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# Sensory perception and food neophobia drive liking of functional plant-based food enriched with winemaking by-products

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## Abstract

The use of phenol compounds obtained from unripe grapes as antioxidant sustainable food ingredients is challenging due to their specific sensory attributes, such as sourness and astringency. The aim was to evaluate sensory attributes perception and consumers' liking for beetroot purees added with phenols from unripe grapes. According to hedonic responses, consumer clusters were identified and characterized for eating behavioral attitudes. Three hundred two subjects (56% women, 18–60 years old) evaluated sweet, sour, astringency, and overall flavor intensity of and liking for four beetroot puree samples added with increasing phenols concentrations (0–1.93 g/kg). Results showed that liking decreased with increasing phenols. Interestingly, samples with highest phenols concentration, characterized by sourness, and astringency, were preferred by a segment of consumers (39% of the group). This group was characterized by a low food neophobia and tended to have high emotional eating scores compared to consumers preferring samples without or with the lowest amount of extract. These results suggest that the development of functional phenol-enriched products using winemaking by-products is challenging due to their sensory properties that negatively influence consumers' acceptance. However, with appropriate segmentation strategies it is possible to identify specific consumer targets who could appreciate these new functional foods.

## Practical Applications

Unripe grapes can be used as a sustainable phenol source for the development of new highly antioxidant foods. Indeed, an addition till 1.9 g/kg, besides improving both the nutritional content of the food matrices, as well as promoting the reuse of winemaking by-products, could be considered feasible from a sensory point of view. Specifically, new sustainable plant-based food product, characterized by specific sensory attributes, could be target for specific groups of consumers to foster the transition to the consumption of food products developed using value-added and sustainable ingredients.

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## 1 | INTRODUCTION

Ongoing research is paying attention to how develop well-accepted food products with both an optimal nutritional profile and a low impact on the environment. One of the priorities of research and food companies is to promote the reuse of waste and by-products of food chain as source of value-added ingredients. In this context, winemaking by-products are promising sources of compounds to be reintroduced in the food chain. For example, recovery ingredients obtained from grape pomace, showing a pro-healthy value due to the presence of phenolic compounds and dietary fibers, have been widely used as ingredient for new food formulations of animal-based products (Sánchez-Alonso, Jiménez-Escrig, Saura-Calixto, & Borderías, 2008; Selani et al., 2011), vegetable-based products (Maier, Fromm, Schieber, Kammerer, & Carle, 2009; Sagdic et al., 2011), dairy products (Marchiani et al., 2016; Tseng & Zhao, 2013) as well as bakery products and pasta (Sant'Anna, Christiano, Marczak, Tessaro, & Thys, 2014; Walker, Tseng, Cavender, Ross, & Zhao, 2014). Similarly, ingredients obtained by other winemaking products such as grape skins and seeds have been used for similar purposes (Chouchouli et al., 2013; Hoye Jr & Ross, 2011; Kulkarni, DeSantos, Kattamuri, Rossi, & Brewer, 2011; Ribeiro et al., 2013; Torri, Piochi, Lavelli, & Monteleone, 2015). Phenols from wine chain by-products show several properties since they can act as antimicrobial, anti-inflammatory, and also as antioxidant compounds (Shahidi & Ambigaipalan, 2015). Indeed, recent data demonstrated that phenol extracts from olive mill waste water increase antioxidant activity of plant-based food with different macro-composition (De Toffoli et al., 2019). Moreover, these compounds can delay the development of off-flavors and rancidity lengthening the shelf-life of food products (Oreopoulou & Tzia, 2007).

Another interesting but scarcely investigated source of phenol compounds is represented by the unripe grapes discarded during thinning operations (Bucalossi et al., 2020). These grapes present several pro-healthy compounds, such as dietary fiber, vitamins, and phenols (Fia, Bucalossi, Gori, Borghini, & Zanoni, 2020; Fia, Gori, Bucalossi, Borghini, & Zanoni, 2018; Shrikhande, 2000). Besides their nutritional components and their potential application in food product development, these grapes are characterized by specific sensory qualities such as sour taste and astringency, which are imparted by the high phenol and organic acid content. Previous research has found that the addition of unripe grapes extracts to food matrices (beetroot puree, tomato puree, and bean puree) increased sourness intensity as a function of extract concentration and of the type of model food (different macro-component; Bucalossi et al., 2020). The specific sensory attributes characterizing winemaking by-products, such as purple color and sourness, have been found to negatively affect consumers perception in terms of liking (Lavelli, Sri Harsha, Piochi, & Torri, 2017; Torri et al., 2015). Indeed, the use of wine by-products can induce important changes in visual aspects leading to unexpected and generally disliked sensory characteristics (see for a review: García-Lomillo & González-SanJosé, 2017). For instance, the addition of grape-skin powders has been found to decrease hedonic ratings to soft cow-milk cheeses due to a marbling aspect (due to the violet or brown color of the extract used), and to an increased granularity, sourness, saltiness, and astringency (Torri et al., 2016). However, some recent findings highlighted that liking slightly decreased with increasing concentrations of phenol extract added in beetroot puree samples, even if all the samples were considered acceptable by the consumers involved (Proserpio et al., 2020).

