Identification of desirable mechanical and sensory properties of bread for the elderly

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Highlights

- Italian commercial breads were evaluated by an instrumental and sensory approach
- Desirable sensory and mechanical properties of bread for the elderly were studied
- Elderly's acceptance was mainly correlated to homemade appearance and texture
- Chewiness and tasteless descriptors corresponded to poor consumers' satisfaction

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Abstract

The aim of this study was to define the desirable sensory and the mechanical properties that a bread targeting elderly consumers should have, and to understand whether the products currently present in the Italian market meet the desired requirements.

Eleven types of commercial bread having different formulations and manufacturing processes were characterized for moisture content, texture and color parameters. A rapid sensory method was used to describe and identify the key sensory attributes driving the consumers overall liking.

The results showed that the instrumental information overlaps quite well with results from the sensory evaluations. Overall, the elderly consumers reported a low acceptance for the Italian commercial breads. The sensory evaluation revealed that the ideal bread should have homemade appearance, odor and flavor of bread, crusty and crumbly texture, and be easy to swallow since these attributes were found to drive consumers' satisfaction.

In conclusion, this study will provide to bakery industry important information to re-design foods adapted to preferences of vulnerable consumers (e.g., the elderly).

Keywords:

older consumers; sensory-hedonic methods; acceptability; Check-all-that-apply; texture analysis.

1. Introduction

For the first time in history, the elderly represents a significant portion of the global population, which is growing faster than any other age group worldwide (United Nations, 2019). Due to this phenomenon, the elderly requirements for food and nutrition are demanding urgent attention (Aguilera & Park, 2016). This rising market represents a unique opportunity for the food industry.

Bread, among all bakery products, is one of the oldest staple food worldwide and a traditional product for the elderly. Bread is a source of complex carbohydrates, easily digestible starch and hence it is an important part of diet, especially in the Mediterranean area and Western Europe (Angelino et al., 2020). Bread can be produced using a variety of different cereals (e.g., wheat, maize, rice and barley) and it is available in the market in different types and formulations (Carocho et al., 2020).

Sensations perceived during bakery products consumption vary continuously because of the breakdown of food structure, releasing stimuli of different sensations (Puerta et al., 2022). Importantly, formulation and texture properties play a key role in taste and aroma perception during oral processing, which prepares food for further digestion (Gao et al., 2018; Pu et al., 2021; Puerta et al., 2020; Puerta et al., 2021). For adult consumers, the key attributes of bread are appearance, odor, flavor and texture characteristics, as well as chewing properties and freshness (Heiniö, 2006; Gellynck et al., 2009; Laureati et al., 2012). Indeed, the structure of bread crumb and crust can have an impact on mastication and consequently on bread choice, particularly by the elderly population (Jourdren et al., 2016; Gao et a., 2017; Pu et al., 2021). It is known that eating capability, which encompasses a combination of hand manipulation, oral processing, sensation, and cognition capacity, and the digestive system functionality are affected by aging (Laguna et al., 2016). Oral processing and sensory performance can be altered due to denture status, lower chewing and swallowing efficiency, and loss of chemosensory sensations. Moreover, the elderly population has specific food preferences and nutritional needs (Rémond et al., 2015). All these factors have to be taken into account in developing foods for the elderly. In particular, the physiological changes due to aging require modification of some sensory properties of foods, including bakery products, to make them acceptable by this population group. The industry, which is always looking for innovation in the bakery sector to respond consumers' requests (Boukid et al., 2020), is currently facing a challenging situation to design products with adequate nutrients without affecting familiarity and palatability (Jędrusek-Golińska et al., 2020; Morley & Flaherty, 2002). Thus, the development of a food product (*i.e.,* bread), intended to satisfy both quality and nutritional needs of a specific consumers' category (*i.e.,* the elderly), also requires information about consumers' needs and sensory expectations. Calling for an integrated approach is pivotal in order to design foods responding to specific sensory, technological and nutritional requisites (Alongi & Anese, 2021; Homem et al., 2021).

Sensory and consumer science comes up as an essential instrument to provide information for quality control, product development and improvement, as well as to obtain a sensory description to understand consumers' preferences (García-Gómez et al., 2022). Thus, various consumers-based approaches, such as internal preference mapping, intensity scales of a given attribute using the Just-About-Right scale and the choice of terms that describe the products using the Check-all-that-apply test have been currently used to obtain information on the sensory characterization of products and on the perception of how much and which sensory attributes could drive consumers' liking or disliking (Ares & Jaeger, 2015; Jaeger et al., 2020; Santos et al., 2021). However, these approaches have never been applied to define attributes of bread targeting elderly consumers.

Therefore, the aim of the present study was to define the desirable sensory and the mechanical properties that a bread targeting elderly consumers should have, and to understand whether different types of Italian breads meet the desired sensory attributes. In particular, an instrumental characterization was performed for breads' moisture content, texture and color parameters. Moreover, a rapid sensory method (*i.e.,* Check-all-that-apply questionnaire) was used to describe and identify the key sensory attributes driving the consumers overall liking. This study will provide to the bakery industry a powerful tool to design bakery products adapted to the elderly consumers' preferences.

2. Materials and Methods

2.1. Samples

Eleven types of commercial bread available in Italy, were selected among the most consumed brands. Samples having different formulations and manufacturing processes (named Sample A to K) were chosen (**Table 1**). The products were either purchased in local supermarkets or kindly provided by producers.

[Please insert **Table 1**]

2.2. Bread characterization

2.2.1. Moisture content

Moisture content of bread samples having the crumb and crust was measured according to AOAC gravimetric method (AOAC, 2000) in triplicate. Around 3.0 g of sample was dried in a vacuum oven (1.32 kPa) at 75 °C until constant weight (12 h).

2.2.2. Texture analysis

Texture was determined using a Texture Analyzer (TA.XP. Plus, Stable Micro System, Godalming, UK) and analyzed using a Texture Expert software (Stable Micro Systems, Godalming, UK). Two slices (7 x 7 cm) were stacked together for each test and subjected to a double compression test (TPA) of the crumb, with different diameter cylinder probes (12 and 36 cm of diameter) based on slice size (for samples A and B the 12 cm diameter probe was used), at 40% deformation (pre-test speed 1 mm/s, test speed 2 mm/s, post-test speed 2 mm/s, 1 g trigger force, distance 10 mm). Bread loaves (samples A and B) were sliced in order to obtain slices of equal thickness (1.2 cm) of sample F. In the case of Sample I, which differed from the other bread types because it was characterized by infinitesimal thickness and crispy texture (Table 1), a three-point bending test (compression 3 mm/s) was performed (Fois et al., 2011). At least eight measurements were taken for each bread type and the obtained textural parameters were hardness (*i.e.* the ratio of peak force of the first compression cycle (N) to the area of cylinder probe (m^2), Pa), springiness (*i.e.* the percentage ratio of the distance from the start of the second area up to the second probe reversal over the distance between the start of the first area and the first probe reversal), cohesiveness (*i.e.* the percentage ratio of positive area during the second to that of the first compression cycle), and chewiness (*i.e.* hardness (Pa) x cohesiveness x springiness, Pa) (Boukid et al., 2018).

