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Role of continuous phase and particle properties on the sensory perception of root vegetable purées evaluated by an expert panel and naïve consumers

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Abstract

Textural properties play an essential role in the development of food products. The complexity of textural attributes has been traditionally overcome with extensive panelist training and the use of generic descriptive analysis. A better understanding on the use of rapid methods with naïve consumers to evaluate texture attributes in complex food products is still needed. The present study aimed to investigate the (i) role of different continuous phases and particle properties (i.e., size and hardness) on the mouthfeel perception of root vegetable purées and (ii) the effect of panel expertise (sensory experts vs. naïve consumers) using Rate-All-That-Apply (RATA). The study included six purées made of two different continuous phase (based on Jerusalem artichoke which is rich in inulin and, parsnip which is rich in starch) and three types of beetroot particles (raw, cooked, and comminuted beetroot). Results showed that both panels were able to discriminate and profile in a similar manner. However, sensory experts showed higher ability to discriminate between samples regarding the particle's attributes whereas consumer's sample discrimination was influenced by attributes such as "ease of swallow" and "creaminess." For the expert panel, the presence of hard particles was a clear factor driving the differences between samples. Our results highlighted the contribution of both continuous and dispersed phases to design the texture profile of particulate semisolid plant-based foods.

KEYWORDS

consumers, experts, inulin, particles, sensory science, starch, texture

1 | INTRODUCTION

In the last decades, the interest in food texture in relation to specific structural and mechanical properties has increased (Chen & Rosenthal, 2015; Lu, 2013). However, food texture is a highly complex

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sensory dimension, that is, a multisensorial component, which can be perceived using visual, tactile, and auditory receptors. Hence, it seems unmistakable to say that food texture is not only a descriptive parameter, but also hedonic and therefore a key player in defining food quality (Chen & Rosenthal, 2015).

Many studies have investigated the structure and mechanical properties of food products and food bolus from a rheological and tribological perspective (Laiho, Williams, Poelman, Appelqvist, & Logan, 2017; Lopez-Sanchez, Svelander, Bialek, Schumm, & Langton, 2011; Macosko, 1994; Stokes, Boehm, & Baier, 2013; Tobin et al., 2020). In those studies, food structure is linked to changes in chemical composition, in particular to polysaccharides, which affect food viscosity and solubility (Harte & Venegas, 2010; Rotureau, Dellacherie, & Durand, 2006). Additionally, polysaccharides interact with other molecules such as phenolics (Garrido-Bañuelos, Buica, & du Toit, 2021), lipids and proteins (Ghosh & Bandyopadhyay, 2012). These interactions influence not only texture but also flavor release from the food matrix (de Loubens, Magnin, Doyennette, Tréléa, & Souchon, 2011).

Food texture modification can be achieved by using thickeners and viscosifiers (Kadam, Tiwari, & O'Donnell, 2015), by conventional cooking techniques (Andersson et al., 2022; Hong, Uhm, & Yoon, 2014) and more advance processes such as high-pressure homogenization (Harte & Venegas, 2010; Lopez-Sanchez, Svelander, et al., 2011; Paciulli, Medina-Meza, Chiavaro, & Barbosa-Cánovas, 2016). Simply altering the order of thermal and mechanical treatments, has been shown to influence particle shapes, size distributions and rheological properties in broccoli and carrot purées (Lopez-Sanchez et al., 2011).

Root vegetables are interesting raw materials as they contain polysaccharides with techno-functional properties. Jerusalem artichoke and parsnip have very different carbohydrate composition. Jerusalem artichoke is rich in inulin (63.1 mg/g) and has a low content of starch (2.9 mg/g) whereas parsnip is rich in starch (90.9 mg/g) and poor in inulin (11.2 mg/g) (Andersson et al., 2022). Starch and inulin have been used as texture modifiers and thickeners within different food matrices (Arocas, Sanz, Salvador, Varela, & Fiszman, 2010; García, Cáceres, & Selgas, 2006; Meyer, Bayarri, Tárrega, & Costell, 2011), improving mouthfeel-related sensations, such as "thickness" or "creaminess" (Balthazar et al., 2015; Sonne, Busch-Stockfisch, Weiss, & Hinrichs, 2014; Villegas, Carbonell, & Costell, 2007).

The contribution of all abovementioned parameters, food texture represents a challenge for sensory science. Despite its complexity, a texture lexicon and standard scale ratings for attributes such as hardness, brittleness, chewiness, gumminess, viscosity, and adhesiveness has been developed (Kohyama, 2020). Other attributes such as "creaminess" are not only sensory attributes, but a multimodal sensory perception (Dickinson, 2018; Upadhyay, Aktar, & Chen, 2020).