Liking is undoubtedly a key factor in defining eating behavior but it is not the only one. Personal factors such as individuals' behavioral and psychological traits play an important role in food preferences and may act as barriers to new food acceptance (Köster, 2009), including plant-based food characterized by high phenol content (Higa, Koppel, & Chambers, 2017; Menezes, Deliza, Chan, & Guinard, 2011). Previous findings revealed that health concerns and food choice motives related to health and weight control had significant roles in individual liking of bilberry and cowberry juice fractions rich in phenols (Laaksonen, Ahola, & Sandell, 2013). Several validated questionnaires are actually available to obtain information about consumers' eating behavior and responses to new foods characterized by specific sensory properties. Among these, the Dutch Eating Behavior Questionnaire (DEBQ; Van Strien, Frijters, Bergers, & Defares, 1986) is widely applied to evaluate consumers eating behavior (i.e., restrained, emotional, and external behaviors) and has been used, for instance, to identify an association between plant-based food intake (fruit and vegetables) and restrained eating in adult subjects (Elfhag, Tholin, & Rasmussen, 2008). Another important psychological construct to be considered when exploring the acceptance of new food formulations is the trait of food neophobia, namely the reluctance to try or eat unfamiliar foods (Pliner & Hobden, 1992). 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 characterized by high intensities of warning sensations (e.g., bitterness, astringency, sourness, and pungency; Knaapila et al., 2011; Laureati et al., 2018; Törnwall et al., 2014). Moreover, it is well-known that health, along with taste, represent two central concepts that influence consumers' decision making (Cox, Melo, Zabaras, & Delahunty, 2012). The Health and Taste Attitude Scales (HTAS; Roininen, Lähteenmäki, & Tuorila, 1999) aims at evaluating the importance that consumers give to perceived health and hedonic characteristics of foods in relation to their food choices. People showing a high interest to the health dimension were found to consume a higher amount of fruit and vegetables, whereas taste related attitude was associated with high-fat sweet snacks consumption (Zandstra, De Graaf, & Van Staveren, 2001).

Considering the complexity of eating behavior, consumer segmentation is an effective strategy for identifying specific population targets that react differently to new food formulations. Indeed, consumer segmentation highlights individual heterogeneity and hinders the limit of considering people as a whole, comparable group (i.e., the fallacy of consumers' uniformity; Köster, 2009; Meiselman, 2013). More specifically, segmentation analysis could help to better understand diversity in new food product acceptability and could improve result interpretation, thus helping in explaining why a product is highly liked by a group of subjects, while is rejected by another group.

In due of the above, the first aim of the present study was to evaluate consumer responses (sensory attributes perception and liking) to beetroot purees added with increasing concentrations of phenols-rich extract from unripe grapes. Beetroot was used as model food to prepare a vegetable-based puree since, as demonstrated in previous studies (Bucalossi et al., 2020; Proserpio et al., 2020), it is congruent in terms of color (intense purple) with the phenol extract obtained by the unripe grapes. The second aim was to identify consumers' clusters according to their hedonic scores to the new food products and to characterize them for sensory perception as well as for eating behavioral attitudes. These variables were evaluated to assess their importance in modulating the acceptability for these new products.

## 2 | MATERIALS AND METHODS

### 2.1 | Participants

Three hundred two subjects (56% women, age range: 18–60 years, mean age = 37.77 ± 14.13; three groups: $A_1$ = 18–30 years, 42%; $A_2$ = 31–45 years, 26%; and $A_3$ = 46–60 years, 32%) completed the evaluations. Three research units took part in data collection and participants were recruited by means of websites, announcements on social networks, mailing lists, pamphlet distribution, and word of mouth. Food intolerances and allergies, pregnancy, and breastfeeding at the moment of the test were exclusion criteria. The study was conducted in compliance with the principles laid down in the Declaration of Helsinki and all subjects signed a written informed consent at the beginning of the test. The protocol of the study was approved by the Ethics Committee of the University of Florence.