2.2.3 Color

A tristimulus Chromameter-2-Reflectance colorimeter (Minolta, Osaka, Japan) with a CR-300 measuring head, standardized against a white tile, was used and data were expressed in CIE units as L* (lightness/darkness), a* (redness/greenness) and b* (yellowness/blueness) (Clydesdale, 1978). Bread slices, which were prepared using the same procedure applied for texture analysis, were positioned on a white cardboard, and the colorimeter head was placed perpendicular to sample surface. At least ten measures were taken on different points of bread crumb and crust samples. The parameters a* and b* were used to compute the hue angle (Eq 1) (Clydesdale, 1978):

$$\text{Hue angle} = tan^{-1}\frac{b^*}{a^*} \qquad \text{Eq 1}$$

Yellow index (YI) was calculated following Eq 2 (Pagliarini et al., 2010):

$$YI = \frac{b^*}{L^*} \times 142.86 \qquad \text{Eq 2}$$

2.2.4. Image acquisition

Bread images were acquired using an image acquisition cabinet (Immagini & Computer, Bareggio, Italy) equipped with a digital camera (EOS 550D, Canon, Milano, Italy). Light was provided by 4 100 W frosted photographic floodlights, in a position allowing minimum shadow and glare.

2.3. Consumer testing

2.3.1. Subjects

Seventy-six healthy active older adults (37 males and 38 females) were recruited through social networks, leaflet, word of mouth and among professors and workers from the Department of Food, Environmental and Nutritional Sciences (University of Milan, Italy) and Department of Agricultural, Food, Environmental and Animal Sciences (University of Udine, Italy). Age, gender, reported height and weight (which were used to calculate the body mass index (BMI) as $kg\cdot m^{-2}$) of subjects were collected. The subjects were 60–75 years old (mean age ± SD = 63.3 ± 3.1), and mainly normal-weight (mean BMI ± SD = 24.2 ± 3.8 $kg\cdot m^{-2}$).

The following inclusion criteria were met: i) good general health; ii) no more than two missing teeth; iii) no mastication or salivation problems. A subject who met any of the following criteria was excluded from participation in this study: i) have any food allergy or intolerance to gluten; ii) have mastication and/or swallowing difficulty caused by neurological problems (*i.e.,* stroke, Parkinson, Alzheimer, Huntington); iii) use medication that may affect the functions of taste, smell, mastication and salivation.

All the subjects that took part in this study were previously informed on the details of the study and about the risks involved in participation. All participants were required to give a written informed consent. The study complied with the principles established by the Declaration of Helsinki and the protocol was approved by the Institutional Review Board of the Department of Agricultural, Food, Environmental and Animal Sciences of the University of Udine (protocol n. 0001520). Cash incentives were not provided.

2.3.2. Terms' generation

A pilot test was conducted with the aim of developing a free listing questionnaire of bread attributes, involving a separate group of 20 adult participants (30-50 years old) in presence of a researcher. The inclusion and exclusion criteria were the same as previously mentioned except for the age range. The subjects were provided with bread samples and were asked to consider their appearance, odor, taste, flavor, texture properties and chewing properties (*e.g.,* hard to chew, hard to swallow). If needed, examples were provided to clarify the task, for instance the meaning of flavor, odor or texture. Subjects were asked to write the terms they considered good descriptors of the sensory attributes of each sample. Subsequently, a list of sensory attributes based on literature data (Callejo, 2011) was provided to the subjects for comparison with their own list, and participants were asked to add missing attributes, if appropriate.

In a following session, the list of terms was finalized. When several terms pointed were synonymous, the most common word was selected (Jaeger et al., 2015). Only the terms reported by at least 20% of subjects were included in the final list (**Supplemental Table S1**), which comprised a suitable number of sensory attributes (n=36; Ares & Jaeger, 2015; Jaeger et al., 2015).

2.3.3. Samples' presentation

A slice of each bread sample, comprising crust and crumb, cut approximately 5 min before tasting was presented to the subjects in a plastic plate labelled with three-digit codes. It was suggested that the subjects only took two bites of each sample. Sample presentation order followed a complete block design balanced for carry-over and position effects. Still mineral water was provided to the subjects to clean their palate between evaluations.

2.3.4. Overall liking assessment and Check-all-that-apply questionnaire

Testing was conducted at two locations (*i.e.,* University of Udine and University of Milan) simultaneously, along different days of the same week at the same time (11:30–13:30). The evaluation took place in standard sensory booths under artificial daylight type illumination, temperature control (22–24 °C) and air circulation. Subjects were asked to refrain from consuming anything but water for 2 h before the evaluation.

In a single session, older subjects were first asked to score their texture liking using a Visual Analogue Scale (VAS), anchored by the extremes "extremely disliked" (rated 0) and "extremely liked" (rated 10). Next, they completed a Check-all-that-apply questionnaire format comprising 36 terms related to sensory characteristics of bread, as defined in the pilot test (**Supplemental Table S1**). The position of attributes in the list was randomized using the "to assessor" list order allocation scheme, meaning the attributes are listed in the same order within subject and in a different order between subjects (Meyners & Castura, 2016). Subjects were asked to check all the terms they consider appropriate to describe each sample. After evaluating all bread samples, participants received the same questionnaire and were asked to select the attributes that an ideal bread should have. They were free to think about any type of bread.

2.4. Data analysis

Results of chemical and physical determinations were expressed as mean ± standard deviation (SD). Statistical analysis was performed by using R v. 3.6.2. for Windows (The R foundation for statistical computing). Welch's t-test was carried out and Tukey's Honest Significant Difference test was used to determine statistically significant differences among means (p < 0.05). Pearson's coefficients correlations were conducted to analyze the relationship between moisture and the texture parameters. Differences in the overall liking scores were assessed by analysis of variance (ANOVA), which was performed considering sample as fixed source of variation and consumer as a random effect. Post hoc comparison (Tukey's Honest Significant Difference test) was used to compare the samples means.

