perception of danger and fear of negative consequences of eating novel food, as well as the expectation that sensory characteristics may be unpleasant, is a fundamental principle of food rejection (Pliner & Salvy, 2006).

Similar to our findings, Törnwall et al. (2014) reported an increased liking for spicy food in people defined as “adventurous” – a term that can be assimilated into the concept of food neophilia – but no differences in taste ability, as measured by PROP responsiveness, were found between adventurous and non-adventurous individuals. Moreover, as we also found in the present study, large differences were shown between adventurous and non-adventurous individuals in liking of foods with specific flavor qualities (e.g. sour fruits and berries and spicy foods and spices), but reported no differences in the liking of bland foods (e.g. salty-and-fatty foods, sweet-and-fatty foods). Kauer et al. (2015) found that “selective” eaters were more likely to reject foods that were bitter or sour but not sweet. Knaapila et al. (2011) reported similar results in a large sample of young adults, whereas Cooke et al. (2003) observed this behavior in children, showing high neophobic reactions for fruit and vegetables as well as fish and meat but not starchy, sweet or fatty snack foods.

These findings are in line with Rozin’s (1988) argument that foods that are generally accepted are those that (are expected to) taste good (e.g. sweets) and those that are seen to be beneficial for survival (e.g. energy dense food). Such foods share sensory characteristics (i.e. saltiness, sweetness, fattiness) that are signals of nutrients and are inconsistent with the need to be wary. Thus, individuals with high levels of FN may indeed perceive energy dense food as “safe”, resulting in increased preference ratings and familiarity for those foods. Further confirmation of this assumption is provided by the fact that in the present study we found not only that food neophobics disliked foods and beverages with strong taste but, in some cases, they even reported greater liking than neophilics for energy dense food and beverages (i.e. milk chocolate, sweetened tea and soft-drinks). The implication of this finding is that FN may contribute quite substantially to the quality of the diet, leading neophobics to opt for more caloric versions of food, as shown in previous studies (Jaeger et al., 2017; Knaapila et al., 2011, 2015; Zickgraf & Schepps, 2016). Moreover, the comparison between our data and data on children (Cooke et al., 2003; Russell & Worsley, 2008) seems to indicate that the rejection of healthy food such as fruit and vegetables and the preference for high-energy dense food are not behaviors observable only in childhood but in all ages. Thus, finding solutions to reduce neophobic reactions in early age groups – or dealing with it in adulthood and third age – should be an important aim of future studies.

Somewhat at odds with the FN in terms of food novelty, we also found that FN seems to be generalized to food that can be considered highly familiar, at least in our representative sample of Italian consumers. In fact, both in the food preference questionnaire and in the actual tasting test we selected food items and beverages that scored high on familiarity in order to avoid unwanted effects of low familiarity on hedonic responses. Despite this, the analysis of familiarity data showed that food neophobics differed from food neophilics for several food items, especially those with strong taste. Thus, it cannot be excluded that familiarity instead of the perception of alarm stimuli played a role in the large hedonic differences observed according to neophobia level. The direction of this association is difficult to predict. Indeed, strong tasting foods and beverages may be less familiar to food neophobics due to their (disliked) taste, which in turn reduces the frequency of consumption and the familiarity toward such foods, thus leading to a vicious circle and possibly to changes in FN level over the lifespan.

Consistent with our findings, Jaeger et al. (2017) also found that the effect of food neophobia extends beyond rejection of unfamiliar/unusual foods to encompass many commonplace food items. It is not easy to explain how such a broad effect of food neophobia might arise. Tuorila et al. (2001) speculated that people scoring high in FN are possibly not only those who have fear of new foods; they may also be individuals who have little interest in foods. Similarly, Jaeger et al. (2017) hypothesized that those high in FN have, in general, less positive associations with food throughout their lives, as a results of more frequent encounters with foods that they wish to avoid. Finally, although in our study we did not include a measure for pickiness, we cannot exclude that the behavior we observed is also representative of pickiness, which is defined as the refusal of familiar and unfamiliar food severe enough to interfere with daily routines to an extent that is problematic (Taylor, Wernimont, Northstone, & Emmett, 2015). Despite the fact pickiness and food neophobia are sometimes considered as distinct constructs, these two behaviors have been reported to be highly correlated (Taylor et al., 2015).

5. Conclusion

The present large-scale study has expanded the existing knowledge on the association between food neophobia, chemosensory responsiveness, and food preference, thus contributing to the understanding of psychological and sensory-driven barriers to healthy food consumption. Our main outcome is that neophobia-related differences in reported liking were found mainly for foods and beverages characterized by high intensities of warning sensations (i.e. bitter, astringency, sourness and alcohol). These hedonic differences were confirmed also with a real food, especially when the concentration of the warning sensation was subtle. This pattern of findings is independent of age and gender and does not seem to be mediated by food neophobics superior taste functioning but rather by higher levels of general trait anxiety, which lead them to be on alert when eating food and/or drinking beverages that are perceived as potentially unpleasant and dangerous. However, it should be underlined that in the present study no measures of anxiety were performed, thus further perspectives of study should aim to better understand the role of anxiety trait in relation to food neophobia and food consumption. Finally, the effect of food neophobia was evident not only for potentially unusual items in the Italian context, but even for items that might be considered highly familiar to the Italian population.