### 2.2 | Phenols enriched model food

Unripe grape cv Merlot extract was obtained using a procedure recently described by Bucalossi et al. (2020). In summary, after the unripe grapes' maceration, the liquid extract was decantated and filtrated. Subsequently, sugar was eliminated by ultrafiltration through a spiral wound configuration membrane (molecular weight cut-off of 2,500 Da; General Electrix, Boston, MA). Hence, the liquid extract was lyophilized with arabic gum (2% w/v) (Nexira Food, Rouen Cedex, France) and stored in a desiccator in the dark at room temperature. In order to remove the arabic gum in excess, the extract (334 g) was diluted in distilled water to a total volume of 1 L and centrifuged at 1646*g*, for 10 min. Supernatant was recovered, its phenol concentration determined by Folin-Ciocalteau assay (Singleton & Rossi, 1965) was 6.81 g/L (Proserpio et al., 2020). The analysis of phenol profile was carried out via liquid chromatography—high-resolution mass spectrometry (LC-HRMS) and revealed that the phenolic acids were the most abundant class of phenolic compounds and the caftaric acid accounted for about the 76% of the sum of phenols measured.

Beetroot was chosen based on previous studies reporting that this root represents a suitable model system to be enriched with the high phenol rich extract (Bucalossi et al., 2020; Proserpio et al., 2020). Indeed, the phenol-rich extract obtained from grapes gathered thinning operations is characterized by an intense purple color that affects the visual aspects when added in a food matrix. Purees of beetroot were prepared by blending, until a homogeneous product was obtained, 500 g of peeled and steamed beetroots (Ghisetti 1870 S.r.l. Rovigo, Italy) using a Kenwood FDM 780 mixer (Kenwood, Treviso, Italy). Four beetroot purees were prepared at different levels of phenol concentrations ($BP_0$ = 0.00, $BP_{0.4}$ = 0.41, $BP_{1.1}$ = 1.11, and $BP_{1.9}$ = 1.93 g/kg). Samples were prepared on the day of the session and were provided to the participants at room temperature in plastic cups coded with three-digit numbers. Beetroot puree samples (15 g) were provided to the participants in a randomized order following a sequential monadic presentation. Participants were instructed to taste a teaspoon of each sample. Water was available for rinsing the palate between the samples.

### 2.3 | Measurements

#### 2.3.1 | Liking and sensory attributes ratings

Stated liking for and familiarity with beetroot were assessed before the laboratory test using a 9-point hedonic scale (1: "extremely disliked"; 9: "extremely liked," Peryam & Pilgrim, 1957 + option: "I have never tasted it") and a 5-point labeled scale (1: "I do not recognize it"; 5 = "I regularly eat it" (Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001), respectively.

Subjects were asked to rate their liking for each beetroot puree sample using the Labeled Affective Magnitude Scale (LAM) scale anchored with the extremes "greatest imaginable dislike" (rated 0) and "greatest imaginable like" (rated 100; Schutz & Cardello, 2001). After a break, they had to rate the intensity of selected attributes (sour, sweet, astringent and overall flavor) using the Generalized Labeled Magnitude Scale (gLMS) anchored with the extremes "no sensation" (rated 0) and "the strongest imaginable sensation of any kind" (rated 100; Bartoshuk et al., 2004). Before tasting, instructions for the correct use of both scales were provided to the participants. As regards the LAM scale, subjects were instructed to consider the extremes "greatest imaginable dislike" and "greatest imaginable like" thinking not only of beetroot purees, but considering generally all experiences in the food sector. They had to think about foods that they do not like at all and about those that they love to eat. The instructions about the use of the gLMS were provided following published standard procedures (Bartoshuk, 2000; Green, Shaffer, & Gilmore, 1993). Subjects were instructed to treat the "strongest imaginable sensation" as the most intense sensation they can imagine involving remembered/imagined sensations in any sensory modality (e.g., the cold of a cube of ice in the mouth or the noise of a plane that is flying low). In order to practice the use of the scale, participant rated intensities of the brightest light they had ever seen, following the procedure described in Dinnella et al. (2018).

### 2.3.2 | Eating behavioral attitudes

*Dutch Eating Behavior Questionnaire*

The tool proposed by Van Strien et al. (1986) and validated in Italian by Dakanalis et al. (2013) was applied to measure restrained (eating less than desired to lose or maintain a particular body weight), emotional (eating in response to internal emotional factors) and external eating behaviors (eating in response to external factors such as the sight and smell of food). This tool is composed by 33 items to be answered on a scale ranged from 1 (never) to 5 (very often). The total score for each domain was calculated as the mean after reverse scoring for selected items, with higher mean scores indicating greater endorsement of the eating behavior.

