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Impact of panelist's age on the ease of swallow and sensory perception of texture-modified broccoli purees

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Abstract

Swallowing disorders affect approximately 8% of the global population. It is more prevalent in the elderly, leading to malnutrition and dehydration. Different strategies have been investigated to design new texture-modified food products that would reduce or mitigate the suffering from these swallowing disorders. Despite the recent interest and research in this area, there are, however, still a lot of unknowns regarding the specific sensory insights by this targeted group. The aim of this work was to understand if the ease of swallow and related sensory characteristics are perceived differently by "young" and "elderly" healthy individuals. Broccoli purees with different textural properties were created by changing the fluid component (water or xanthan solution) or processing conditions. Samples were evaluated by an elderly panel ($n = 19$, average age $= 68.9$ years) and a young panel ($n = 16$, average age $= 25.4$ years). Multivariate data analysis strategies were used to understand the intrapanel sample discrimination and to compare between panels. Results showed a similar overall discrimination between samples between young and elderly panels. The use of xanthan improved the ease of swallow in both age groups. In the absence of xanthan gum, processing conditions determined the ease of swallow, which was related to the particle size distribution. Nevertheless, small differences were found between panels. For example, the elderly panel was more sensitive when discriminating samples based on the ease of swallow ($p = .005$). Therefore, panelist age seems to be relevant when designing tailored foods enhancing the ease of swallow for the elderly populations.

Practical Applications

The present study highlights new insights on the relevance of age and sensory capabilities when designing new texture-modified food products. It also provides new insights regarding the key sensory attributes to consider and how these are affected by the type of food processing.

1 | INTRODUCTION

Functional foods are natural or processed food products containing known or unknown micro- and macronutrients which can help to improve health and well-being (Bhaskarachary, Vemula, Gavaravarapu, & Joshi, 2016). This can vary from the production of food alternatives for consumers suffering specific food intolerances or allergies (Muthukumar, Selvasekaran, Lokanadham, & Chidambaram, 2020), to the design of food products for different age groups, or population suffering of specific medical disorders, such as dysphagia (Cuomo et al., 2021; Rofes, Arreola, Mukherjee, Swanson, & Clavé, 2014; Stading, 2021; Tobin et al., 2020).

The design of texture-modified foods can alter the bolus properties, playing a crucial role in the oral phase of swallowing (Laguna, Manickam, Arancibia, & Tárrega, 2020; Marconati & Ramaioli, 2020; Stading, 2021; Tobin et al., 2020). Texture modification can be achieved in various forms, from applying different processing techniques (Lopez-Sanchez et al., 2011; Tobin et al., 2020), to the use of specific ingredients such as thickeners like xanthan gum, locus bean gum, or carrageenan (Laguna et al., 2020; Marciani et al., 2019; Tobin et al., 2020; Vieira et al., 2021). For example, by alternating the order of processing techniques, such as heating and blending, suspensions with different particle size and distributions can be achieved, which may affect the sensory profile (Tobin et al., 2020). However, there is still a need to understand whether these differences are perceptible in the same manner by different age groups. Most of studies involving texture-modified foods are firstly approached from a rheological properties point of view (Cuomo et al., 2021; Stading, 2021) but a correlation (Munialo, Kontogiorgos, Euston, & Nyambayo, 2020) and confirmation from a sensory angle is still necessary in product development (Chung, Olson, Degner, & McClements, 2013; Laguna et al., 2020; Pascua, Koç, & Foegeding, 2013; Ross, Tyler, Borgognone, & Eriksen, 2019; Tobin et al., 2020). The lower number of studies focusing on the sensory perspective may partly be because sensory descriptors for texture are complex (Guénard-Lampron, Masson, & Blumenthal, 2021; Nishinari & Fang, 2018; Rustagi, 2020), and panelists have problems with evaluating them in a consistent manner. It is therefore important to provide good references and definitions of the descriptors and ensuring that they are well discussed and clearly understood by the panelist because a single word in one language cannot define multiple texture attributes in another (Kohyama, 2020) or even in the same language (Antmann et al., 2011). The use of different thickeners, such as xanthan gum or carboxymethylcellulose gum, have been successfully used in foods and drinks for dysphagic people (Merino, Gómez, Marín-Arroyo, Beriain, & Ibañez, 2020; Park & Yoo, 2020; Ross et al., 2019). The change in texture induced by xanthan can be perceived as "easier to swallow" by both dysphagic (Rofes et al., 2014) and healthy elderly people (Tobin et al., 2020). Research by Tobin et al., 2020, with a sensory panel of elderly, but healthy people, found that broccoli puree samples prepared with xanthan gum were easier to swallow than those prepared with water.

In sensory science, the comparison between different methodologies (Fleming, Ziegler, & Hayes, 2015; Reinbach, Giacalone, Ribeiro, Bredie, & Frøst, 2014) or different sensory panels is a common practice. Tailored data strategies can help to investigate the specific sensory insights from cross-cultural or demographic studies (Chung & Chung, 2007; Machingura et al., 2019; Weightman, Bauer, Terblanche, Valentin, & Nieuwoudt, 2019), to understanding the level of expertise or training (i.e., the case of wine) (Ballester, Mihnea, Peyron, & Valentin, 2013; Mihnea, Aleixandre-Tudó, Kidd, & du Toit, 2019), or, to understand the impact of age on the perception of food products (Conroy, O'Sullivan, Hamill, & Kerry, 2017; Estay, Pan, Zhong, & Guinard, 2020; Withers, Gosney, & Methven, 2013; Zhang et al., 2020).

Linking to the scope of the present work, different studies have shown how sensory capabilities can change with age, especially the perception of specific flavors and in-mouth texture (Conroy et al., 2017; Honnens de Lichtenberg Broge, Wendin, Rasmussen, & Bredie, 2021; Kremer, Mojet, & Kroeze, 2005, 2007; Withers et al., 2013). For example, research by Kremer et al. (2005), showed that elderly people were less sensitive in perceiving flavor differences between flavored versus nonflavored soups, as well as differences in creaminess induced by the addition of potato starch, compared to young people. Results from Forde and Delahunty (2004) showed that young panelists based their liking on taste and smell, whereas elder panelist's liking was also influenced by the texture and irritation of the products.

In essence, an elder sensory panel may perceive texture-modified food products differently than a younger panel, as age may hypothetically impair their sensory capabilities. Therefore, the aim of this work was to investigate if ease of swallow and related sensory characteristics of texture-modified broccoli purees were perceived differently by two age groups: "young" and "elderly" sensory panels. The insights into the main sensory drivers for each age group, when evaluating texture-modified broccoli purees prepared with different processing conditions, will aid in designing texture-modified foods for specific populations.