For the Check-all-that-apply questionnaire, the frequency of use of each sensory attribute was determined by counting the number of consumers that used that term to describe each sample. Cochran's Q test was carried out to identify significant differences between samples for each of the terms included on the questionnaire. When the Cochran's Q test was positive (p < 0.05), a minimum required difference for a significant difference between two proportions was calculated (Sheskin, 2011) and a table was displayed showing which of the proportions were significantly different from the others.

Correspondence analysis (CA) was used to get a bi-dimensional representation of the samples and the relationship between samples and terms from the Check-all-that-apply questionnaire. This analysis was performed on the frequency table containing the samples in rows and the terms from the questionnaire on the columns, considering liking as supplementary variables. The ideal product was considered as other supplementary variable in the analysis.

Penalty analysis was carried out on consumer responses to determine the drop in overall liking associated with a deviation from the ideal for each attribute from the Check-all-that-apply questionnaire.

In order to identify consumer segments with different preference patterns, a hierarchical cluster analysis was performed on the overall liking scores using Euclidean distances and Ward's method of aggregation (Næs, Brockhoff, & Tomic, 2010). Based on the shape of the dendrogram, two-cluster solutions were retained. To confirm that the derived consumer segments had different patterns of product liking and disliking, ANOVA was performed on overall liking scores considering segment, sample and their interaction as fixed sources of variance. When significant effects were established, Tukey's test was used for post-hoc comparison of means. Differences related to gender within clusters were analyzes using the chi-square test. Differences related to age and BMI within clusters were analyzed using the ANOVA. In addition, for each consumer segment differences in the sensory description of the samples were evaluated using Cochran's Q test. CA was used to investigate the relationship between responses to the questionnaire of the two consumer groups identified in the cluster analysis.

3. Results and discussion

3.1. Bread characterization

Different types of bread were characterized for moisture content, texture, and color (**Table 2** and **Supplemental Table S2**). As well known, moisture content is an important bread feature and a key parameter that influences bread liking. **Table 2** shows the moisture content of bread samples having different formulation (**Table 1**). Moisture content ranged from 29 to 37%, except for Sample I, a typical bread of Sardinia region, which is characterized by a crunchy structure, that had the lowest value (7.9%). **Table 2** also shows the textural parameters of bread (hardness, springiness, cohesiveness and chewiness). Hardness, which represents the force the teeth have to apply on the food during the first mastication, ranged from 2020 to 42376 Pa, in agreement with literature data (Di Monaco et al., 2008; Fois et al., 2011). Rye bread (sample H) was the hardest bread with the highest content of moisture, probably due to the presence of rye in the formulation (Carocho et al., 2020), followed by *Sfilatino* bread and Burger bread (samples A and B), while Sardinia bread (sample I) was the least hard. According to these results, it can be concluded that differences in this parameter can be attributable to the formulation as well as to the processing. Springiness is the time it takes for the food to recover from deformation during unloading, while cohesiveness represents the degree to which a food can be deformed before it breaks (Di Monaco et al., 2008, Alvarez, Canet, & López, 2002). Although some differences were observed among the samples, all types of bread showed very low springiness and cohesiveness values, in agreement with the literature (Carocho et al., 2020). Also, chewiness, which is related to the capacity that the sample structure is changed from chewable to swallowable (Chandra & Shamasundar, 2015 Gong et al., 2020), showed significant differences among bread samples. The highest chewiness value was observed for Rye bread (sample H), which was the hardest bread and required more energy to be eaten (Carocho et al., 2020). No correlations were found between moisture and the texture parameters ($p > 0.05$).

[please insert **Table 2**]

Color is another important feature of bread. L*, hue angle and YI values of breads' crumb and crust were analyzed (**Supplemental Table S2**). L* values ranged from 55 to 82 for crumb and from 41 to 79 for crust. Among the breads, Rye bread (sample H) was the darkest one with the presence of yellow color (the highest YI crumb value). As expected, hue angle values of samples crusts were higher than those of crumbs, indicating the occurrence of brown Maillard reaction products on breads surface. Moreover, sample H showed the lowest hue angle values for both crumb and crust (74. 6 ± 1.1 and 42.3 ± 4.3, respectively), indicating a high brown color level, which can be mainly attributable to the use of rye flour. On the contrary, Sardinia bread crust (sample I) presented the highest value that might be associated to the baking process. The latter is generally carried out at high temperature for short time, which allows rapid moisture evaporation while preventing excessive brown colour development (Fois et al., 2011).

3.2. Consumer testing

Significant differences ($F = 7.2$; $p < 0.001$) in the overall liking of the evaluated bread samples were found. As depicted in **Figure 1**, mean liking scores were low, ranging from 3.8 (SD = 2.6) to 6.4 (SD

= 2.5). According to their mean overall liking score, samples were sorted into two groups. Samples A, B, C and I (most preferred) showed an overall liking score higher than 5, which represented the middle of the scale and has been defined as limit for consumers' acceptability. The other samples showed overall liking scores lower than 5, indicating a negative hedonic attitude. In particular, samples E and J were the least preferred by consumers.

[Please insert **Figure 1**]

Overall, these results showed that more than half of the products remained below the acceptability score of 5.0 in a VAS (0-10). This unexpected result can be attributed to the fact that most of the evaluated breads (samples D, E, F and G) were sandwich breads, which are generally appreciated and consumed after being toasted or with spreads and in combination with other foods. Toasting has been shown to modify positively the sensory properties of breads by increasing crunchiness, firmness and crumbliness (Aleixandre et al., 2021). Thus, the consumption habits may have influenced the hedonic scores.

As known, Check-all-that-apply questionnaire captures consumers' perception of food products, by asking consumers to check all the appropriate terms that describe each sample from a given list (Ares et al., 2014). It is a valid, rapid, and consumer-friendly method to gather information about sensory and non-sensory properties of a product.

Significant differences ($p \leq 0.05$) in the frequency with which 34 out of the 36 terms of the questionnaire were used to describe the bread samples suggesting that consumers perceived differences in the sensory characteristics of the evaluated samples (**Table 3**). The subjects described their ideal bread as homemade, with a porous and soft crumb and a crusty and dark colored crust, characterized by a typical odor and flavor of bread, and easy to chew and swallow.

It is interesting to note that the instrumental and sensory evaluations showed a good agreement (Ares et al., 2014). Indeed, the darkness of the crust and crumb was selected 64 and 69 times for the Rye bread (sample H), in agreement with L* and hue angle parameters (**Supplemental Table S2**). As well, this sample presented the highest moisture content (39.1% ± 0.7) and the term moistness was frequently selected by consumers. For sample I (Sardinia bread), dryness and crumbliness were selected 56 and 45 times, respectively, in agreement with the lowest moisture content (7.9% ± 0.2) and lowest hardness (2020 ± 464 Pa) measured. However, consumers have described this bread as the hardest one, and hardness is the only parameter that did not match between instrumental and sensory analyzes. This mismatch could be due to the fact that participants who took part in the study were not trained judges and may have associated the characteristics of crunchiness, crispness and dryness with the hardness of the product. The sample F, one of the sandwich breads, was characterized with the highest springiness (0.93% ± 0.01) and thereby springiness was more often selected (24 times) than for the other breads (**Table 2**).