*Health and Taste Attitude Scale*

The questionnaire proposed by Roininen et al. (1999) and validated in Italian by Saba et al. (2019) was used to measure subjects' orientation toward the health and hedonic characteristics of foods. This questionnaire consists of a series of items to measure Health attitude (20 items in three sub-scales: *General health interest*; *Light product interest*; and *Natural product interest*) and a series of items to measure Taste attitude (18 items in three sub-scales: *Craving for sweet foods*; *Using food as a reward*; and *Pleasure*). The *Pleasure* sub-scale was not measured in the present study due to the very low internal reliability of this scale in Italian subjects (Monteleone et al., 2017; Saba et al., 2019). Each statement was evaluated using a 7-point Likert scale ranging from "I strongly disagree" (score 1) to "I strongly agree" (score 7). For each participant and each subscale, after reversing the statements negatively-worded, a mean score was calculated.

*Food Neophobia Scale*

The questionnaire developed by Pliner and Hobden (1992) and validated in Italian by Laureati et al. (2018) was applied to investigate the reluctance to try and eat unfamiliar foods. Each of the 10 statement was evaluated using a 7-point Likert scale ranging from "I strongly disagree" (score 1) to "I strongly agree" (score 7). The Food Neophobia Scale (FNS) score was calculated, after reversing the neophilic items, as a sum of the responses, yielding a range of 10–70. Higher scores reflected higher food neophobia levels.

### 2.4 | Experimental procedure

Before attending the laboratory session, participants were asked to fill in an online questionnaire providing eating behavioral attitudes information (Dutch Eating Behavior Questionnaire [DEBQ], Health and Taste Attitude Scale [HTAS], and Food Neophobia Scale [FNS]) as well as stated liking for and familiarity with beetroot. Participants attended one session, starting with the training to the use the LAM and gLMS scales as detailed above. Subsequently, they were asked to rate their liking for beetroot puree samples and after a short break to rate sensory attributes intensity. Evaluations were performed in individual booths under white lights. The entire laboratory session took approximately 1 hr. Data were collected using the Fizz v2.51 software program (Biosystemes; Couternon, France).

### 2.5 | Data analysis

ANOVA model was performed considering gender (women and men), age ($A_1 = 18$–30 years, $A_2 = 31$–45 years and $A_3 = 46$–60 years) and sample ($BP_0 = 0.00$, $BP_{0.4} = 0.41$, $BP_{1.1} = 1.11$ and $BP_{1.9} = 1.93$ g/kg of extract), as well as their interactions, as factors, while liking and sensory attributes ratings as dependent variables. In order to identify consumer's segments according to the hedonic scores, a map was obtained by means of a Principal Component Analysis (PCA). The matrix included the four samples as rows and subjects with their liking ratings as columns. Hence, consumers segmentation was performed based on loading scores considering the first two PCs. Differences in age class and gender distribution by cluster were verified by chi-square test ($p$ <.05). ANOVAs were computed considering cluster as fixed factor whereas eating behavioral attitudes (HTAS, DEBQ, and FNS), familiarity with and stated liking for beetroot were considered as dependent variables. When a significant difference ($p$ <.05) was found, the Bonferroni post hoc test was performed as multiple comparison test. The analyses were performed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY) and the XLSTAT-Sensory software for Windows, Version June 1, 2015 (Addinsoft, France).

## 3 | RESULTS

### 3.1 | Liking and sensory attributes ratings

Results showed a significant sample effect on sour ($F_{(3,1,184)} = 93.79$; $p$ <.0001), astringency ($F_{(3,1,184)} = 16.24$; $p$ <.0001), overall flavor ($F_{(3,1,184)} = 58.12$; $p$ <.0001) ratings, as well as on hedonic scores ($F_{(3,1,184)} = 8.81$; $p$ <.0001). No significant differences in sweet taste among samples were found ($F_{(3,1,184)} = 1.04$; $p = .38$). The intensity ratings of sour, astringency, and overall flavor perceptions significantly increased with phenol concentrations (Figure 1).

Phenols addition at 0.4 g/kg ($BP_{0.4}$) did not lead to perceived changes in terms of astringency (7.40 ± 0.67) and overall flavor (20.87 ± 0.79) compared with control sample $BP_0$ (5.79 ± 0.67 and 18.93 ± 0.79, respectively), while a significant increase was observed in sourness ($BP_0 = 5.94 \pm 0.86$; $BP_{0.4} = 8.62 \pm 0.86$). With the addition of higher phenol amounts to the beetroot purees (1.1 and 1.9 g/kg), the intensity of all these sensations significantly increased.