Additionally, intra-individual variability and the existence of different "mouth-behavior" groups (chewers, crunchers, smooshers and suckers) (Jeltema, Beckley, & Vahalik, 2015) and, texture-liking groups (Kim & Vickers, 2020) play an important role in the sensory evaluation of food texture. The work form Kim and Vickers (Kim & Vickers, 2020) found four "mouth-behaviors" based on clusters obtained from oral physiological measurements: "low particle-size sensitivity," "high biting force," "high saliva flow rate," and "low saliva flow and low chewing efficiency." The outcomes of these studies highlight the importance of exploring the sensory perception with different population groups. Panel comparison is a field on its own, and there are numerous studies investigating the sensory perception performed by different age groups (Issanchou, 2015; Kremer, Mojet, & Kroeze, 2005), or panelists with different level of expertise (Giacalone & Hedelund, 2016; Mihnea, Aleixandre-Tudó, Kidd, & du Toit, 2019).

Descriptive Analysis (DA) and trained panelists have been the most common strategy to overcome the complexity of food texture evaluation. The use of sensory rapid methods is a cost-effective alternative, and their use in research and food product development is increasing (Cadena et al., 2014; Delarue, 2015). Each type of sensory methodology (discrimination or descriptive tests) provides different insights. The choice of method, but also the type of sensory panel, is done according to the specific goals and needs. Having a better understanding about the main differences between untrained and trained panelists is therefore essential (Danner et al., 2018; Mihnea et al., 2019; Oppermann, de Graaf, Scholten, Stieger, & Piqueras-Fiszman, 2017). As an example, Opperman and colleagues investigated the use of Rate-All-That-Apply (RATA) with consumers (i.e., untrained panelists) and DA with trained panelists to evaluate mouthfeel attributes in double emulsions (Oppermann et al., 2017). Results showed a similar overall configuration, finding a similar discriminating capacity between untrained and trained panelists. However, the study also showed specific differences. First, untrained panelists used a larger number of attributes (21) compared to trained panelists (9). Second, the use of the scale, especially for untrained panelist who used it on its lower scale level (Oppermann et al., 2017). A recent study (Niimi et al., 2022) has evaluated the suitability of RATA to explore the perception of meat-alternative products by consumers.

The present work aimed to investigate the role of the continuous phase (inulin vs. starch-based) and particle characteristics (size and hardness) on the textural properties of root vegetable purées using RATA by two sensory groups: sensory experts versus naïve consumers. The initial hypothesis is that both panels would characterize and discriminate the samples in a similar manner. However, the expert panel is expected to have a better discrimination for more complex sensory attributes. This study brings new insights on consumer's sensory perception of texture attributes in complex food products, which may be of special interest for food industry to tailor specific strategies in new product development.

2 | MATERIALS AND METHODS

2.1 | Sample preparation

The present study was performed on six root vegetable purées as model systems. The raw materials used were Jerusalem artichoke

TABLE 1 Composition and coding of the root vegetable purées used for the study.

Code	Continuous phase	%	Beet root particles	%
P-BP	Starch—parsnip puree (P)	90	Puree (BP)	10
P-CB	Starch—parsnip puree (P)	90	Cooked (CB)	10
P-RB	Starch—parsnip puree (P)	90	Raw (RB)	10
JA-BP	Inulin—Jerusalem artichoke puree (JA)	90	Puree (BP)	10
JA-CB	Inulin—Jerusalem artichoke puree (JA)	90	Cooked (CB)	10
JA-RB	Inulin—Jerusalem artichoke puree (JA)	90	Raw (RB)	10

(*Helianthus tuberosus* L.), parsnip (*Pastinaca sativa*) and beetroot (*Beta vulgaris*). Root vegetables were grown in Sweden and were purchased at a local grocery store and stored at 4°C until processing.

Samples consisted of two different continuous phases, inulin rich and starch-rich, and three types of disperse phase that is, particles with different characteristics. Further details and coding used through the study are described in Table 1. The two different continuous phases were Jerusalem artichoke purées—JA (inulin-rich) and parsnip purées—P (starch-rich). The three different types of disperse phase were represented by different type of beetroot particles that were added to the purées (comminated BP, cooked CB, and raw RB).

The continuous phase (P, JA) was prepared as follow: root vegetables (peeled, washed, and chopped at about 1–2 cm^3) were boiled in water for 15 min. The amount of water added was based on the dry matter of the vegetables to achieve 8% solid content (Andersson et al., 2022). The cooked vegetables and corresponding water were blended using a kitchen blender (TURBO blender, Moulinex; France) for 1 min and 30 s at maximum speed using the options "puree" and "pulses."