[Please insert **Table 3**]

In order to determine differences in sensory properties among the commercial breads, a multiple pairwise comparison using the Critical difference of the Sheskin procedure (Sheskin, 2011) was computed. The main differences highlighted by the multiple pairwise comparisons ($p < 0.05$) were summarized below.

As for the appearance characteristics, most of the products were found to be very similar. The product that has distinguished itself the most was sample H (rye bread), which was found to be the firmest with the darkest crust and crumb. Moreover, this sample presented marked fermented odor and flavor, while the flavor of bread was slightly perceived. Sandwich breads, in particular samples D and G, differed from the others for their characteristic alcoholic odor and flavor, likely due to the lower degree of porosity and the surface aspersion with ethyl alcohol during manufacturing to prevent mold growth.

Regarding the taste characteristics, Tuscan and Bruschetta breads (samples J and K) resulted as the most tasteless. Based on the nutrition fact, sample J actually had the least amount of salt (0.09 g per 100 g of product), while the latter had a high salt content (1.8 g per 100 g of product) which was not perceived. Older active consumers perceived as the saltiest samples the durum wheat loaf (sample C) and Sardinia bread (sample I) and, in this case, the nutrition labels confirmed the results, in particular for sample I which was the bread with the highest salt content (2.0 g per 100 g of product). The sweet taste particularly characterized the Burger bread (sample B) and sandwich bread (sample G), with the latter that appeared to be the product with more simple sugars (9.5 g per 100 g of product) partly due to the addition of sugar in the formulation (4.2%). Once again, sample H (rye bread) stood out among all samples for being the sourest and the most bitter by far, due to rye flour as the main ingredient, sodium acetate as an acidity regulator, and sorbic acid as a preservative.

Finally, the multiple comparison test found that almost all bread samples were very similar in texture, and therefore they were defined as springy, chewy and particularly soft. The only sample that differed in consistency was Sardinia bread (sample I), which was characterized for its crustiness, crumbliness, dryness and hardness. In general, all the samples were evaluated as easy to chew and easy to swallow.

Correspondence analysis (CA) was used to get a bi-dimensional representation of the samples and the relationship between samples and terms from the questionnaire (**Figure 2**). The first and second dimensions of the CA accounted for 75.5% of the variance of the experimental data, representing 47.5% and 28.0% of the variance, respectively.

[Please insert **Figure 2**]

According to their sensory characteristics, samples were placed into four main groups of bread. A first group, composed only of Sardinia bread (sample I), was located at positive values of the first and second dimension, being mainly characterized by their crustiness, crumbliness, dryness and hardness. Rye bread (sample H) was located at negative values of the first dimension and positive values of the second dimension. It was characterized by moistness, sourness, bitterness, darkness of crust and crumb and characterized by fermented odor and flavor, which could be explained by the fact that this sample was prepared by using sour sourdough and rye flour (**Table 1**). Tuscany and Bruschetta breads (samples J and K) were described as homemade, heterogeneous, firm and with a typical bread's odor and flavor. The last group, which included *Sfilatino*, Burger, Durum wheat loaf and Sandwich breads (samples A, B, C, D, E, F, G), was located at negative values of the second dimension, and breads were characterized by adhesiveness, springiness, doughiness, chewiness, softness, sweetness, with a characteristic alcoholic odor and flavor due to the treatment with ethyl alcohol on the surface.

As shown in **Figure 2**, the ideal bread was characterized by the terms heterogeneous, homemade, saltiness and with odor and flavor of bread. The ideal product was positioned in-between samples I (Sardinia bread), which showed the highest liking scores, and K (Bruschetta bread), which presented some of the sensory characteristics desired by consumers even if it was not so appreciated because tasteless (**Table 2**). These results seem to be related to the physiological changes of the elderly. Chewing problems are accentuated in the case of a chewy bread which requires more time and more energy before swallowing (Laguna & Chen, 2016). On the contrary, a crispy product breaks easily during chewing. The reduction of the sense of taste and smell with advancing age could lead the elderly to prefer salty breads with more intense smell and flavor (Laureati et al., 2006). Analogously, a crunchy texture seems to be preferred because of the weakening of the sensory perception (Laguna & Chen, 2016). Finally, the predilection of this target population for traditional and family products (Laureati et al., 2006) could have led to preferring rustic and homemade breads, such as Bruschetta bread (sample K).

3.2.1 Drivers of liking and disliking

The penalty analysis was performed to obtain information about the impact of deviation from the ideal product on liking scores. A graphical representation of the differences between observed and ideal products and their impact on associated liking scores are depicted in **Figure 3,** wherein the mean drop chart shows the attributes with a significant mean impact on overall liking.

[Please insert **Figure 3**]

The 'must have' attributes (displayed in blue) were those chosen by a large number of consumers for the ideal product, but were missing in the actual products, thus showing a highly significant positive impact on the overall liking scores (Meyners, Castura & Carr, 2013). On the contrary, the 'must not have' attributes (displayed in red) represented the percentage of respondents describing the commercial products positively but relatively unchecked for the ideal product, implicating a highly significant negative impact on the overall liking scores (Meyners, Castura & Carr, 2013). For the consumer, the key attributes of bread were flavor and texture (Heiniö, 2006), which along with chewing properties, dramatically influenced the overall perception of bread. A homemade appearance, the odor and flavor of bread, a crusty and crumbly texture, and the easiness in swallowing were the attributes that drove consumer satisfaction, increasing liking by up to 2 points on the hedonic scale when present compared to being absent. Conversely, chewiness and tasteless corresponded to poor consumers' satisfaction.

3.2.2 Cluster analysis based on overall liking scores

Cluster analysis on overall liking scores enabled the identification of two consumer segments with different preference patterns. The interaction *cluster × samples* showed a significant effect (F = 2.5; $p < 0.01$) on liking scores. Cluster 1 accounted for the majority of the consumers (n = 51, 67%), who clearly gave higher liking scores to all samples. Sardinia bread (Sample I), *Sfilatino*, Burger, durum wheat loaf and sandwich breads (samples A, B, C and F) were the most accepted breads. On the contrary, the remaining 25 consumers (33% of the total group of consumers) that composed Cluster 2 preferred only the sample I, whereas they disliked all the other samples (**Figure 4**). No gender-related ($\chi^2 = 1.9$; p = 0.2), age-related (F = 0.2; p = 0.9) or BMI-related (F = 0.9; p = 0.3) differences were found between the two clusters.