Focusing on liking results, the phenol addition at the lowest concentration did not affect the hedonic responses ($BP_0 = 55.76 \pm 1.01$; $BP_{0.4}$ 55.89 ± 1.00), while samples with the higher extract

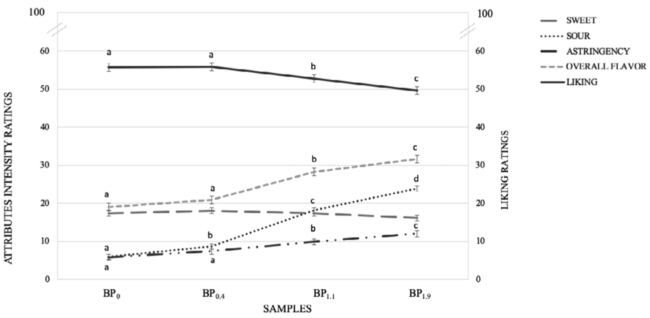


**FIGURE 1** Mean attributes intensity and liking ratings (±*SEM*) provided to the beetroot puree samples ($BP_0$; $BP_{0.4}$; $BP_{1.1}$; and $BP_{1.9}$). Different letters show significant differences ($p$ <.05) according to post hoc test

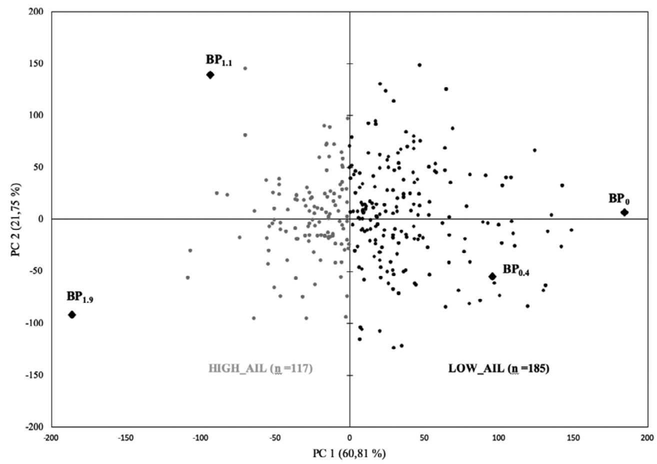


**FIGURE 2** Bi-plot with participants (gray dots) and beetroot puree samples (black diamonds and bold font)

concentrations obtained progressively significant lower scores ($BP_{1.1}$ = 52.71 ± 1.01; $BP_{1.9}$ = 49.53 ± 1.00).

A significant age effect was found on all sensory attribute perception (sweet: $F_{(2,1,184)} = 13.95$; $p$ <.0001; sour: $F_{(2,1,184)}$ 3.37; $p$ <.05; astringency: $F_{(2,1,184)} = 2.97$; $p = .05$ and overall flavor: $F_{(2,1,184)} = 5.16$; $p$ <.001). Sweet taste was rated higher by the youngest subjects ($A_1$) compared to older ($A_2$ and $A_3$), these last did not significantly differ from each other. Sourness, astringency, and overall flavor were rated lower by age group $A_2$ (31–45 years) than by $A_1$ (18–30 years) and $A_3$ (46–60 years), which not significantly differ from each other. A significant gender effect was found only on astringency perception ($F_{(1,1184)}$= 8.63, $p$ <.01), with men showing higher scores (9.77 ± 0.50) compared to women (7.77 ± 0.46).

The interaction age*gender showed a significant effect on sweet ($F_{(2,1,184)} = 4.87$, $p$ <.01) and overall flavor ($F_{(2,1,184)} = 4.99$, $p$ <.01). In both cases, ratings scores provided by men in the three age groups did not significantly differ, while significant higher scores were provided by youngest women compared to age groups $A_2$ and $A_3$.

The interaction gender * samples was significant only for sweetness perception ($F_{(3,1,184)} = 3.03$, $p$ <.05) and highlighted that scores provided by men did not differ with increasing concentrations, while women perceived $BP_0$ and $BP_{0.4}$ as significantly sweeter than samples with the highest phenol amount. The other two- and three-ways interactions were not significant.

## 3.2 | Consumers segmentation according to liking ratings

The PCA performed on the liking data provided by each participant for the beetroot purees samples resulted in two dimensions accounting for 82.56% of variance in the data. The bi-plot (Figure 2) is an Internal Preference Map in which the subjects are represented on the map by points, which can be considered as end-points of vectors from the origin. The direction of the vector denotes the direction of increasing individual "preference" (Monteleone, Frewer, & Mela, 1998).