As a final remark, it should be highlighted that the actual product chosen in this study to test the relation between FN, food preference and chemosensory responsiveness (i.e. chocolate pudding) is a rather familiar product in Italy, thus it would be interesting to replicate the study in order to verify whether the effect of FN would be stronger when using novel and unfamiliar foods.

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Author contributions

ML undertook the data analyses and wrote the manuscript; ML, SS, EM, CD contributed to plan the data analyses; ML, SS, EM, CD, ADT, EP, JP discussed the interpretation of the results; ML, SS, EM, CD, LT, FG, IE, EP collaborated in the design of the Italian Taste project; all authors helped with data collection, reviewed and offered critical comments on the manuscript.

Appendix A

Validation of the Italian version of the FNS

Results – reliability of the scale

FNS internal consistency was 0.87, much greater than the suggested value of 0.70 given by Nunnally and Bernstein (1988). The correlation among items was always positive and highly significant ($p < .0001$) with Pearson's correlation coefficients ranging from 0.20 to 0.72. Item total correlation with FNS score ranged from 0.48 for item 8 to 0.71 for item 10. The analysis of Cronbach's alpha with deleted variables did not show significant increase or decrease in the standardized alpha coefficients, thus suggesting that all items were measuring the same construct.

Overall mean FNS scores and individual item scores in the test–retest evaluation are reported in Table A1. The correlation between responses in the first and second administration of the FNS was high in all cases, indicating good stability of the measurement over time. The correlation between the first and second administration of the whole scale was 0.77 ($p < 0.01$).

The relationship between the items was further investigated through PCA (Fig. A1). The total variance explained by the first two PCs was 61%. PC1 accounted for 48% of total variance whereas PC2 explained a further 13%. All items were positively related on PC1. Moreover, Fig. A1 clearly shows that PC2 separates reversed (negative correlation) from unreversed items (positive correlation), indicating the ability of the instrument to measure two distinctive dimensions that describe opposite reactions to food, namely food neophobia and food neophilia. Since correlation loadings plot showed that items 8 and 9 explained less than 50% of the explained variance, a further analysis was conducted omitting these two items. The Cronbach's alpha resulting from the 8-item scale was 0.87. Moreover, the correlation between the 8-item scale and the original 10-item scale was $r = 0.975$ ($p < 0.0001$), indicating that no improvement would have been obtained by the omission of items 8 and 9.

Results – predictive validity

Despite the correlation coefficients were somewhat low, FNS score was significantly and negatively related to vegetables reported liking ($r = -0.19$, $p < 0.0001$) and familiarity ($r = -0.15$, $p < 0.0001$).

Results – comparison with other FNS versions

The comparison of internal consistency of the FNS scores among the present study, the original FNS on a sample of Canadian subjects (Pliner & Hobden, 1992) and previous research involving Finns (Knaapila et al., 2015; Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001), Swiss (Siegrist et al., 2013), Spanish (Fernández-Ruiz et al., 2013), Swedish subjects (Koivisto-Hursti & Sjödén, 1997) and New Zealand (Jaeger et al., 2017) provided similar results. This indicates that the internal consistency of the FNS does not change substantially in relation to cultural aspects, as also reported by Ritchey et al. (2003) (Table A2).

Table A1
Mean value, standard deviation (SD) and Pearson's correlation coefficient of each FNS item and total FNS score (n = 117) in the test–retest evaluation. In the first column, R indicates the neophilic items for which the score was reversed.

Item	Test		Retest		Pearson's r	p-value
	Mean	SD	Mean	SD		
1R	3.6	1.6	3.3	1.6	0.64	< 0.0001
2	2.8	1.5	2.6	1.4	0.33	< 0.001
3	2.2	1.5	2.3	1.4	0.23	< 0.05
4R	2.7	1.8	2.9	1.9	0.64	< 0.0001
5	2.1	1.3	2.1	1.4	0.45	< 0.0001
6R	2.7	1.8	2.8	1.9	0.78	< 0.0001
7	2.2	1.4	2.3	1.5	0.54	< 0.0001
8	2.9	1.9	2.8	1.8	0.45	< 0.0001
9R	2.8	2.1	3.0	2.0	0.53	< 0.0001
10R	3.1	1.9	3.1	1.8	0.81	< 0.0001
FNS	**27.1**	**10.8**	**27.2**	**10.9**	**0.77**	**< 0.01**