The particles added to the purées were prepared from beetroot as follows. Cooked or raw pieces (CB and RB) were chopped in the blender for 20 s using the options "chopping" option and "pulses" after removing the water from the pieces and dry slightly with paper. Comminated beetroot particles (BP) were obtained using the same processing conditions as for the continuous phase. Therefore, particles with different sizes (chopped or purées) and hardness (cooked or raw) were used to modify the texture of the purées.

2.2 | Sensory evaluation

Root vegetable purées were prepared and stored at 8°C for 24 h prior to the tasting. Samples were served (serving size: 1 dL) in odorless, black plastic cups covered with transparent plastic.

2.2.1 | Assessors

A total of 10 expert sensory assessors from RISE—Research Institutes of Sweden analytical panel (selected and trained according to SS-EN ISO 8586:2014) participated in the lexicon development as well as in one profiling session using RATA (Rate-all-that-Apply). The assessors frequently attended sensory evaluations of a variety of food product categories and were highly familiar with quantitative descriptive analysis techniques as well as with rapid methods. A consumer panel ($N = 55$, 67.3% female, aged from 18 to 65+) was also selected to carry out the sensory evaluation using the same methodology. Sensory evaluations were performed following principles of Helsinki Declaration. Prior to evaluations, all participants signed a written informed consent and were informed about vegetables used in the study and their origin. After completing the task, they received economical compensation.

2.2.2 | Sensory space and methodology

The focus of the study was to understand the perception of the mouthfeel and texture; therefore, samples were profiled only for texture and mouthfeel using Rate-All-That-Apply (RATA) (Ares et al., 2014). The assessors were asked to select and rate all the perceived texture attributes from a pre-defined list of 17 texture-attributes (Table 2). Intensity was rated on a 7-point-category scale with endpoint anchors defined as 1 = "very low" to 7 = "very high." The texture attributes and tasting instructions were inspired by the work of Shewan, Stokes, & Smyth, 2020 (Shewan et al., 2020) and based on experience from previous work on vegetable purées (Tobin et al., 2020). An initial list of attributes was discussed with the expert panel ($n = 10$) in one session (1 h) prior to the evaluation to select the final list and attribute definitions. During this session, the protocol and the different sensory attributes were explained and discussed with the panelists to ensure that they were familiar with the samples and the vocabulary used.

A "warm-up" sample (a mix 1:1:1 parsnip puree, beet root puree and Jerusalem artichoke puree at 8% dry weight) was used during the evaluation session to enable participants to get familiar with the tasting procedure and the list of attributes. Samples were served in a randomized order according to a William Latin square design and labeled with a three-digit code. Plastic spoons as well as palate cleaner agents (tap water, sliced cucumber and unsalted water crackers) were provided. A 3-min break was introduced between samples when panelists were to cleanse their palate. The participants always had available the list of attributes with definitions and/or examples to help them (Table 2). During the evaluation, participants had the opportunity to use their own attributes if needed and evaluating the warm-up sample participants were also invited to ask questions.

Sensory experts as well as consumers followed the same procedure. Given tasting instructions were as follows: Lift the lid and stir three times. Take 1–2 full spoons of puree, place it in your mouth, press

TABLE 2 Definitions and examples for the sensory attributes used to evaluate the samples.

Attribute	Definition
Thickness	The thickness of the sample when first in the mouth, from "slightly" (low) being *light* and *watery* to "very high" being *thick*, *full*, *dense* and *heavy in the mouth*)
Smoothness	The sensation of smoothness detected when the tongue slides the sample across the roof of the mouth. From "slightly" to "very high" being *very smooth* almost *silky*
Creaminess	For example, cream cheese
Viscosity	Elasticity
Cloying/sticky	A cloying sticking sensation in the entire mouth cavity. From "slightly" to "very high" being **very** *sticky* and *cloying*, for example, peanut butter
Teeth-stick	The sensation of teeth-stick, where the teeth feel tacky against each other when biting lightly together, for example, caramel
Presence of particles	From "none" to "a lot"
Hardness of particles	From "very soft" to "very hard"
Size of particles	From "very small" to "very big"
Easy to swallow	From "very hard to swallow" to "very easy to swallow"
Clearance	Number of particles remained in the mouth and throat after swallowing—from "very low" (*many particles left*) to "very high" (*none or very little particles left*)
Mouthcoating	The sensation of mouth-coating adherence of the sample to the surfaces of the mouth and throat **after swallowing**
Chalkiness	A chalky, fine powdery sensation left in mouth after swallowing, for example, starch in water
Grittiness	Amount of particles in the mouth after swallowing-related to heterogeneity
Glossiness	Shining sensation of the mouth surfaces when passing the tongue over
Drying	A drying and rough sensation I mouth and on the tongue after swallowing, for example, black tea, red wine, tannins
Lingering sensation	The duration of the mouthfeel or flavor sensations in the mouth. From short to lingering a long time

the tongue onto the sample and slide against the roof of the mouth. Gently tap the teeth together with the sample in the mouth and assess in-mouth texture and mouthfeel. Now, swallow and assess ease of swallow and residual mouth feel. Repeat if necessary.