2 | MATERIALS AND METHODS

2.1 | Plant material and sample preparation

Broccoli (*Brassica oleracea*) was purchased from the local supermarket in Sweden and used for sample preparation after a maximum storage of 3 days in the fridge (±4°C). Broccoli samples were prepared using two type of processing methods (heat followed by blend—H + B, and blend followed by heat—B + H) and two different fluid phases (water and xanthan gum). More details about the preparation conditions can be found in Tobin et al. (2020). Xanthan gum used during the study was purchased from Sigma-Aldrich Co. (St. Louis, MO).

2.2 | Sensory analysis

The ease of swallow and sensory properties of a total of four different texture-modified broccoli purees (water H + B, xanthan H + B, water

TABLE 1 Sensory vocabulary and scaling for the evaluation of texture/mouthfeel attributes of texture-modified broccoli puree samples

Stage	Sensory attribute	Definition	Scaling
First spoon: Compression of the sample with the tongue against the palate and swallow	Ease of swallow	Used to measure the difficulty of swallowing referring to the effort required to swallow the bolus	Scale: From very easy to very difficult Very Low (1) indicated it was no difficulty in swallowing, that is, easy to swallow Very high (5) indicated that the sample was not easy to swallow
Second spoon: Compression and rubbing the sample with the tongue against the palate	Viscosity	Required force to remove the sample from the spoon to the mouth	Scale: From less viscous to high viscous Example: Low viscosity = water; high viscosity = potato puree
	Moistness	Presence of water in the sample	Scale: From dry to moist
	Cohesiveness	The degree to which the mass holds together in the mouth and during swallowing	Scale: From low to high Example: Low = apple sauce; high = potato puree
	Adhesiveness	The amount of force to remove the sample from oral surfaces (palate and teeth)	Scale: From low to high Example: Low = pudding; high = peanut butter
	Stickiness	Effort of the tongue needed to transfer the bolus to the back of the mouth for swallowing	Scale: From not to very Example: Low = water; high = peanut butter
Third spoon: Rubbing the sample with the tongue against the palate and just before swallowing	Smoothness	Velvety feeling of the sample in the mouth	Scale: From low rough, to high smooth Example: Low = water; high = potato puree
	Mouthcoating	Sensation of a layer forming in the mouth	Scale: From low to high Example: Low = water; high = cream
	Particle size	The proportion of large particles felt in the oral surfaces of the mouth compared to small particles	Scale: From low to high Example: Low = not many large particles; high = a lot of large particles
	Effort required to prepare to swallow		Scale: From low (easy) to high (difficult)
	Residues (in mouth)	After swallowing	Scale: From none to a lot

B + H, and xanthan B + H) were evaluated by two different sensory panels using descriptive analysis (5-point categorical scale), as described in Tobin et al. (2020) and outlined in Table 1. The categorical scale limits and the corresponding verbal labels for each attribute (e.g., from very easy to swallow to very difficult to swallow) are also described in Table 1. Figure 1 outlines the details of each of the panels, including age range and number of panelists. Participants were recruited through an internal database of sensory panelists at Research Institutes of Sweden AB (RISE) and received an economical compensation for their participation in the study. Sensory evaluations were performed in separate sessions for each of the panels.

Prior to the sensory evaluation, panelists in each group participated in a 1-hr familiarization session. The list of attributes given to the panelists to evaluate the samples was generated from available literature (Ong, Steele, & Duizer, 2018; Sharma, Kristo, Corredig, & Duizer, 2017; Vickers et al., 2015). During this session, model foods were used as examples to demonstrate, define, and facilitate the discussion about the different in-mouth sensory attributes and scaling. All commercial products used during the familiarization

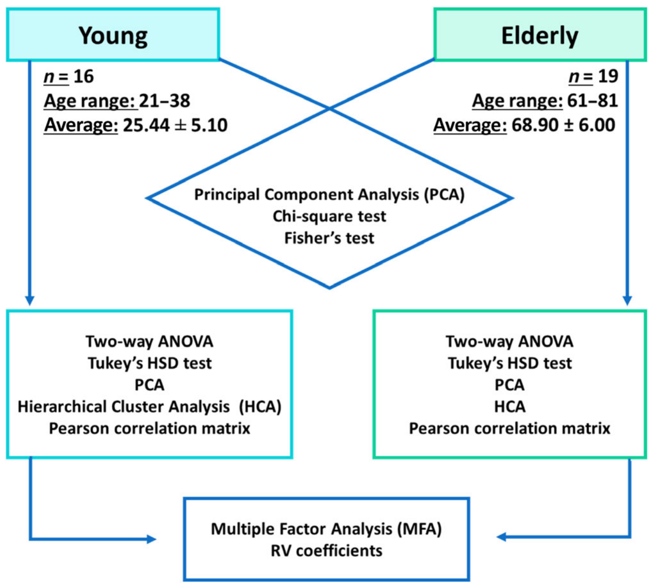

FIGURE 1 Flowchart illustrating the data and statistical analysis performed in the study

session were purchased at ICA Supermarket. These products and corresponding trademarks (in brackets) were the following: Äpple mos 750 g (Felix) as apple purée; Klassiskt Potatis mos 12 port 444 g (Felix) as potato purée, Jordnötssmör 350 g (ICA) as peanut butter, Chokladpudding 480 g (Ekströms) as pudding, and Crème fraiche Lätt 13% 2 dl KRAV (ICA I love eco) as cream. The descriptions can be found in Table 1.

Panelists were also given instructions about the procedure for the sensory evaluation during this familiarization session, to ensure understanding of the in-mouth sensory method.

Directly after the familiarization session, panelists evaluated the pureed broccoli samples under controlled room temperature (22°C) and daylight equivalent conditions. Sensory evaluations were undertaken in individual booths equipped with computers. A volume of 20 ml of puree samples were served cold, on plastic cups labeled with a three-digit code, in a randomized order.

Panelists were instructed to evaluate the samples using three spoonful's of approximately 5 g of sample. The first spoonful was used to rate the ease of swallow. Second spoonful (compression and rubbing the sample with the tongue against the palate) to rate the attributes of viscosity, moistness, cohesiveness, adhesiveness, and stickiness. The third spoonful (rubbing the sample with the tongue against the palate and just before swallowing) was used to rate attributes such as smoothness, particle size sensation, mouthcoating, and effort required to prepare the bolus for swallowing. After swallowing the third spoonful, they were also asked to rate the residues left in mouth. More detailed information on the sensory scale can be found in Table 1. Sensory data were captured and collected using EyeQuestion v.3.8.6, Logic 8 BV software.

2.3 | Statistical analysis

Statistical analysis was performed using XLStat statistical software (Addinsoft, New York, NY). Figure 1 outlines the statistical analysis and the procedure used to analyze the data.

Firstly, raw sensory data was subjected to unsupervised multivariate strategies, using principal component analysis (PCA) and chi-square test, to assess whether there were differences between the two panels or not. The latter was performed on the square cosines of the observations obtained for the first two components.