[Please insert **Figure 4**]

Significant differences ($p < 0.05$) were found in the frequency with which all the terms included in the Check-all-that-apply questionnaire were used by the two clusters to describe the bread samples, suggesting that consumers grouped in the two clusters perceived large differences in the sensory characteristics of the evaluated products. Indeed, Cluster 1 significantly used 34 out of the 36 terms of the questionnaire to describe the bread samples (non-discriminating attributes with $p > 0.05$): alcoholic flavor and hard to swallow), while Cluster 2 significantly used 27 out of the 36 terms and, in particular, did not highlight any significant difference in the terms related to chewing properties (non-discriminating attributes with $p > 0.05$: yeasty odor and flavor; bread flavor, alcoholic flavor, chewiness, easy to chew/swallow and hard to chew/swallow).

Sample representation in the first and second dimensions of the CA showed the disposition of breads, attributes used to describe them and liking according to both consumer clusters (**Figure 5**). Despite the sensory maps of the samples and their general description being quite similar, the clusters differed in the position of their ideal bread, in the number of terms used and how they used them to describe the samples. Indeed, the ideal product for Cluster 1 was positioned in-between samples I (Sardinia bread) and K (Bruschetta bread), quite similar to the representation obtained when considering the total group of consumers. On the contrary, the ideal bread for Cluster 2 is only represented by the most liked sample (Sardinia bread). Distinct drivers of liking and disliking were identified depending on the cluster considered. In particular, the homemade appearance along with the aroma (*i.e.,* bread odor) and texture characteristics (*i.e.,* crumbliness and crustiness) had positive impact on Cluster 2 consumers' liking, whereas the whiteness of crust and crumb negatively influenced their hedonic judgment. Moreover, as reported above the chewing properties did not affect the liking score provided by the consumers belonging to this cluster, neither positively nor negatively. Thus, the must have/must not have attributes identified will not satisfy both groups of consumers in the same way. However, because the two cluster did not differ in terms of age and gender or BMI distribution, further studies are warranted to determine which factors, such as taste perception, eating behavioral attitudes or the consumption habits, could be involved in driving the different consumers' hedonic responses.

[Please insert **Figure 5**]

4 Conclusions

The combination of a rapid descriptive sensory method and instrumental analyses was useful to obtain feasible indications for Italian bread producers. Based on the results of this study, the characteristics to be kept under control for the development of a bread targeting the elderly should be a homemade appearance, the odor and flavor of bread, crusty and crumbly texture and the easiness in swallowing, which were the attributes that drove consumers' satisfaction. The darkness, porosity and softness of the crust did not affect liking and, therefore, are scarcely relevant. Knowing these key attributes will allow the food companies and experts in the field to make more accurate reformulations, which lead to cost savings, and to build up tailor-made marketing strategies for bakery product development.

For future perspectives, due to the young age of the elderly panel involved in the present study, it would be interesting to repeat the study with older subjects to assess whether differences in the desirable sensory characteristics are observed with advancing age.

Acknowledgements

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Conflict of Interest

All authors declare that no conflict of interest exists in the conduct and reporting of this research.

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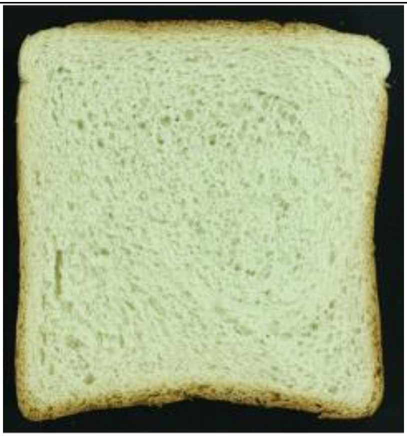
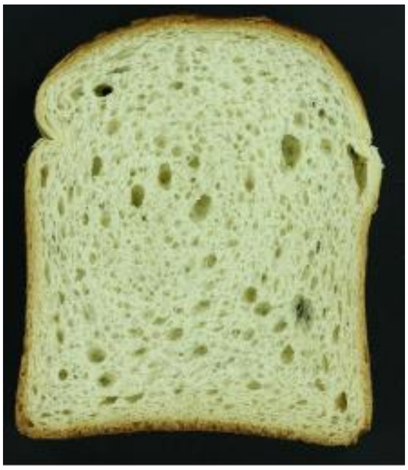
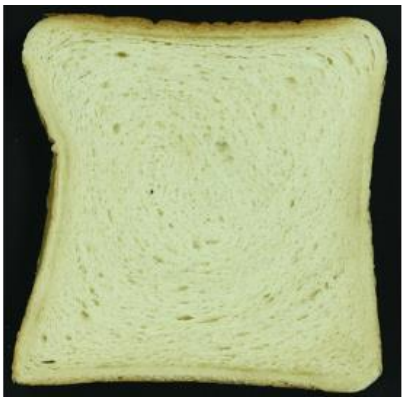
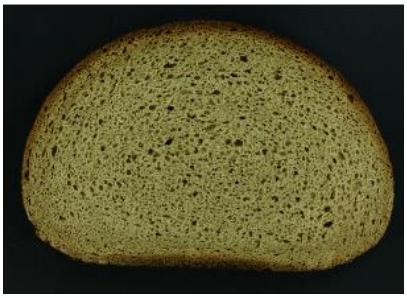
Table 1. Appearance and formulation of different types of bread.