Looking at the bi-plot, the first component (from the left to the right of the plot) separates the samples according to their phenols amount. Hence, based on loading plot scores, subjects were divided in two clusters. One cluster of consumers, on the left side of the map, preferred high phenol rich purees, characterized by more intense sensory attributes (High attribute intensity likers, HIGH_AIL: $n = 117$; 39%); and one cluster, on the right side of the map, gave higher liking scores to the samples without ($BP_0$) or with the lowest concentration ($BP_{0.4}$) of phenols from unripe grapes, characterized by less intense sensory attributes (Low attribute intensity likers, LOW_AIL $n = 185$; 61%).

## 3.3 | Clusters characterization

A cluster effect was found only on overall flavor intensity ratings ($F_{(1,1,200)} = 15.44$; $p$ <.001). Subjects preferring samples with highest amounts of phenols (HIGH_AIL) perceived generally the overall flavor as significantly less intense (23.3 ± 0.62) compared to LOW_AIL (26.4 ± 0.49; Figure 3a).

The interaction sample*cluster was found to have a significant effect ($F_{(3;1,200)} = 2.57$, $p = .05$) on sweetness perception and a tendency was highlighted also for sourness ($F_{(3;1,200)} = 2.01$, $p = .10$). As reported in Figure 3b, subjects belonging to LOW_AIL did not perceive a change in sweet taste perception among beetroot puree samples with increasing amount of phenol extract, while significant changes according to phenol content have been perceived by HIGH_AIL. Sourness perception was increased by phenol addition already at the lowest concentration only in LOW_AIL, whereas a modification in this taste quality rating was detected by HIGH_AIL at highest phenol concentrations (Figure 3c).

Cluster characterization by gender, age, eating behavior variables is reported in Table 1. According to $\chi^2$ results, no differences according to age and gender distributions have been highlighted in the two clusters. No differences in stated liking of and familiarity with beetroot were found between HIGH_AIL and LOW_AIL.

Subjects preferring more intense sensory attributes (HIGH_AIL) showed a significant lower food neophobia level and

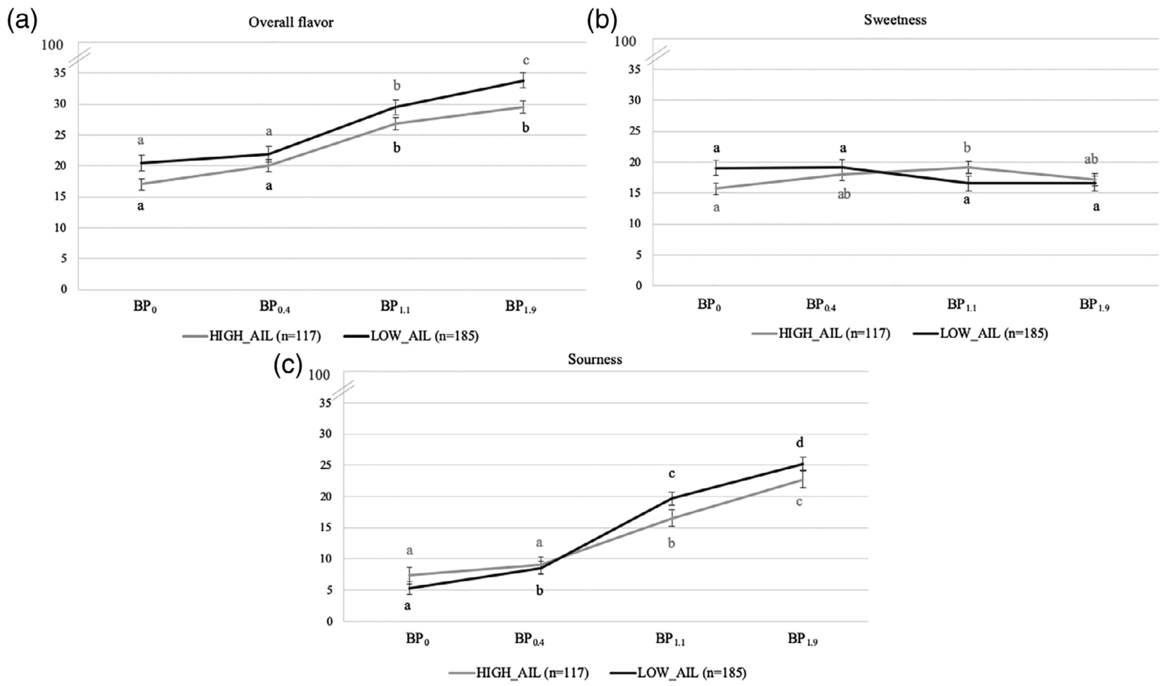


FIGURE 3 (a–c) Mean overall flavor (a), sweetness (b), and sourness (c) intensity ratings ± *SEM* by clusters and samples. Different letters, within each cluster (gray font for HIGH_AIL, black font for LOW_AIL), show significant differences ($p < .05$) according to post hoc test