2.2.3 | Testing conditions

Due to the COVID-19 pandemic, and to ensure enough distance between participants, sensory evaluations were conducted in a spacious seminar room at RISE—Research Institutes of Sweden, in Gothenburg. Sensory evaluations were performed under controlled room temperature (22°C) and under white light conditions. The test was set-up as an online test enabling participants to use their private smartphones (iPads were provided in case of technical problems). Data were collected using RedJade® Sensory Solutions (Silicon Valley, CA, USA). The link to the test as well as individual verification codes were made available via printed packing slips.

2.3 | Data analysis

Raw data, as captured by sensory experts and consumers, was submitted to a two-way ANOVA with purées samples as fixed effect, and assessors as random effect. Pairwise comparisons on the sample mean values were conducted with Tukey's HSD test ($p < 0.05$). Overall sample discrimination and distribution along a perceptual map was analyzed using Principal Component Analysis (PCA). Data were analyzed separately for each panel. PCAs were performed using the average values of the different sensory attributes (i.e., quantitative variables) for the different root vegetable purées (observations) following a Pearson correlation criterion. Observations and variables were projected on a symmetric biplot. Agglomerative Hierarchical Clustering (AHC) following Ward's criterion and Euclidean distances was performed on the sample loadings. AHC was also performed on the factor loadings to understand the perceptual relationship between attributes for each panel.

Comparison between panels was performed by Multifactorial Analysis (MFA) on mean values as performed by Mihnea et al. (2022). Regression Vectors (RV) coefficients are a numerical value used to compare the configuration between different data matrices, in this case two sensory maps (expert panel and naïve consumers). In sensory science, RV values >0.7 are considered to represent an overall similar configuration and therefore discrimination between samples (Perrin & Pagès, 2009). All data analysis were performed using XLSTAT April 1, 2021 (AddinSoft, New York, USA).

3 | RESULTS

3.1 | Texture profile and sample discrimination by sensory experts

Sensory results showed differences between the purées. The biplot in Figure 1a illustrates the sample distribution based on the sensory attributes. The total explained variance achieved with the first two dimensions accounts for 73.51%. The square cosines of the variables are the reflection of the representation of one variable on one PCA axis. Based on this parameter, the following variables were shown to significantly contribute to the separation along the PC1 (47.07%): "ease of swallow," "smoothness," "teeth-stick," "presence of particles," "hardness of particles," "size of particles," "clearance" and "grittiness." Among them, "ease of swallow" and "smoothness" are