Secondly, sensory data were analyzed separately for each age group. Sample discrimination was firstly investigated by performing a multiple analysis of variance (ANOVA) (including the "fluid phase" and "processing technique" as a fixed effect and the panelists as random effect). Statistically significant differences were defined as $p < .05$. If a significant difference in means of the sensory attributes was found, post hoc pairwise comparisons were performed using Tukey's honest significant difference (HSD) test. A second two-way ANOVA (including the "broccoli puree sample" as a fixed effect and the panelists as random effect) was performed to determine the product effect on the different sensory attributes for both age groups. Sample distribution was illustrated using PCA on the mean values from the sensory attributes and similarities of the samples was evaluated by using hierarchical cluster analysis (HCA).

The relationship between sensory attributes was explored with Pearson's correlation coefficients.

Similarities and correlations between age groups were performed with multiple factor analysis (MFA), comparing the sensory space and sample distribution (Abdi, Williams, & Valentin, 2013). The similarity between panels can be expressed quantitatively with the RV, Pearson correlation coefficient (range between 0 and 1), with values >.70 indicating greater similarity (Perrin & Pagès, 2009).

3 | RESULTS

3.1 | Effect of texture modification on the ease of swallow and sensory perception of broccoli purees by young and elderly panels

Figure 2 shows the outcome of the unsupervised multivariate analysis in a PCA score plot, with the broccoli samples colored according to the age group. The total variance explained by the first two components is 54.7%. The corresponding HCA (not shown) on the first five components (79.2% of eigenvalue) showed an absence of specific clusters related to the age group. This was confirmed by chi-square and Fisher's exact tests on the square cosines of the observations, showing no significant differences between young and elderly when evaluating the samples. However, when looking at the score plot in Figure 2, a trend separating the young and elderly panels can be observed along the first component PC1 (39.8%). This can be due to different scaling/intensity rating of the attributes, as it has been shown by Forde and Delahunty (2002) (Forde & Delahunty, 2002). Their findings showed that younger consumers tended to use the higher part of a hedonic scale more than older. However, familiarization sessions were meant to minimize this factor, defining, and discussing the scaling for each individual attribute, to highlight panelists' sensitivity differences. Nonetheless, the data from each panel was also analyzed separately and the findings are discussed further.

ANOVA results showed the impact of fluid phase and processing on the perception of specific sensory attributes. These variables showed similarities and differences between panels (Tables S1 and S2). For example, whereas the type of processing had a significant impact on the perceived viscosity by the young panel ($F = 4.60$, $p = .04$), it did not for elderly ($F = 0.48$, $p = .49$). The interaction between fluid phase and type of processing only had an impact on the perception of "residues in-mouth" for the young panel (Table S1), and "adhesivity," "stickiness," "particle size," and "residues in-mouth" for elderly (Table S2).

Detailed ANOVA results of each individual panel can be found in Table 2 (panel A—young, and panel B—elderly). The type of fluid phase played a role on the ease of swallow. Both panels perceived water B + H as more difficult to swallow; however, elderly panel showed a higher sensitivity. They found significant differences between water H + B and xanthan H + B (Table 2), whereas the young panel was not

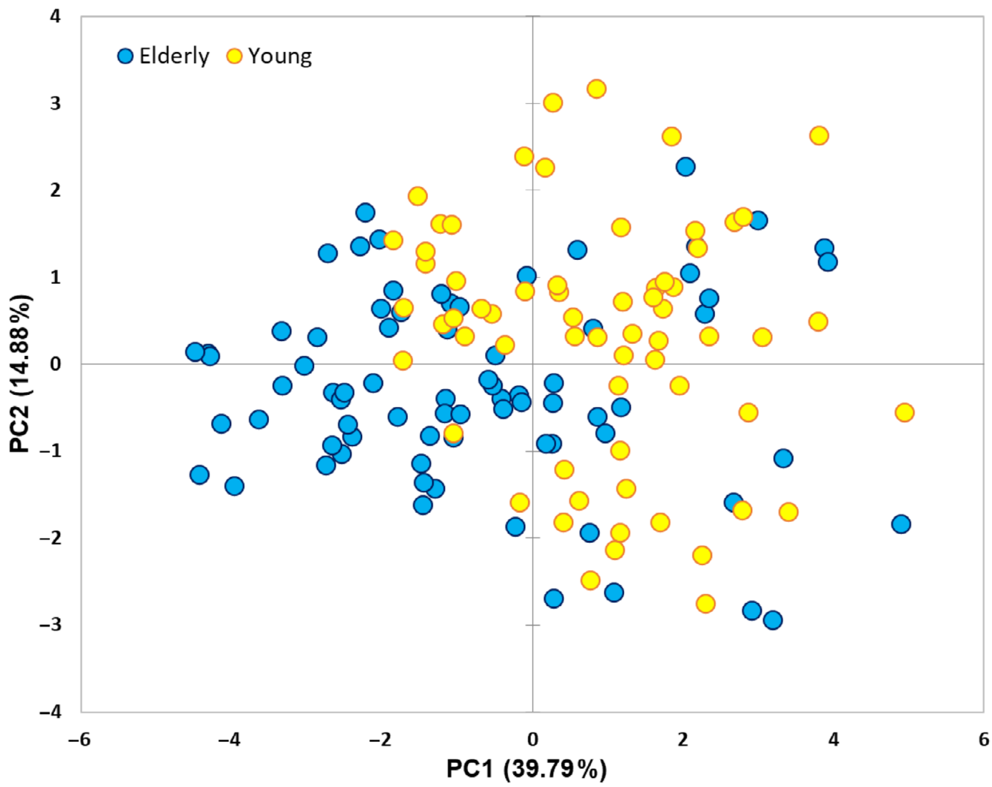

FIGURE 2 Principal component analysis (PCA) score plot illustrating sample distribution for both panels based on the evaluated sensory attributes. Sample dots represent all evaluated samples, and they are colored according to the age group (yellow—young panel and dark blue—elderly panel)

able to discriminate between water H + B, xanthan B + H, and xanthan H + B. Elderly also showed a higher sample discrimination based on the perceived "adhesivity" and "stickiness," being water B + H significantly higher than the other samples (Table 2).

Water B + H was also characterized with a higher "particle size," "residues in-mouth," and "effort required to prepare to swallow." In this case, young panel showed a higher discrimination. As described in Table 2, xanthan H + B was described as significantly lowest "particle size" and "residues in-mouth." Oppositely, elderly panel was not able to differentiate between water H + B, xanthan B + H, and xanthan H + B.

Similarly, young panel also showed a higher discrimination based on sample's perceived "viscosity" (Table S1).

Data were also analyzed considering different broccoli samples as products. The results showed that sensory attributes had different discriminating capacity for each age group. The product effect for each sensory descriptor can be found in Table S3. For the young panel it was "viscosity" ($F = 2.858$, $p = .047$) and "adhesivity" ($F = 8.080$, $p = .000$), whereas for the elderly panel it was "stickiness" ($F = 7.057$, $p = .000$) (Table S3). The mean values were subjected to individual PCA as displayed in Figure 3 (panel a—young and panel c—elderly). All sensory attributes were included, as the aim was not only to see the discrimination between samples but to also gain a better understanding of the impact of age in sensory perception. The significant attributes (as a result of product effect) are highlighted in green in Figure 3.