TABLE 1 Age and gender (%) distribution and mean ratings ± *SEM* by cluster according to Food Neophobia Scale (FNS), Health and Taste Attitude Scale (HTAS), and Duct Eating Behavior Questionnaire (DEBQ)

| | | Cluster | | | |
|---|---|---|---|---|---|
| | | HIGH_AIL | LOW_AIL | $\chi^2$ | *p* |
| Gender (%) | Female | 49 | 60 | 2.44 | .12 |
| | Male | 51 | 40 | | |
| Age (%) | 18–30 | 44 | 42 | 0.21 | .90 |
| | 31–45 | 26 | 25 | | |
| | 46–65 | 30 | 33 | | |
| | | HIGH_AIL | LOW_AIL | *F* | *p* |
| Familiarity with beetroot | | 3.6 ± 0.07 | 3.7 ± 0.06 | 0.51 | .47 |
| Liking for beetroot | | 5.6 ± 0.23 | 5.5 ± 0.18 | 0.02 | .88 |
| FNS | | 22.6 ± 0.95 | 25.4 ± 0.76 | 5.41 | .02* |
| HTAS | | | | | |
| *General health interest* | | 4.6 ± 0.09 | 4.6 ± 0.08 | 0.01 | .94 |
| *Light product interest* | | 3.2 ± 0.11 | 3.3 ± 0.09 | 0.47 | .49 |
| *Natural product interest* | | 4.1 ± 0.11 | 4.3 ± 0.09 | 2.08 | .15 |
| *Craving for sweet food* | | 4.8 ± 0.13 | 4.6 ± 0.11 | 1.56 | .21 |
| *Using food as reward* | | 4.5 ± 0.11 | 4.5 ± 0.09 | 0.37 | .54 |
| DEBQ | | | | | |
| *Restrain eating* | | 2.8 ± 0.06 | 2.8 ± 0.05 | 0.24 | .64 |
| *Emotional eating* | | 2.4 ± 0.08 | 2.2 ± 0.06 | 3.01 | .08** |
| *External eating* | | 3.2 ± 0.05 | 3.1 ± 0.04 | 1.13 | .28 |

*$p < 0.05$, **$p < 0.10$, respectively.

tended to show higher scores in emotional eating compared to LOW_AIL. No significant differences between the two clusters according to the other questionnaire's subscales have been found.

## 4 | DISCUSSION

In the present study, the effect of unripe grapes' phenol addition on beetroot puree samples liking and sensory attributes perception was investigated. Food neophobia and eating behavioral attitudes were also evaluated to assess their importance in modulating the acceptability for these new products.

The phenol addition into beetroot puree samples led to a significant increase in intensity ratings of sourness, astringency, and overall flavor perception. In particular, the strongest effect induced by the phenols was found on sourness and overall flavor, and to a lesser extent on astringency. The increased intensity of specific sensory properties is in line with the documented contribution of phenolic compounds on generally disliked oral sensation of food and beverages (Hufnagel & Hofmann, 2008). These findings further expand what reported, in a small group of adult subjects, where the phenol extract added to beetroot puree samples induced the strongest effect on sourness while astringency slightly increased with increasing phenols amount (Bucalossi et al., 2020). Few literature data on sensory perception of food matrices added with wine-chain by-products are available. Previous research has focused on consumer hedonic responses to new food fortified with grape pomace but few studies have been performed on attributes intensity ratings (see for a review: García-Lomillo & González-SanJosé, 2017). For instance, high amounts of grape skin powders from two grape varieties (Barbera and Chardonnay) were found to be associated with an increase in the perceived sourness and astringency in soft cow milk functional cheeses (Torri et al., 2016). Accordingly, other authors showed an effect of phenol compounds addition, even if from different sources (e.g., olive chain by-products), on sour and/or bitter perception in mayonnaise (Flamminii et al., 2020) and in different plant-based food prototypes such as bean puree, tomato juice, and potato puree (De Toffoli et al., 2019). The present data revealed a decrease of sweetness perception at higher amount of phenols, thought differences were not significant. It is worth considering that the lack of differences in sweetness perception is limited to men, whereas women were able to detect a significant decrease in this taste perception in samples $BP_{1.1}$ and $BP_{1.9}$ compared with $BP_{0.4}$ and the control samples.