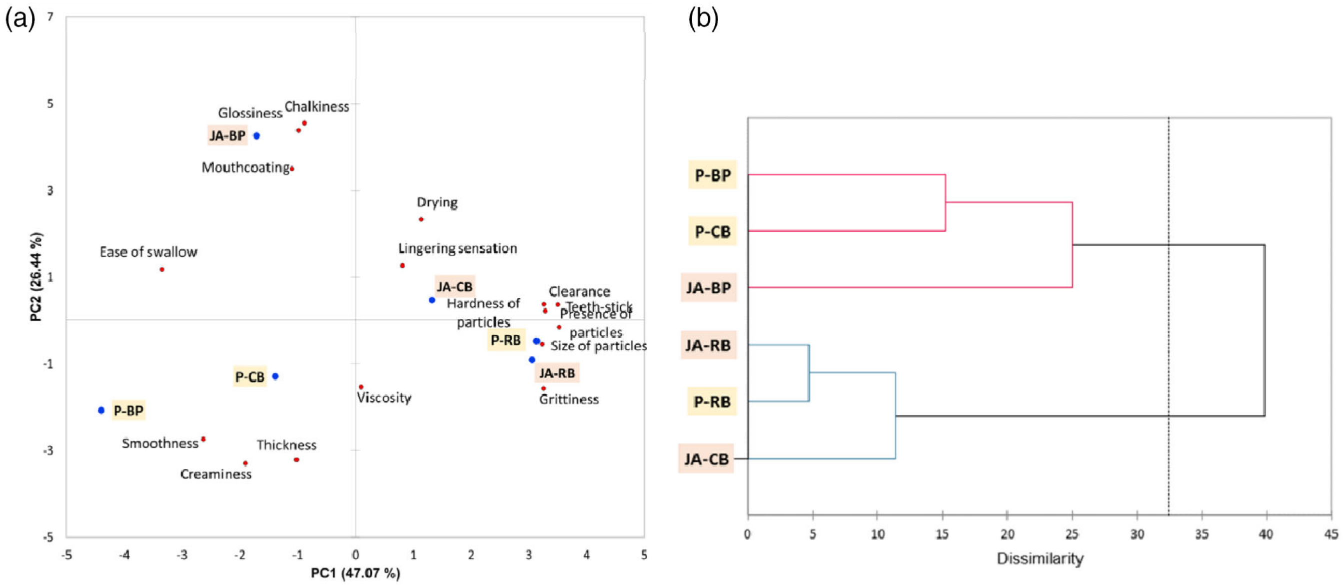


FIGURE 1 (a) Biplot of the principal component analysis (PCA) and (b) corresponding agglomerative hierarchical clustering (AHC) illustrating the sample distribution and clustering based on the sensory attributes used in Rate-All-That-Apply (RATA) evaluated by experts.

found to be drivers on the negative side of PC1 where we find P-BP, P-CB and JA-BP. On the right side, we can observe JA-RB, P-RB and JA-CB. Purées containing raw beetroot (RB) particles (hard particles) can be found on the right side of the plot, independently of the type of continuous phase. The presence of hard particles was therefore a clear factor driving the differences between samples. AHC results (Figure 1b) support this statement, revealing the formation of two clusters. The first cluster is composed of P-BP, P-CB and JA-BP whereas JA-RB, P-RB and JA-CB are part of the second cluster.

A more detailed description of the differences between individual sensory attributes and samples can be found on supplementary data (Table S1). We can observe how samples containing comminuted beetroot particles BP (P-BP and JA-BP) were characterized by a significantly lower number of perceived particles, a lower size, and hardness level, compared to the other two samples with the same continuous phase and larger particles (P-RB and P-CB, JA-RB and JA-CB). Differences in attributes related to the presence of particles (i.e., "presence of particles," "hardness level" and "size of particles") between purées containing RB (i.e., hard particles) and CB (i.e., soft particles) were significant for P but not for JA (except for "hardness level") (Table S1). These findings indicate that the type of continuous phase may be playing a role in the particle's perception. This can explain why JA-CB is found clustered together with JA-RB and P-RB. Different particle sizes and level of hardness also influenced other attributes, such as "grittiness." Samples containing raw beetroot pieces (P-RB and JA-RB) showed the highest "grittiness" scores. However, differences in "grittiness" between CB and BP were not significant, irrespectively of the continuous phase (Table S1).

Sample separation along PC2 (26.44%) is driven by "thickness," "creaminess," "mouth-coating," "chalkiness" and "glossiness." All P purées are found on its negative side. Table S1 shows how all P purées were characterized with a higher "thickness"; this was expected due their starch content. Also, "creaminess," although P-RB was not statistically significant when comparing to JA purées. Despite contributing to PC2, no significant differences were found for "mouth-coating" and "glossiness."

3.2 | Texture profile and sample discrimination by naïve consumers

The total explained variance from PC1 and PC2 accounts 90.53% (Figure 2a). A better sample discrimination is achieved by consumers than by the expert panel. The term "cloying" was used as a descriptor by the consumers, especially to describe P purées (Table S2), while experts did not use this term. The separation along PC1 (60.98%) is influenced by the presence of particles, in agreement with the results of the expert panel. Purées containing raw beetroot (P-RB and JA-RB), but also JA-CB, are found on the negative side of PC1. In the corresponding AHC (Figure 2b), both P-RB and JA-RB are clustered together. A second cluster is formed by all the other purées. The separation of purées with different continuous phases along PC2 (Figure 2a) seems to be better defined than for the expert panel (Figure 1a). Starch-rich samples (P-RB, P-CB and P-BP) are perceived with higher "thickness," "creaminess," but also showed a greater "viscosity" perception and "cloying." A consumer's segmentation was performed with AHC on the raw data. Results from panel analysis showed that consumers could be split into two clusters, with 15 and 40 assessors, respectively (Figure 3a). Sample's effect for each sensory descriptor was then evaluated for each cluster. In Figure 3b, we can observe the table of significances. Results clearly showed that assessors in the second cluster had a larger discriminant capacity, as more descriptors were found to be significant. These differences can also be observed in the sample distribution in the PCA biplot found in Supplementary data (Figure S1). Samples are colored according to these two clusters. Despite having an explained variance of 28.20% for PC1, there is a clear trend of consumers being separated along this