Figure 3a shows a separation based on the type of fluid phase (water and xanthan) used to prepare the broccoli puree samples along PC1 (55.62%) for the young panel. Broccoli purees (B + H) with water as the fluid phase were on the positive side of the PC1 driven attributes such as "ease of swallow," "effort required to prepare to swallow," "residues in-mouth," and "particle size." On the other hand, broccoli samples containing xanthan were perceived as being "smoother." The separation along PC2 (31.05%) is driven by "viscosity," "stickiness" perception and "mouthcoating." These attributes are driving the separation based on the type of processing technique used, as samples prepared with heat followed by blending (H + B) are found to have a higher "viscosity" and "mouthcoating" (Table 2). Results from HCA (Figure 3b) showed the formation of two clusters. First cluster was formed by water B + H and the second cluster by water H + B, xanthan B + H, and xanthan H + B.

A similar configuration and clustering were observed for the elderly panel (Figure 3c,d). Sample separation was clearly driven along PC1 (82.87%) indicating the influence of the fluid phase on the overall sensory perception. Water B + H samples were profiled by a higher difficulty on the "ease of swallow," "effort to prepare to swallow," "particle size," but also by higher "adhesivity" and "stickiness." However, elderly panelists were not able to discriminate between the rest of the samples (water H + B, xanthan B + H, and xanthan H + B) based on sensory attributes. For example, when comparing both panels, elderly panelists were not able to discriminate the samples based on the smoothness.

However, elderly panel showed a slightly better sample discrimination based on the "ease of swallow" ($F = 9.124$; $p = <.0001$) than the young panel ($F = 4.276$; $p = .008$). Both panels could clearly discriminate water B + H broccoli sample and the rest, suggesting that in

TABLE 2 Mean scores of sensory attributes using a 5-point categorization for young panel (A) and elderly panel (B)

	Water		Xanthan	
	B + H	H + B	B + H	H + B
(A) Young				
Ease of swallow	4.00 a	3.37 ab	2.87 b	2.94 b
Viscosity	3.33 ab	3.56 a	2.81 b	3.37 ab
Moistness	3.53 a	3.31 a	3.31 a	3.69 a
Cohesivity	3.33 a	3.37 a	3.19 a	3.12 a
Adhesivity	3.65 a	3.56 a	3.25 a	3.12 a
Stickiness	3.50 a	3.37 a	2.94 a	3.31 a
Smoothness	2.65 c	3.75 ab	3.25 bc	4.31 a
Mouthcoating	3.20 ab	3.56 a	2.75 b	3.50 ab
Particle size	3.69 a	2.12 bc	2.69 b	1.69 c
Effort required to prepare to swallow	4.25 a	3.50 b	3.31 b	3.06 b
Residues in-mouth	4.25 a	2.81 b	2.87 b	2.19 c
(B) Elderly				
Ease of swallow	3.68 a	2.95 ab	2.37 bc	1.89 c
Viscosity	3.05 a	2.68 a	2.53 a	2.68 a
Moistness	2.63 a	2.63 a	2.84 a	2.95 a
Cohesivity	3.37 a	3.10 a	2.79 a	3.10 a
Adhesivity	3.42 a	2.47 b	2.26 b	2.42 b
Stickiness	3.00 a	2.37 b	2.00 b	2.05 b
Smoothness	2.47 b	3.21 ab	2.74 ab	3.32 a
Mouthcoating	3.68 a	3.21 ab	2.68 bc	2.42 c
Particle size	3.21 a	1.79 b	2.10 b	1.47 b
Effort required to prepare to swallow	3.05 a	2.10 b	2.05 b	1.74 b
Residues in-mouth	3.79 a	2.53 b	2.47 b	2.26 b

Note: Different letters within the same row (i.e., sensory attribute) indicate significant differences between samples (as a result of the interaction between fluid phase and processing technique) according to Tukey's test ($p < .05$). Broccoli samples were prepared with two different fluid phases (water and xanthan gum), using two type of processing methods (heat followed by blend—H + B, and blend followed by heat—B + H): water H + B, water B + H, xanthan H + B, and xanthan B + H.

the absence of xanthan gum, processing conditions played an important role on the perceived ease of swallow. Larger average particle size and narrower particle size distribution in B + H broccoli puree, resulted in making the sample more difficult to swallow. For the young panel there were no significant differences in the "ease of swallow" between water H + B, xanthan B + H, and xanthan H + B. However, elderly panel was able to discriminate between water H + B and xanthan H + B samples, showing that age might be playing a role in the perception of "ease of swallow," even for healthy consumers.

3.2 | Exploring the different sensory attribute perception/associations between panels

Based on the results, and despite both panels given the same familiarization training, the authors considered the possibility that the discriminating capacity of some attributes may not only be explained by differences in rating, but also by possible different perception/associations between attributes. Therefore, the Pearson's correlation coefficients between attributes were explored for each panel (Figure S1, A—young; B—elderly), "ease of swallow" showed a high positive correlation with the "effort required to prepare to swallowing" (Figure S1, A—$r = .959$ and B—$r = .939$), the "particle size" ($r = .758$ and $r = .866$), and the "residues in-mouth" ($r = .893$ and $r = .903$) for both panels. However, some differences can be highlighted. Firstly, elderly panel showed a high positive correlation between "ease of swallow" and "mouthcoating" sample ($r = .997$) and a negative correlation with "moistness" ($r = -.921$) for the broccoli puree, compared to the low correlations for the same attributes in the young panel ($r = .253$ and $r = .141$, respectively). "Mouthcoating" was the only attribute that was significantly different, when discriminating samples by elderly panel (Figure 3c).

Differences between the two panels were also found with regards to viscosity. For the elderly panel, sample "viscosity" was