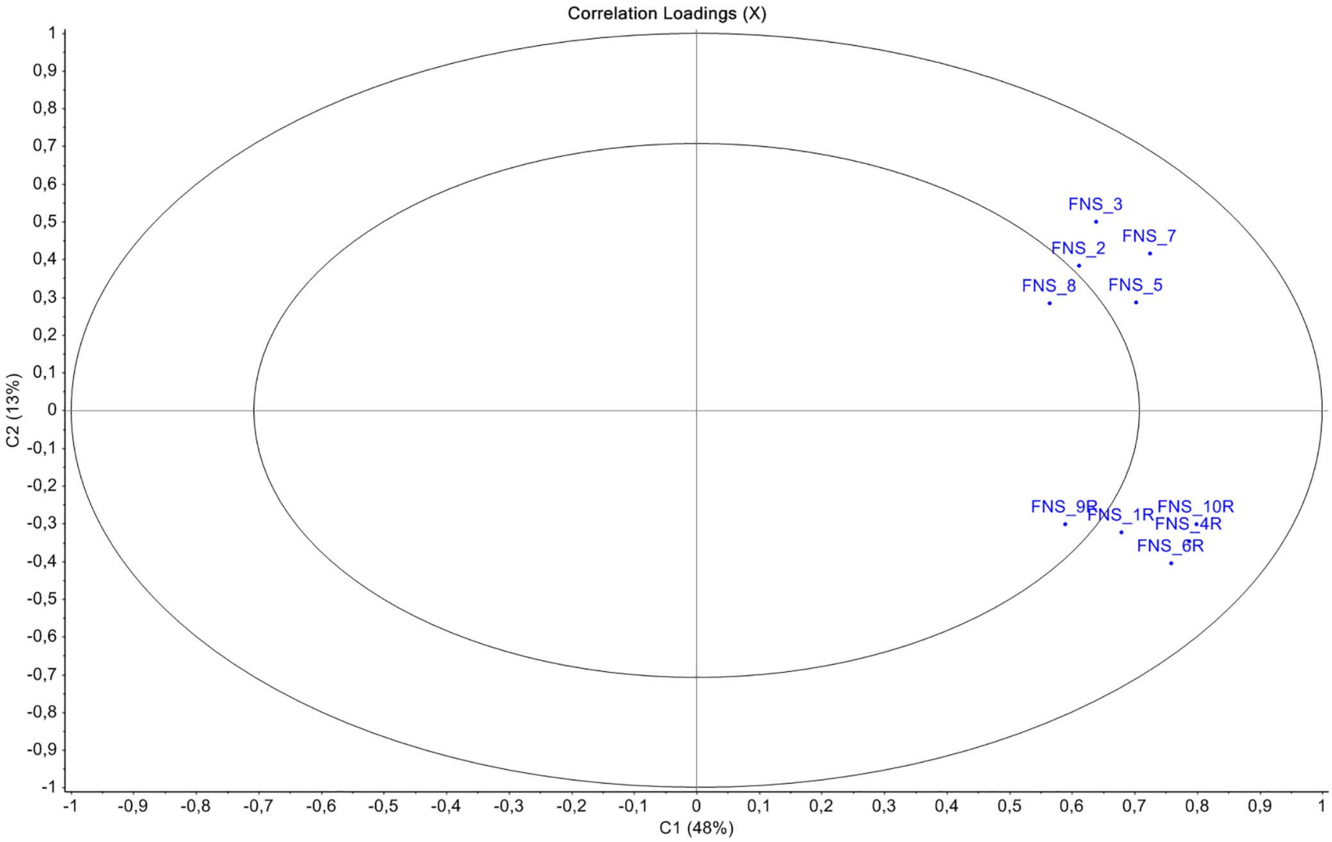

Fig. A1. Correlation Loadings Plot obtained by PCA performed on scores of each item of the FNS (n = 1225). Concentric circles show the locus of 100 and 50% explained variance.

Table A2
Descriptive statistics and Cronbach's alpha of the FNS as measured in the present study and comparison with other studies with similar subjects' age range (SD = standard deviation).

Paper	N	Age range	FNS Range	FNS Mean	SD	Cronbach's α
Present paper (Laureati et al.)	1225	18–60	10–69	27.4	11.7	0.87
Fernández-Ruiz et al. (2013)	309	25–60 +	10–66	31.7	11.0	0.82
Jaeger et al. (2017)	1167	18–72	10–68	27.4	–	0.83
Knaapila et al. (2015)	2191	18–57	10–70	28.5	11.0	0.88
Koivisto-Hursti and Sjödén (1997)	722	10–66	10–66	25.6	–	0.81–0.90
Pliner and Hobden (1992)	75–135	18–74	10–68	34.5	11.9	0.88
Siegrist et al. (2013)	4436	21–99	–	–	–	0.80
Tuorila et al. (2001)	1083	16–80	10–70	33.9	11.4	0.85

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodqual.2018.02.007.

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