Concerning hedonic responses, it should be noted that even if liking decreased with increasing concentration of phenols, all samples were considered acceptable (scores higher or close to the middle of the scale "neither like or dislike") by the consumers involved confirming previous findings obtained in a smaller group of subjects (Proserpio et al., 2020). Moreover, our data suggest that small additions of phenols from unripe grapes (up to 0.4 g/L) is feasible to obtain a phenol enriched product well-liked as the nonenriched puree. Consumer segmentation according to liking data depicted two groups of subjects: a non-negligible proportion preferring the samples with the highest phenol concentrations $BP_{1.1}$ and $BP_{1.9}$, and one preferring the control sample without phenol addition and the sample with the lower amount of unripe grape's extract. It is worth to notice that the two clusters did not differ in liking and familiarity with beetroot, thus this different hedonic pattern may be directly associated with the phenol content and with the change on the sensory profile of the samples that it caused. The two clusters, which did not differ in terms of age and gender distribution, perceived significantly different the overall flavor and the sweet taste of the samples. In particular, subjects preferring samples with higher phenol amounts (HIGH_AIL) perceived generally the overall flavor of the samples as less intense compared to the other group of subjects (LOW_AIL). These results confirm previous findings showing that the limited ability to perceive intensity of "warning" sensations (e.g., sourness) could translate in higher acceptance of food products characterized by specific sensory qualities (Cox et al., 2012;Laureati et al., 2018; Spinelli et al., 2018). Differences in the hedonic responses to the beetroot purees could lie also in the eating behavioral attitudes of the consumers involved. Our study showed that subjects belonging to HIGH_AIL cluster had a lower food neophobia level compared to subjects that generally gave lower liking scores to the samples enriched with phenols. These results are in line with a large body of literature demonstrating that subjects more prone to try and eat unfamiliar and new food respond better to innovative formulations (Tuorila & Hartmann, 2020), such as of "novel foods" (e.g., functional foods or nutritionally modified foods; van den Heuvel, Newbury, & Appleton, 2019). In this context, Urala and Lähteenmäki (2007) depicted negative correlations between food neophobia scores and willingness to use functional foods and, accordingly, recent data demonstrated that the use of value-added sustainable ingredients in enriched food formulations led to higher liking scores in subjects showing a less food neophobia level compared to neophobic subjects (Proserpio, Pagliarini, Laureati, Frigerio, & Lavelli, 2019). Food neophobia is also widely reported to be negatively associated with dietary pattern rich in vegetables (Knaapila et al., 2011; Törnwall et al., 2014) and with food characterized by warning sensations, such as pungency and sourness (Laureati et al., 2018; Spinelli et al., 2018). An association between health-related issues interest and hedonic scores was expected. Indeed, previous findings revealed that health concern and food choice motives related to health and weight control had significant roles in individual liking of bilberry and cowberry juice fractions rich in phenols (Laaksonen et al., 2013). However, the HTAS did not contribute to differentiate the two clusters.

Subjects preferring samples characterized by intense sensory attributes tended to have higher *Emotional eating* scores compared to subjects preferring $BP_0$ and $BP_{0.4}$ samples. A clear explanation about this tendency is critical to be found. Emotional eaters, that overeat in response to negative emotions, were found to have a higher intake and preference for both sweet and salty high-calorie or high-carbohydrate food as well as fat and high-energy dense foods (Nguyen-Michel, Unger, & Spruijt-Metz, 2007; Spinelli et al., 2020; van Strien et al., 2013), thus for food characterized by intense sensations. Therefore, it could be speculated that subjects belonging to HIGH_AIL cluster could be more satisfied by intense sensory attributes compared with LOW_AIL cluster.

## 5 | CONCLUSIONS

In conclusion, the results of the present study suggest that unripe grapes can be used as a sustainable phenol source for the development of new highly antioxidant foods. Indeed, despite the peculiar sensory characteristics of the extract used, such as sourness and astringency, all experimental samples were considered acceptable by the consumers involved. Thus, an addition till 1.9 g/kg could be considered feasible from a sensory point of view, besides improving both the nutritional content of the food matrices, as well as promoting the reuse of winemaking by-products. Different consumer segments have been here identified, with 39% of subjects preferring samples enriched with higher amount of phenols. This depicts the real possibility of targeting new food products characterized by specific sensory attributes to subjects more prone to accept and consequently consume innovative formulations. On the other hand, the present results revealed that both sensory perception and food neophobia could be barriers to the adoption of new sustainable plant-based food product with pro-health activities for specific groups of subjects. Although consumers are increasingly aware about the importance of following a balanced diet, many people face a variety of barriers to the consumption of healthy products. Thus, several strategies could be applied, for example, promoting a consumer engagement as well optimizing food product formulations to make them more palatable, to foster the transition to the consumption of food products developed using value-added and sustainable ingredients.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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