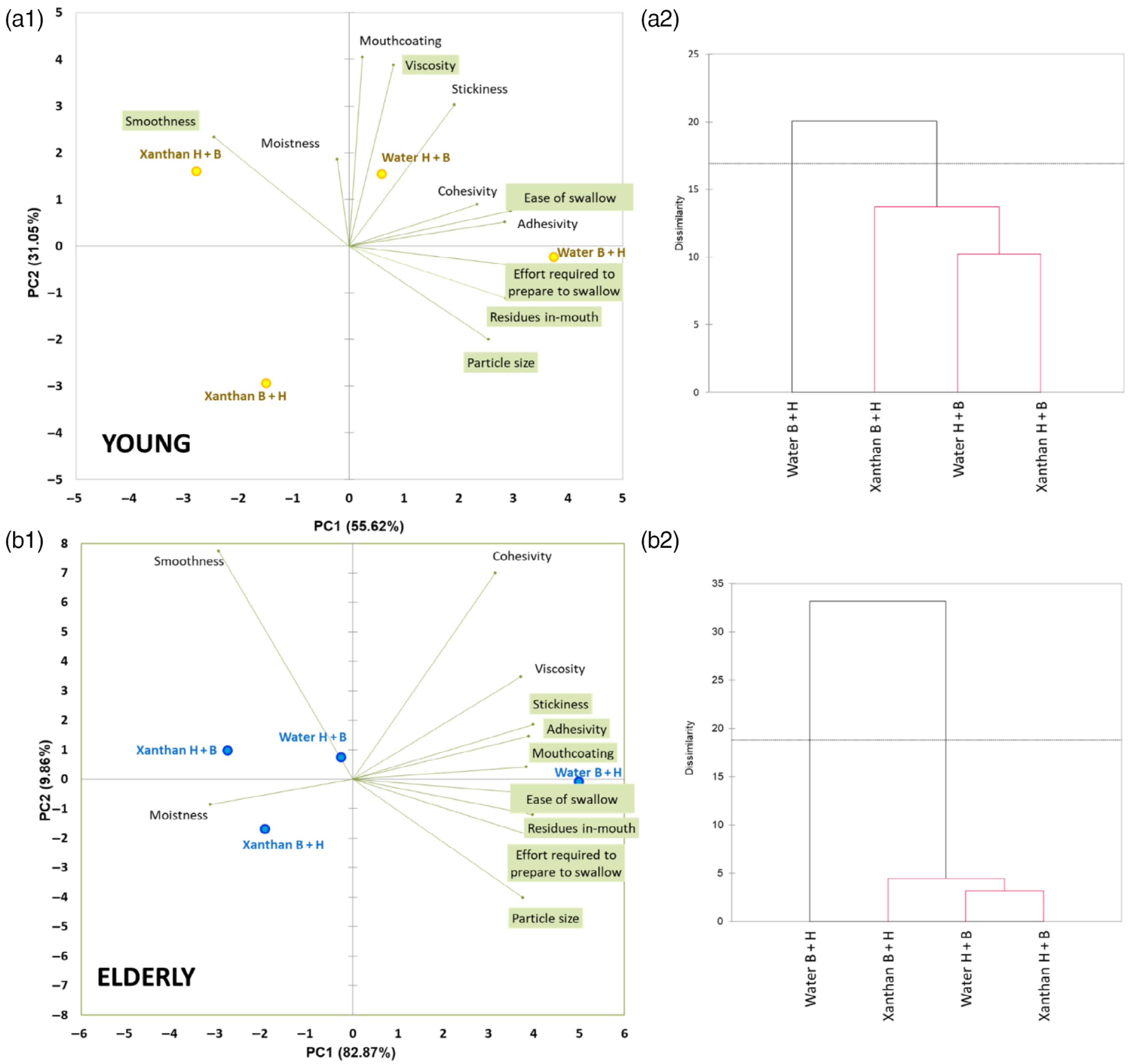

FIGURE 3 Principal component analysis (PCA) biplots illustrating the broccoli puree sample discrimination based on the mean score values from the sensory evaluation performed by the young (a) and elderly panels (c). Sensory attributes highlighted in green correspond to significant attributes as a consequence of product effect (i.e., broccoli puree). Hierarchical clustering analysis (HCA) was performed on the first two dimensions (>80% cumulative eigenvalue) for young (b) and elderly panels (d). Observations are representing broccoli samples prepared with two different fluid phases (water and xanthan gum), using two types of processing methods (heat followed by blend—H + B, and blend followed by heat—B + H): water H + B, water B + H, xanthan H + B, and xanthan B + H

positively correlated with “cohesivity” (r = .943), “adhesivity” (r = .954), “stickiness” (r = .939), and “residues in-mouth” (r = .912), whereas for the young panel, viscosity perception was positively correlated to “mouthcoating” (r = .977). Nevertheless, all these attributes had a positive correlation with the “ease of swallow.” However, contrary to what was observed for the elderly panel (Figure S1B), no strong correlation was found between viscosity and attributes related to the ease of swallowing for the young panel (Figure S1A).

3.3 | Comparing the sensory space and sample discrimination between young and elderly panels

The sample discrimination and sensory space of young and elder panel showed a good similarity, with an RV coefficient of .894. RV coefficients to the MFA were also high (young RV = .977, and elderly RV = .969). The projected points of the MFA observations are displayed in Figure 4. Plots like this can help visualize the variability

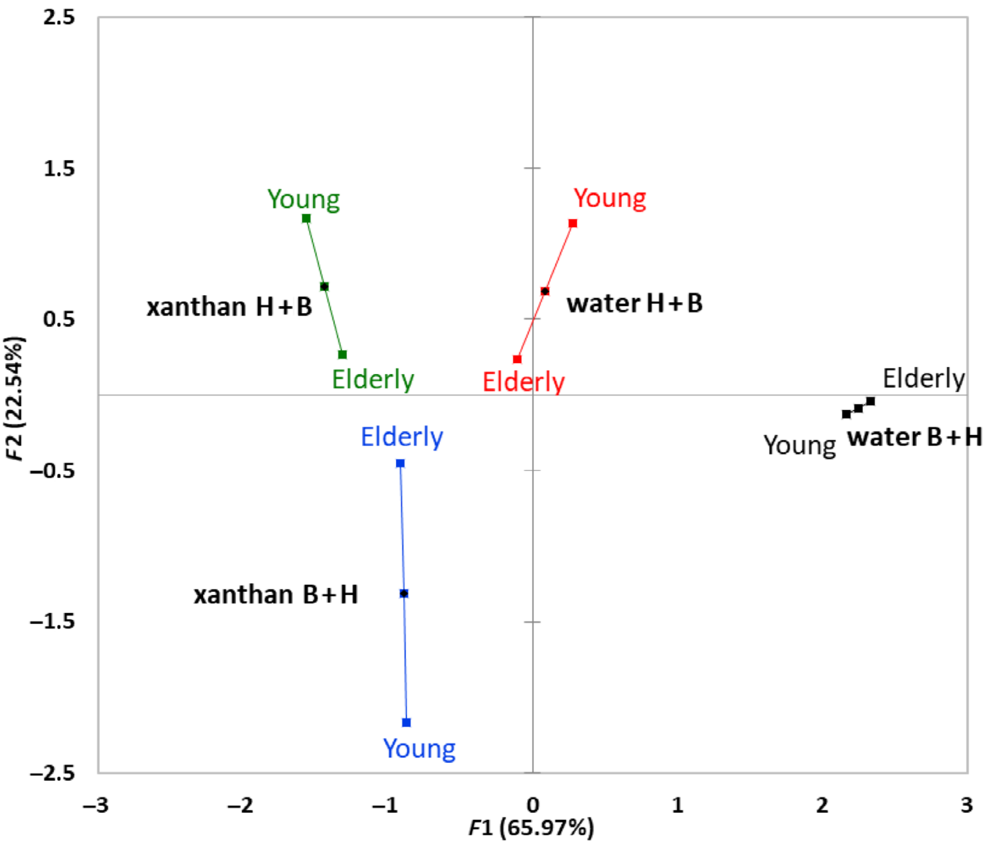

FIGURE 4 Consensus of multiple factor analysis (MFA) map with superimposed projected coordinates from each age group for each broccoli puree sample. Observations are representing broccoli samples prepared with two different fluid phases (water and xanthan gum), using two types of processing methods (heat followed by blend—H + B, and blend followed by heat—B + H): water H + B, water B + H, xanthan H + B, and xanthan B + H

between panels based on their responses about the sensory space of a specific product, while also providing information between different samples. The superimposed projected points allow use to visualize the relative distances between the same observation from different dataset (young and elderly). Therefore, based on Figure 4, we can observe a clear agreement between age groups on the perception of water B + H samples, which is not observed for the other three samples. This is especially noticeable in the case of xanthan B + H. Results have shown that samples containing xanthan, irrespectively of the processing technique used, are generally perceived as easier to swallow by both panel groups. However, elderly panel showed a better discrimination between samples on the attribute of "ease of swallow."