Sample	Appearance	Ingredients
Sample A – *Sfilatino* bread		Common wheat flour type 0 (67.8%), Water, Yeast, Sunflower oil (3.1%), Dextrose (1.5%), Gluten, Salt, Re-milled durum wheat semolina, Dry sourdough (1.1%), Emulsifiers: mono and diglycerides of fatty acids, Malted barley flour Treated with ethyl alcohol on the surface
Sample B – Burger bread		Common wheat flour type 0 (67.0%), Water, Sugar, Sunflower oil (3.2%), Yeast, Emulsifiers: mono and diglycerides of fatty acids, Gluten, Salt, Malted barley flour Treated with ethyl alcohol on the surface
Sample C- Durum wheat loaf		Re-milled durum wheat semolina (64.3%), Water, Sourdough (8.2%), Yeast, Extra virgin olive oil (2.4%), Salt, Common wheat flour type 0 Treated with ethyl alcohol on the surface
Sample D – Sandwich bread		Common wheat flour type 0 (64.9%), Water, Sourdough (15.6%), sunflower oil (3.2%), Salt, Yeast, Malted barley flour, Gluten Treated with ethyl alcohol on the surface

Sample E – Sandwich bread		Common wheat flour type 0 (70.8%), Water, Sunflower oil (3.4%), Dextrose (3.4%), Yeast, Salt, Malted barley flour, Barley and corn malt extract Treated with ethyl alcohol on the surface
Sample F – Sandwich bread		Common wheat flour type 0 (70.6%), Water, Extra virgin olive oil (2.4%), Yeast, Salt, Sugar, Malted barley flour Treated with ethyl alcohol on the surface
Sample G – Sandwich bread		Common wheat flour type 0 (66.8%), Water, Sugar (4.2%), Extra virgin olive oil (2.6%), Yeast, Salt Treated with ethyl alcohol on the surface
Sample H – Rye bread		Common wheat flour type 0, Sour sourdough (15.5% rye flour in the finished product, water), rye flour (21.0%), Water, Yeast, Salt, Acidity regulators: Sodium acetates, Preservatives: Sorbic acid, Natural flavoring Treated with ethyl alcohol on the surface

Sample I – Sardinia bread		Durum wheat semolina, Brewer's yeast, Water, Salt
Sample J – Tuscany bread		Common wheat flour type 0, Water, Suet, Yeast, Malted barley flour, Aromas, Emulsifiers: E472, Dextrose, Preservatives: Calcium propionate
Sample K – Bruschetta bread		Common wheat flour type 0, Water, Non-hydrogenated vegetable oils (1.5%): sunflower oil, palm oil, coconut oil, Salt, Brewer's yeast, Extra virgin olive oil, aromas

Table 2. Moisture content and texture of different types of bread.

Sample	Moisture content (%)	Hardness (Pa)	Springiness (%)	Cohesiveness (%)	Chewiness (Pa)
Sample A	29.7^{b} ± 0.6	16673^{b} ± 1602	0.86^{b} ± 0.02	0.67^{bc} ± 0.02	9509^{b} ± 981
Sample B	29.4^{b} ± 0.3	13885^{c} ± 1806	0.76^{c} ± 0.02	0.59^{d} ± 0.03	6415^{c} ± 661
Sample C	33.2^{c} ± 0.6	4451^{f} ± 504	0.92^{a} ± 0.01	0.73^{a} ± 0.03	2880^{f} ± 336
Sample D	37.1^{e} ± 0.2	7808^{e} ± 362	0.88^{ab} ± 0.06	0.60^{ab} ± 0.06	4289^{e} ± 151
Sample E	30.4^{b} ± 0.2	7153^{ef} ± 1025	0.88^{ab} ± 0.02	0.71^{ab} ± 0.03	4431de ± 356
Sample F	32.8^{c} ± 0.1	7769^{e} ± 415	0.93^{a} ± 0.01	0.72^{ab} ± 0.03	5105de ± 195
Sample G	32.2^{c} ± 0.3	7082^{e} ± 1031	0.65^{d} ± 0.04	0.55^{de} ± 0.06	2504^{f} ± 299
Sample H	39.1^{f} ± 0.7	42376^{a} ± 4214	0.89^{ab} ± 0.02	0.52^{e} ± 0.03	19715^{a} ± 1165
Sample I	7.9^{a} ± 0.2	2020^{g} ± 464	-	-	-
Sample J	35.1^{d} ± 0.4	9250de ± 1274	0.90^{ab} ± 0.02	0.69^{ab} ± 0.06	5692^{cd} ± 615
Sample K	34.4^{d} ± 0.7	10765^{d} ± 2308	0.72^{c} ± 0.07	0.55^{de} ± 0.04	4231^{e} ± 937

Data points Means ± SD; $^{a–f}$ in the same column, means indicated by different letters are significantly different ($p < 0.05$).

Table 3. Frequency mention of sensory attributes associated with each commercial bread by active older adults (n=76) to describe the eleven bread samples and the ideal one

	IDEAL	A	B	C	D	E	F	G	H	I	J	K
Homogeneous ***	16	43	43	30	64	41	42	40	47	40	21	30
Heterogeneous ***	25	9	4	15	1	10	6	11	6	12	29	16
Darkness of the crust ***	41	8	23	40	0	17	16	38	64	0	46	28
Whiteness of the crust ***	13	57	33	18	19	35	41	23	0	28	14	32
Darkness of the crumb ***	8	1	0	3	0	1	1	3	69	1	4	2
Whiteness of the crumb ***	39	66	65	58	66	64	57	61	2	5	54	65
Firmness ***	8	17	28	13	45	35	19	39	62	45	9	27
Porosity ***	41	32	33	43	11	21	35	15	15	1	48	38
Homemade ***	46	9	13	28	0	6	5	2	28	27	32	41
Yeasty (O)**	10	15	18	15	9	11	18	17	15	2	14	20
Alcoholic (O)***	0	8	8	17	22	16	15	18	12	0	3	5
Fermented (O)***	3	9	7	8	11	7	12	12	40	2	25	6
Bread (O)***	64	33	28	32	11	22	21	15	13	30	19	27
Saltiness ***	34	9	4	14	4	10	9	6	11	20	0	10
Sweetness ***	11	21	49	25	30	21	26	51	11	5	18	10
Bitterness ***	1	4	5	2	2	2	1	1	16	2	13	5
Tasteless ***	10	22	10	18	27	26	23	13	6	21	53	45
Sourness ***	1	6	6	5	4	6	5	4	41	1	8	8
Bread (F)***	57	21	29	28	20	19	30	16	6	34	20	23
Yeasty (F) n.s.	13	16	13	15	8	9	13	6	13	5	8	13
Alcohol (F)**	0	3	9	10	12	11	5	14	7	1	4	7
Fermented (F)***	3	5	3	6	9	5	5	11	42	1	12	6
Softness ***	41	59	59	53	53	47	47	52	31	2	32	27
Hardness ***	4	0	0	0	0	1	2	0	3	23	3	2
Dryness ***	7	3	3	4	1	20	8	2	4	56	18	24
Moistness ***	8	17	16	16	29	10	15	14	36	1	6	5
Doughiness ***	9	36	33	34	36	28	34	34	37	0	27	30
Adhesiveness ***	0	17	12	12	19	21	12	21	7	1	12	18
Crustiness ***	42	0	0	0	0	0	2	0	0	70	1	0

Springiness ***	12	18	20	13	22	11	24	19	11	2	7	4
Chewiness ***	3	25	23	22	27	25	22	26	21	1	11	12
Crumbliness ***	19	5	3	1	1	6	4	2	4	45	13	11
Easy to chew ***	54	63	61	50	58	53	62	49	55	46	50	46
Hard to chew [n.s.]	2	5	1	7	2	5	3	4	4	10	6	8
Easy to swallow **	53	40	51	46	41	37	43	38	37	37	30	32
Hard to swallow *	1	13	7	10	14	15	8	15	15	12	14	24

[n.s.] non-significant difference according to Cochran's Q test. Significant difference for *$p < 0.05$. **$p < 0.01$. *** $p < 0.001$.