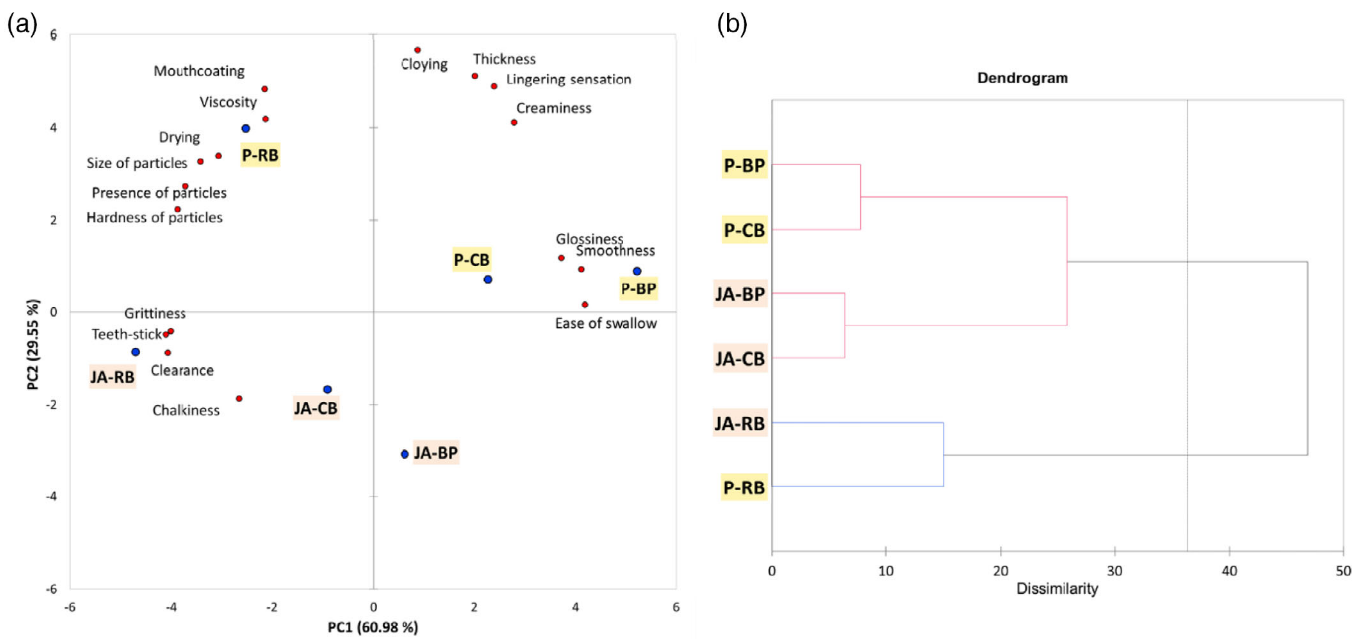
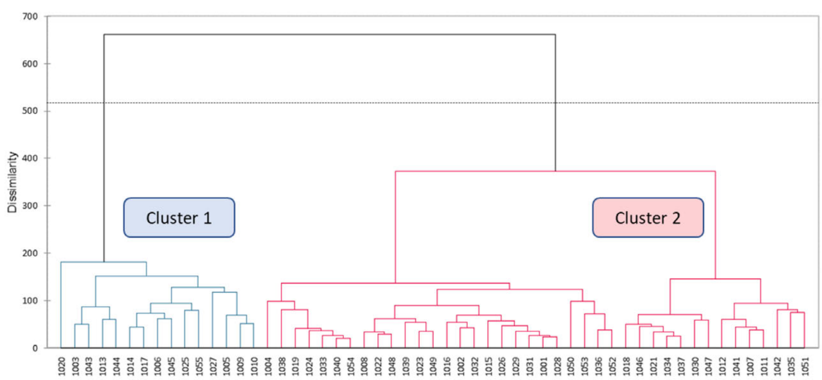


FIGURE 2 (a) Biplot of the principal component analysis (PCA) and (b) corresponding agglomerative hierarchical clustering (AHC) illustrating the sample distribution and clustering based on the sensory attributes used in Rate-All-That-Apply (RATA) evaluated by naïve consumers.