4 | DISCUSSION

Results have shown that despite a similar sample discrimination, the relevance of specific sensory attributes was not always the same for young and elderly panels. Physical parameters of the samples may help to understand the in-mouth perception by both sensory panels. The rheological properties of the purees were previously analyzed and reported (Tobin et al., 2020). In short, results showed that the shear viscosity and viscoelasticity were higher in samples with xanthan gum as the fluid phase. Xanthan B + H samples also had a higher cohesivity and apparent yield stress, a parameter that is linked to the ease of swallow. Both panels found water base samples as more difficult to swallow compared to xanthan samples. Additionally, the use of different processing techniques has been shown to have an impact on ease of swallow for the elderly panel, even when without the addition of a thickener to the sample. Heating the broccoli before blending seemed to facilitate the ease of swallow in water base samples, as H + B samples showed higher viscosity than B + H, and smaller average particle size and broader particle size distribution, compared to the B + H (Tobin et al., 2020).

Research by Lopez-Sanchez et al. (2011), had previously shown that alternating the order of mechanical and thermal treatments could influence the particle size in broccoli dispersions. Particle size seems to be directly linked to the "ease of swallow." In the present work, young panel was able to perceive the differences in particle size induced by the order of the mechanical and thermal treatment, within each fluid phase (Table 2). However, and despite elderly panel perceived water B + H as the samples with the largest particle size, panelists were not able to discriminate between the rest (water H + B, xanthan B + H, and xanthan H + B).

On top of that, particle size is also related to the sample's smoothness. Tobin et al. (2020) showed that B + H particles were larger in size, with broken cell walls on the surface, compared to H + B which had smaller particles with smooth surface. From a sensory perspective, present results show that the broccoli samples with smallest particle size were also perceived as the smoothest by the young panel. Thus, smoothness perception, which was significant for young, but not for elderly, seem to be playing an important role on the discrimination between panels. Pearson correlation coefficients showed a negative correlation between particle size and smoothness

(Figure S1A,B), being significant ($p < .05$) only for young panel. These findings agree with the results from the research by Appelqvist et al. (2015) who also found that concentrated plant-based suspensions with softer and smaller particles were perceived by panelists (average of 48 years old) as having a smoother texture.

Besides heating before blending, the use of xanthan also led to a greater smoothness perception by young panel (not statistically significant) as observed in Table 2. Similar findings were observed by Sharma et al. (2017), where samples containing xanthan gum were rated as the smoothest (together with a starch–xanthan gum blend). The sensitivity and dimension of smoothness perception in elderly may require further investigation, as it has been shown that the perception of attributes such as "creaminess" can be altered with age (Kremer et al., 2005).

Mouthcoating was also found to be different between both panels. This attribute was influenced by the type of processing for the young panel (Table S1), while fluid phase played a larger role for the elderly (Table S2). Elderly scored water base samples with a higher mouthcoating, which were also described as more difficult to swallow. When looking at the Pearson's correlation coefficients (Figure S1), we observe a significant positive correlation ($p < .05$) between mouthcoating and "ease of swallow" for elderly ($r = .997$), but not for the young panel ($r = .254$). These results differ from the findings reported on dairy beverages (Withers et al., 2013), where mouthcoating perception was not perceived differently by young or elderly individuals. However, elderly individuals were more sensitive to "dryness," which can be related to "moistness." Moistness of food is linked to the ease to form a bolus (Hutchings & Lillford, 1988). Our results show that samples that were moister, were easier to swallow for the elderly (Figure S1B) panel, which was not the case for the young panel ($r = .141$).

The complexity of sensory attributes is one of the biggest challenges for in-mouth evaluations. The combination of terms such as "adhesivity" and "stickiness" as potential synonymous terms has been discussed in a recent review by Guénard-Lampron et al. (2021). This combination was suggested because of similar definitions and methodologies were found in several scientific publications to define both terms. However, this correlation between the two terms ("adhesivity" and "stickiness") was not found for the young panel. These differences, also in attributes such as moistness, viscosity, or smoothness, may not only be a matter of conceptual perception, but also the impact of age on human senses (Cavazzana et al., 2018; Conroy et al., 2017). For example, saliva plays an essential role on the in-mouth perception and rheological properties of the food boluses (Laguna, Fiszman, & Tarrega, 2021).

5 | CONCLUSION

This work showed that, panelists discriminated the samples in a similar way, independently of the group age, with water B + H samples always being the most different. Differences between panels were related to intensity rating and relevance of attributes. Young panel generally gave a higher rating than elderly panel, including for specific attributes such as sample smoothness, particle size, and residues in-mouth, which are associated with the processing technique. These attributes had a larger discriminating power for the young panel. On the other side, ease of swallow was more relevant for elderly when discriminating between samples. This research provides new insights regarding the key sensory attributes to consider when developing food products for healthy elderly individuals.

AUTHOR CONTRIBUTIONS

Conceptualization: Mihaela Mihnea, Aarti B. Tobin, and Patricia Lopez-Sanchez; data curation: Mihaela Mihnea and Gonzalo Garrido-Bañuelos; formal analysis; funding acquisition: Patricia Lopez-Sanchez; investigation: Mihaela Mihnea, Aarti B. Tobin, and Patricia Lopez-Sanchez; methodology: Mihaela Mihnea and Gonzalo Garrido-Bañuelos; project administration: Mihaela Mihnea and Patricia Lopez-Sanchez; resources: Mihaela Mihnea and Patricia Lopez-Sanchez; software: Mihaela Mihnea and Gonzalo Garrido-Bañuelos; supervision; validation Mihaela Mihnea and Gonzalo Garrido-Bañuelos; visualization: Gonzalo Garrido-Bañuelos; roles/writing—original draft: Mihaela Mihnea and Gonzalo Garrido-Bañuelos; writing—review and editing: Mihaela Mihnea, Aarti B. Tobin, Patricia Lopez-Sanchez, and Gonzalo Garrido-Bañuelos.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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REFERENCES

Abdi, H., Williams, L. J., & Valentin, D. (2013). Multiple factor analysis: Principal component analysis for multitable and multiblock data sets. *Wiley Interdisciplinary Reviews: Computational Statistics*, *5*(2), 149–179. https://doi.org/10.1002/wics.1246

Antmann, G., Ares, G., Varela, P., Salvador, A., Coste, B., & Fiszman, S. M. (2011). Consumers' texture vocabulary: Results from a free listing study in three Spanish-speaking countries. *Food Quality and Preference*, *22*(1), 165–172. https://doi.org/10.1016/j.foodqual.2010.09.007

Appelqvist, I. A. M., Cochet-Broch, M., Poelman, A. A. M., & Day, L. (2015). Morphologies, volume fraction and viscosity of cell wall particle dispersions particle related to sensory perception. *Food Hydrocolloids*, *44*, 198–207. Poelman, A. A. M. ; Day, L.

Ballester, J., Mihnea, M., Peyron, D., & Valentin, D. (2013). Exploring minerality of Burgundy Chardonnay wines: A sensory approach with wine experts and trained panellists. *Australian Journal of Grape and Wine Research*, *19*(2), 140–152. https://doi.org/10.1111/ajgw.12024

Bhaskarachary, K., Vemula, S. R., Gavaravarapu, S. R. M., & Joshi, A. K. R. (2016). Traditional foods, functional foods and nutraceuticals. *Proceedings of the Indian National Science Academy*, *82*(5), 1565–1577. https://doi.org/10.16943/ptinsa/2016/48888

Cavazzana, A., Röhrborn, A., Garthus-Niegel, S., Larsson, M., Hummel, T., & Croy, I. (2018). Sensory-specific impairment among older people. An investigation using both sensory thresholds and subjective measures across the five senses. *PLoS One*, *13*(8), 1–15. https://doi.org/10.1371/journal.pone.0202969

Chung, C., Olson, K., Degner, B., & McClements, D. J. (2013). Textural properties of model food sauces: Correlation between simulated mastication and sensory evaluation methods. *Food Research International*, *51*(1), 310–320. https://doi.org/10.1016/j.foodres.2012.12.005

Chung, L., & Chung, S. J. (2007). Cross-cultural comparisons among the sensory characteristics of fermented soybean using Korean and Japanese descriptive analysis panels. *Journal of Food Science*, *72*(9), S676–S688. https://doi.org/10.1111/j.1750-3841.2007.00542.x

Conroy, P. M., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2017). Sensory capability of young, middle-aged and elderly Irish assessors to identify beef steaks of varying texture. *Meat Science*, *132*(May), 125–130. https://doi.org/10.1016/j.meatsci.2017.05.020

Cuomo, F., Angelicola, M., De Arcangelis, E., Lopez, F., Messia, M. C., & Marconi, E. (2021). Rheological and nutritional assessment of dysphagia—Oriented new food preparations. *Food*, *10*(3), 663. https://doi.org/10.3390/foods10030663

Estay, K., Pan, S., Zhong, F., & Guinard, J. X. (2020). The relationship between children's and mothers' vegetable liking in Chile, China and the United States. *Food Quality and Preference*, *86*(June), 104000. https://doi.org/10.1016/j.foodqual.2020.104000

Fleming, E. E., Ziegler, G. R., & Hayes, J. E. (2015). Check-all-that-apply (CATA), sorting, and polarized sensory positioning (PSP) with astringent stimuli. *Food Quality and Preference*, *45*, 41–49. https://doi.org/10.1016/j.foodqual.2015.05.004

Forde, C. G., & Delahunty, C. M. (2002). Examination of chemical irritation and textural influence on food preferences in two age cohorts using complex food systems. *Food Quality and Preference*, *13*(7–8), 571–581. https://doi.org/10.1016/S0950-3293(02)00036-8

Forde, C. G., & Delahunty, C. M. (2004). Understanding the role cross-modal sensory interactions play in food acceptability in younger and older consumers. *Food Quality and Preference*, *15*(7–8), 715–727. https://doi.org/10.1016/j.foodqual.2003.12.008

Guénard-Lampron, V., Masson, M., & Blumenthal, D. (2021). Critical review of sensory texture descriptors: From pureed to transitional foods for dysphagia patients. *Journal of Texture Studies*, *13*(3), 287–288. https://doi.org/10.1016/s0740-5472(96)90021-5

Honnens de Lichtenberg Broge, E., Wendin, K., Rasmussen, M. A., & Bredie, W. L. P. (2021). Changes in perception and liking for everyday food odors among older adults. *Food Quality and Preference*, *93*, 104254. https://doi.org/10.1016/j.foodqual.2021.104254

Hutchings, J. B., & Lillford, P. J. (1988). The perception of food texture—The philosophy of the breakdown path. *Journal of Texture Studies*, *19*(2), 103–115. https://doi.org/10.1111/j.1745-4603.1988.tb00928.x

Kohyama, K. (2020). Food texture—Sensory evaluation and instrumental measurement. In K. Nishinari (Ed.), *Textural characteristics of world foods* (pp. 1–13). Chichester, UK: John Wiles & Sons. https://doi.org/10.1002/9781119430902.ch1

Kremer, S., Mojet, J., & Kroeze, J. H. A. (2005). Perception of texture and flavor in soups by elderly and young subjects. *Journal of Texture Studies*, *36*(3), 255–272. https://doi.org/10.1111/j.1745-4603.2005.00015.x

Kremer, S., Mojet, J., & Kroeze, J. H. A. (2007). Differences in perception of sweet and savoury waffles between elderly and young subjects. *Food Quality and Preference*, *18*(1), 106–116. https://doi.org/10.1016/j.foodqual.2005.08.007

Laguna, L., Fiszman, S., & Tarrega, A. (2021). Saliva matters: Reviewing the role of saliva in the rheology and tribology of liquid and semisolid foods. Relation to in-mouth perception. *Food Hydrocolloids*, *116* (February), 106660. https://doi.org/10.1016/j.foodhyd.2021.106660

Laguna, L., Manickam, I., Arancibia, C., & Tárrega, A. (2020). Viscosity decay of hydrocolloids under oral conditions. *Food Research International*, *136*(October 2019), 109300. https://doi.org/10.1016/j.foodres.2020.109300

Lopez-Sanchez, P., Nijsse, J., Blonk, H. C. G., Bialek, L., Schumm, S., & Langton, M. (2011). Effect of mechanical and thermal treatments on the microstructure and rheological properties of carrot, broccoli and tomato dispersions. *Journal of the Science of Food and Agriculture*, *91*, 207–217. https://doi.org/10.1002/jsfa.4168

Machingura, T., Kaur, G., Lloyd, C., Mickan, S., Shum, D., Rathbone, E., & Green, H. (2019). An exploration of sensory processing patterns and their association with demographic factors in healthy adults. *Irish Journal of Occupational Therapy*, *48*(1), 3–16. https://doi.org/10.1108/IJOT-12-2018-0025