(a)



(b)

Descriptors	Cluster 1 F	Cluster 1 Pr > F	Cluster 2 F	Cluster 2 Pr > F
Thickness	1.66	0.16	46.19	0.00
Smoothness	2.28	0.06	21.68	0.00
Creaminess	11.82	0.00	59.00	0.00
Viscosity	0.31	0.90	0.23	0.95
Cloying	1.67	0.15	3.98	0.00
Teeth-stick	4.99	0.00	7.75	0.00
Presence of particles	2.48	0.04	14.20	0.00
Hardness of particles	1.45	0.22	17.12	0.00
Size of particles	3.88	0.00	12.51	0.00
Ease of swallow	1.26	0.29	6.43	0.00
Clearance	1.03	0.41	8.24	0.00
Mouthcoating	0.45	0.81	1.48	0.20
Chalkiness	0.73	0.61	0.78	0.57
Grittiness	1.48	0.21	5.60	0.00
Glossiness	1.14	0.35	3.33	0.01
Drying	0.81	0.54	1.84	0.11
Lingering sensation	1.19	0.32	4.10	0.00

FIGURE 3 (a) Agglomerative Hierarchical Clustering (AHC) from naïve consumer's sensory evaluation. (b) Sample's effect for each individual descriptor and cluster of consumers. Significances are identified with Type III Sum of Squares.

axis, driven by attributes related to the presence, size and hardness of particles. It seems clear to say that particle's perception is a feature differentiating cluster 1 and cluster 2.

4 | DISCUSSION AND CONCLUSION

4.1 | Can experts and naïve consumers discriminate similarly?

Results from previous sections already evidenced similarities between both panels. When comparing the overall sample discrimination, RV coefficient between experts and consumers was found to be high (RV = 0.883). Also, a high similarity between the confirguration of the MFA and each panel (RV coeffiecients = 0.972 for experts and 0.968 for naïve consumers). In sensory science, values >0.7 represent similar spacial configurations between different datasets. In our case, RV coefficients show that both, expert panelists and naïve consumers have an overall similar sample discrimination. This is an indicator that the use of RATA to evaluate texture properties with naïve consumers is suitable. In Figure S2, we can observe a map with the projected coordinates representing the specific differences between panels for each root vegétable purée. The map shows a good agreement between panels for P-CB and P-BP and larger differences when it comes to JA purées, especially JA-BP and JA-RB. Interestingly, when looking at the projected coordinates from both purées containing raw beetroot (P-RB and JA-RB), we can observe how the scores from the expert panel are closer to each other than those from consumers. This could indicate that when an attribute is easily perceived (such as the presence of particles, their size and hardness), experienced panelist convert it into a key driver for the evaluation. In methods, such as classical Descriptive Analysis, panelist has been shown to memorize products (Lestringant, Delarue, & Heymann, 2018). The level of the panelist experience using the proposed sensory methodology may also lead to specific behaviors, including confidence using the rating scales. In the present study, a generally larger value bracket (for the sensory mean score values) was observed for the expert panel compared to consumers. This is in agreement with the findings from Oppermann et al. (Oppermann et al., 2017). As previously discussed, potential differences among consumers can also be seen as a result of different "mouth-behavior." The work by Kim and Vickers in 2020 (Kim & Vickers, 2020) reported the existence of different consumer's groups based on their in-mouth behavior, such as the subgroup formed by assessors with a "low particle size sensitivity." However, the current study does not include any physiological measurement. Further research is needed to understand these consumers in-mouth behavior. A larger sample size and oral physiological measurements measured by Kim and Vickers (2020) such as chewing efficiency or particle size sensitivity, could have been an asset to confirm these potential differences in consumer's sensitivity.

4.2 | Understanding the similarities and differences for the individual sensory attributes

Despite the overall similarities, specific differences were also found. A table of significance can be found in Supplementary data (Table S3). A larger number of sensory attributes were found to be a statistical significant discriminant for consumers. The "ease of swallow" attribute was not significant for the expert panel (Table S1), whereas it was for consumers (Table S2). They identified sample P-BP as the easiest to swallow, interestingly this is expected to be the sample with the smaller particle size (comminuted beetroot particles) and high viscosity of the continuous phase (starch base).

Furthermore, both panels showed a higher "grittiness" perception when RB (hard particles) was added to the purées. Shewan et al. (2020) investigated model suspensions of agar particles and, stated that the particle modulus had a larger effect than the matrix phase. The same study also concluded that increasing particle size led to a greater "grittiness" and lower "smoothness" perception. These findings agree well with our results obtained with consumers. However, for experts, the type of continuous phase may be contributing to particle's perceptibility. Both panels describe P purées, with a generally higher "thickness," "smoothness" and "creaminess" than JA purées. Smoothness and creaminess were more significant for consumers than for experts. When comparing samples with the same continuous phase, experts described P-BP with the highest "smoothness." However, no significant differences were found for JA purées.

Additionally, the dendrograms in Figure 4 (a—experts, and b—consumers) aimed to explore the clustering formation of the sensory attributes. Cluster association, as a result of attribute discriminant capacity, may unveil specific differences on how trained and untrained panelist use the different attributes. Results showed differences in the clustering for the terms "hardness of particles," "presence of particles" and "size of particles." For the expert panel, these three attributes clustered together with a low number of other attributes ("clearance," "teeth-stick" and "grittiness") (Figure 4a). When we look at the consumer panel (Figure 4b), these three attributes clustered with a larger number of other attributes that is, "drying," "chalkiness," "mouth-coating" and "viscosity," in addition to "clearance," "teeth-stick" and "grittiness." These results can indicate that expert panel is making a better use of attributes related to the presence of particles to discriminate between the different samples. Nonetheless, similarities were also found between panels. In both cases, "ease of swallow" clustered together with attributes such as "smootheness," "thickness," "creaminess" or "lingering sensation." These attributes may be related to the different continuous phase (Arocas et al., 2010; Meyer

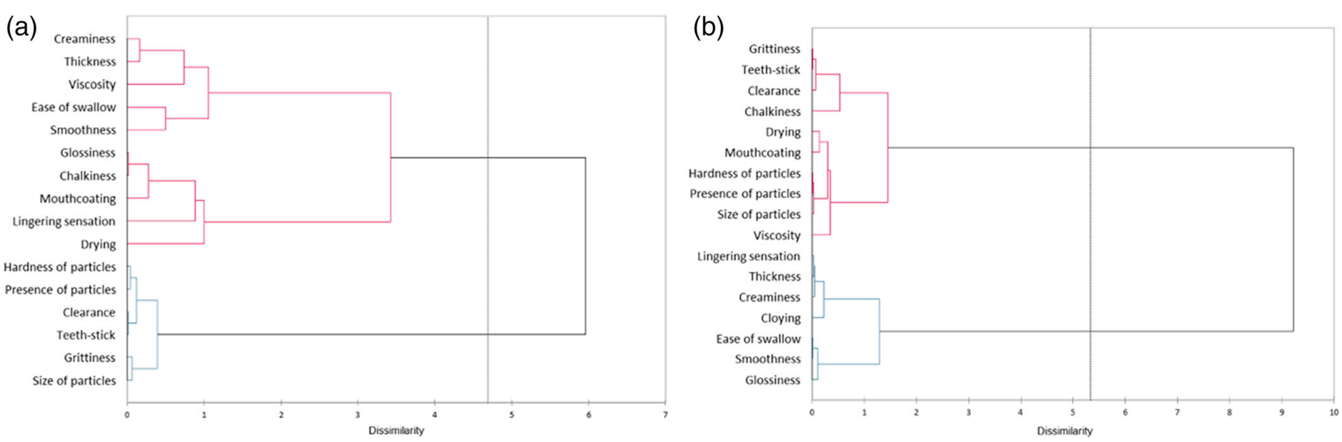


FIGURE 4 Agglomerative Hierarchical Clustering (AHC) performed on the factor loadings for individual sensory attributes when evaluated by the expert panel (a) and naïve consumers (b).

et al., 2011). The term "creaminess" is a complex attribute, but often associated to "thickness" and "mouthcoating" (Dickinson, 2018).

4.3 | General discussion and conclusion

This study has highlighted how the interplay between continuous and dispersed phase contributes to the overall texture perception of root vegetable purées. The role of starch as a thickener to facilitate the ease of swallow in patients in post-stroke oropharyngeal dysphagia was already investigated by Vilardell et al. (Vilardell, Rofes, Arreola, Speyer, & Clavé, 2016). Their results showed an increase in safety to swallow, but also an increase in the number of residues when compared to other thickener alternatives such xanthan gum. The present findings have also shown that on an overall level, both expert and naïve consumer assessors discriminate samples in a similar manner. Our results show the suitability of RATA with naïve consumers as to evaluate texture properties in complex food products. The expert panel showed a better discrimination between samples based on attributes such as "particle size," "presence of particles" and "hardness of particles." While consumers were able to have a better discrimination between samples based on "ease of swallow" and "creaminess." In short, the combination of different continuous phases and particle properties can tailor specific texture properties and therefore, the outcomes of this study could be used to tailor textural properties of particulated foods for specific populations.

AUTHOR CONTRIBUTIONS

Gonzalo Garrido-Bañuelos: Data curation, formal analysis, validation, visualization, writing—original draft, review & editing, investigation, methodology, software. **Patricia Lopez-Sanchez**: Conceptualization, investigation, funding acquisition, writing—original draft, review & editing, validation, supervision, project administration. **Mihaela Mihnea**: Conceptualization, methodology, validation, investigation, funding acquisition, writing—original draft, review & editing, formal analysis, supervision, resources, project administration.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICAL STATEMENTS

Conflict of Interest: The authors declare no conflict of interest.

Informed Consent: Prior to evaluations, all participants signed a written informed consent and were informed about vegetables used in the study and their origin. After completing the task, they received economical compensation.

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