Marciani, L., Lopez-Sanchez, P., Pettersson, S., Hoad, C., Abrehart, N., Ahnoff, M., & Ström, A. (2019). Alginate and HM-pectin in sports-drink give rise to intra-gastric gelation in vivo. *Food & Function*, *10*(12), 7892–7899. https://doi.org/10.1039/c9fo01617a

Marconati, M., & Ramaioli, M. (2020). The role of extensional rheology in the oral phase of swallowing: An in vitro study. *Food & Function*, *11*(5), 4363–4375. https://doi.org/10.1039/c9fo02327e

Merino, G., Gómez, I., Marín-Arroyo, M. R., Beriain, M. J., & Ibañez, F. C. (2020). Methodology for design of suitable dishes for dysphagic people. *Innovative Food Science and Emerging Technologies*, *64*(January), 102383. https://doi.org/10.1016/j.ifset.2020.102383

Mihnea, M., Aleixandre-Tudó, J., Kidd, M., & du Toit, W. (2019). Basic in-mouth attribute evaluation: A comparison of two panels. *Food*, *8*(1), 3. https://doi.org/10.3390/foods8010003

Munialo, C. D., Kontogiorgos, V., Euston, S. R., & Nyambayo, I. (2020). Rheological, tribological and sensory attributes of texture-modified foods for dysphagia patients and the elderly: A review. *International Journal of Food Science & Technology*, *55*(5), 1862–1871. https://doi.org/10.1111/ijfs.14483

Muthukumar, J., Selvasekaran, P., Lokanadham, M., & Chidambaram, R. (2020). Food and food products associated with food allergy and food intolerance—An overview. *Food Research International*, *138*(PB), 109780. https://doi.org/10.1016/j.foodres.2020.109780

Nishinari, K., & Fang, Y. (2018). Perception and measurement of food texture: Solid foods. *Journal of Texture Studies*, *49*(2), 160–201. https://doi.org/10.1111/jtxs.12327

Ong, J. J. X., Steele, C. M., & Duizer, L. M. (2018). Challenges to assumptions regarding oral shear rate during oral processing and swallowing based on sensory testing with thickened liquids. *Food Hydrocolloids*, *84*, 173–180. https://doi.org/10.1016/J.FOODHYD.2018.05.043

Park, J., & Yoo, B. (2020). Particle agglomeration of gum mixture thickeners used for dysphagia diets. *Journal of Food Engineering*, *279*(August 2019), 109958. https://doi.org/10.1016/j.jfoodeng.2020.109958

Pascua, Y., Koç, H., & Foegeding, E. A. (2013). Food structure: Roles of mechanical properties and oral processing in determining sensory texture of soft materials. *Current Opinion in Colloid and Interface Science*, *18*(4), 324–333. https://doi.org/10.1016/j.cocis.2013.03.009

Perrin, L., & Pagès, J. (2009). A methodology for the analysis of sensory typicality judgments. *Journal of Sensory Studies*, *24*(5), 749–773. https://doi.org/10.1111/j.1745-459X.2009.00237.x

Reinbach, H. C., Giacalone, D., Ribeiro, L. M., Bredie, W. L. P., & Frøst, M. B. (2014). Comparison of three sensory profiling methods based on consumer perception: CATA, CATA with intensity and Napping®. *Food Quality and Preference*, *32*, 160–166. https://doi.org/10.1016/j.foodqual.2013.02.004

Rofes, L., Arreola, V., Mukherjee, R., Swanson, J., & Clavé, P. (2014). The effects of a xanthan gum-based thickener on the swallowing function of patients with dysphagia. *Alimentary Pharmacology and Therapeutics*, *39*(10), 1169–1179. https://doi.org/10.1111/apt.12696

Ross, A. I. V., Tyler, P., Borgognone, M. G., & Eriksen, B. M. (2019). Relationships between shear rheology and sensory attributes of hydrocolloid-thickened fluids designed to compensate for impairments in oral manipulation and swallowing. *Journal of Food Engineering*, *263* (May), 123–131. https://doi.org/10.1016/j.jfoodeng.2019.05.040

Rustagi, S. (2020). Food texture and its perception, acceptance and evaluation. *Biosciences, Biotechnology Research Asia*, *17*(3), 651–658. https://doi.org/10.13005/bbra/2869

Sharma, M., Kristo, E., Corredig, M., & Duizer, L. (2017). Effect of hydrocolloid type on texture of pureed carrots: Rheological and sensory measures. *Food Hydrocolloids*, *63*, 478–487. https://doi.org/10.1016/j.foodhyd.2016.09.040

Stading, M. (2021). Physical properties of a model set of solid, texture-modified foods. *Journal of Texture Studies*, *52*((5–6)), 578–586. https://doi.org/10.1111/jtxs.12592

Tobin, A. B., Mihnea, M., Hildenbrand, M., Miljkovic, A., Garrido-Bañuelos, G., Xanthakis, E., & Lopez-Sanchez, P. (2020). Bolus rheology and ease of swallowing of particulated semi-solid foods as evaluated by an elderly panel. *Food & Function*, *11*(10), 8648–8658. https://doi.org/10.1039/d0fo01728k

Vickers, Z., Damodhar, H., Grummer, C., Mendenhall, H., Banaszynski, K., Hartel, R., … Robbins, J. (2015). Relationships among rheological, sensory texture, and swallowing pressure measurements of hydrocolloid-thickened fluids. *Dysphagia*, *30*(6), 702–713. https://doi.org/10.1007/S00455-015-9647-9

Vieira, J. M., Andrade, C. C. P., Santos, T. P., Okuro, P. K., Garcia, S. T., Rodrigues, M. I., … Cunha, R. L. (2021). Flaxseed gum-biopolymers interactions driving rheological behaviour of oropharyngeal dysphagia-oriented products. *Food Hydrocolloids*, *111*(February 2020), 106257. https://doi.org/10.1016/j.foodhyd.2020.106257

Weightman, C., Bauer, F. F., Terblanche, N. S., Valentin, D., & Nieuwoudt, H. H. (2019). An exploratory study of urban South African consumers' perceptions of wine and wine consumption: Focus on social, emotional, and functional factors. *Journal of Wine Research*, *30*(3), 179–203. https://doi.org/10.1080/09571264.2019.1652149

Withers, C., Gosney, M. A., & Methven, L. (2013). Perception of thickness, mouth coating and mouth drying of dairy beverages by younger and older volunteers. *Journal of Sensory Studies*, *28*(3), 230–237. https://doi.org/10.1111/joss.12039

Zhang, L. L., Zhao, L., Zhang, Q. B., Shi, B. L., Zhong, K., Wang, H. Y., … Liu, L. Y. (2020). The effect of the pungent sensation elicited by Sichuan pepper oleoresin on the sensory perception of saltiness throughout younger and older age groups. *Food Quality and Preference*, *86* (April), 103987. https://doi.org/10.1016/j.foodqual.2020.103987

SUPPORTING INFORMATION

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