Figure 1

Click here to access/download;Figure;Figure 1.png

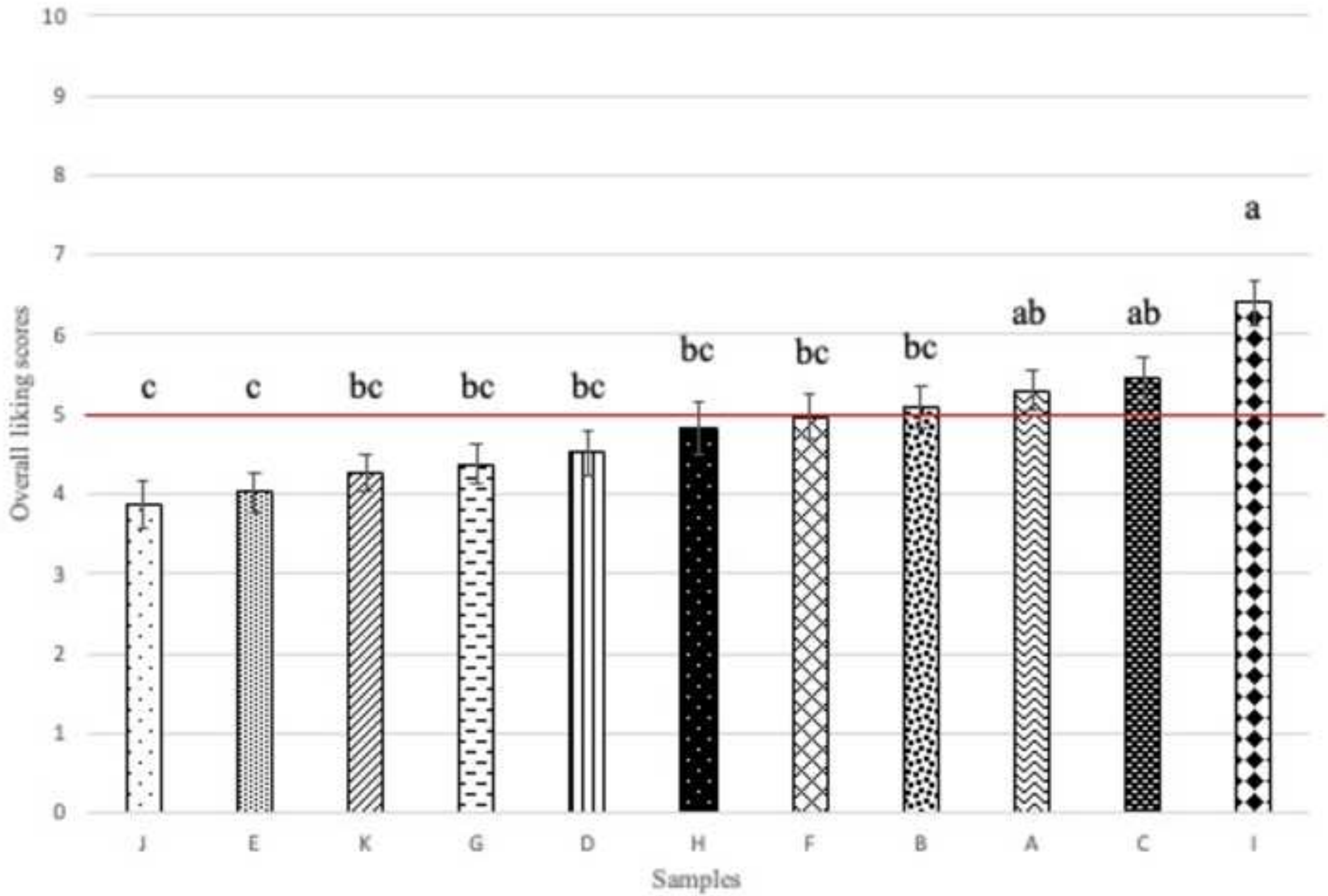
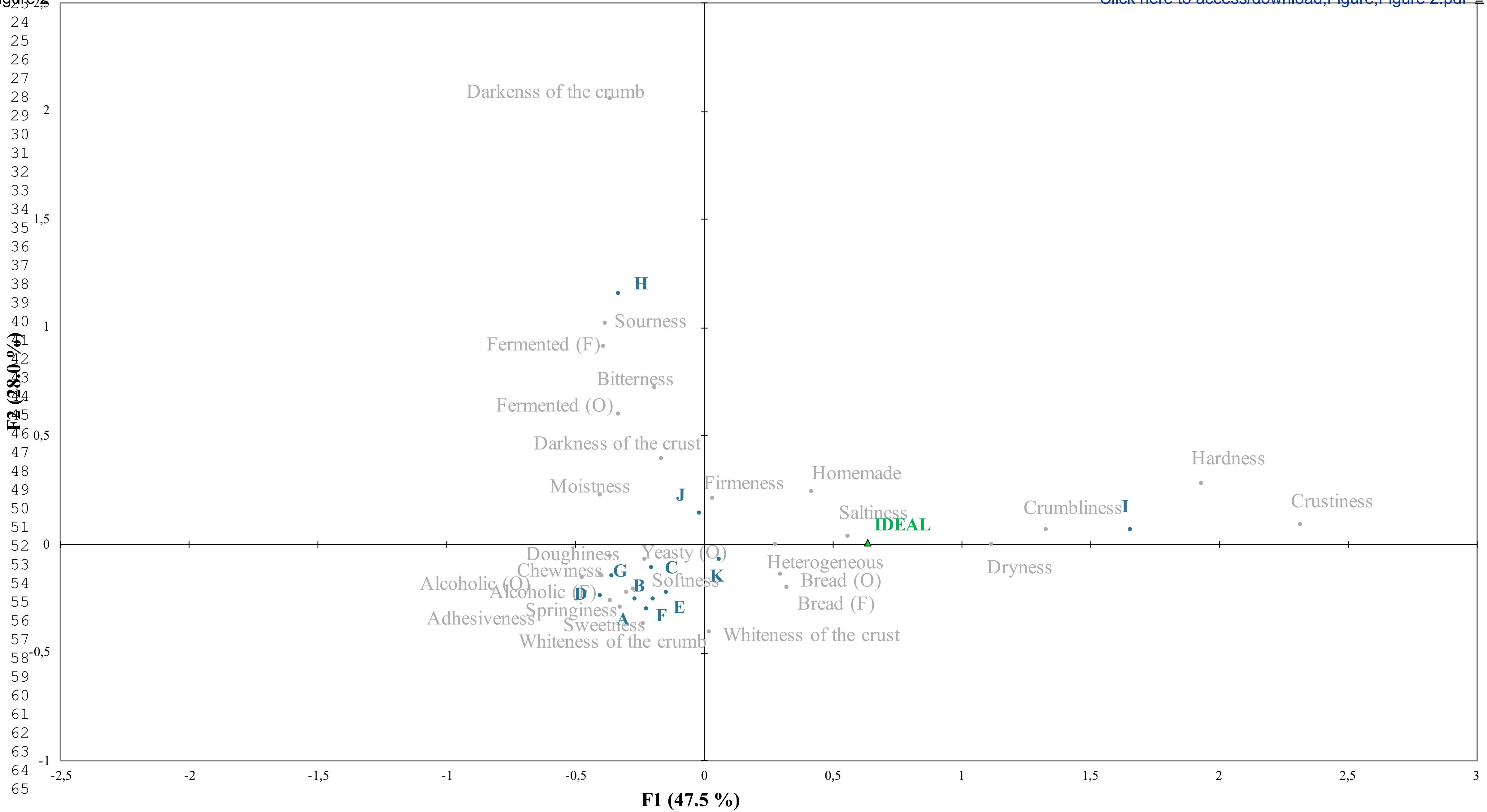
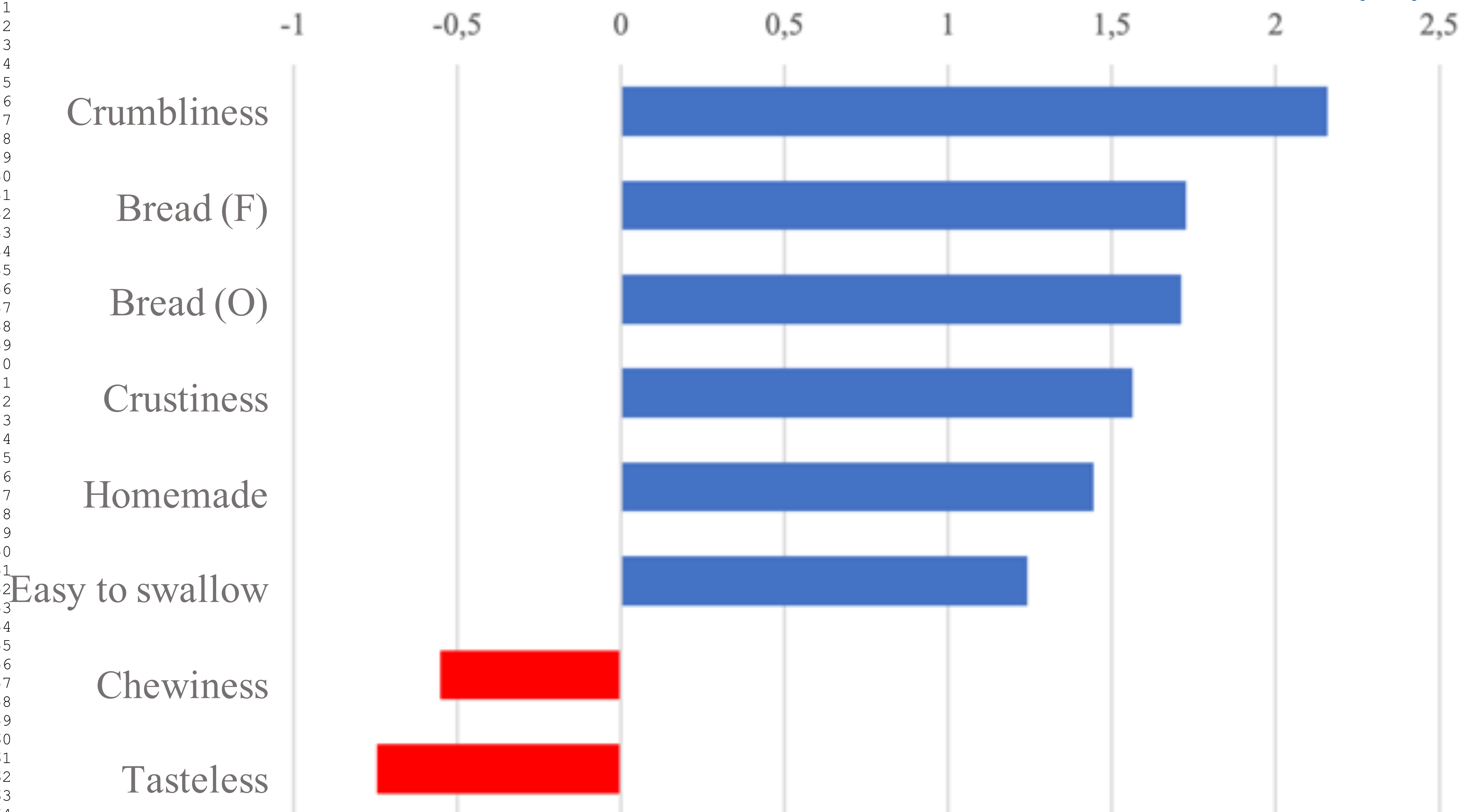


Figure 2



F2 (28.0 %)
F1 (47.5 %)
2,5
2
1,5
1
0,5
0
-0,5
-1
-2,5
-2
-1,5
-1
-0,5
0
0,5
1
1,5
2
2,5
3
Darkenss of the crumb
H
Sourness
Fermented (F)
Bitterness
Fermented (O)
Darkness of the crust
Moistness
J
Firmeness
Homemade
Hardness
Crumbliness
I
Crustiness
Saltiness
IDEAL
Doughiness
Yeasty (O)
Chewiness
G
C
K
Softness
Alcoholic (O)
Alcoholic (F)
B
D
Springiness
E
F
A
Adhesiveness
Sweetness
Whiteness of the crumb
Whiteness of the crust
Heterogeneous
Bread (O)
Bread (F)
Dryness

Figure 3


-1
-0,5
0
0,5
1
1,5
2
2,5
Crumbliness
Bread (F)
Bread (O)
Crustiness
Homemade
Easy to swallow
Chewiness
Tasteless

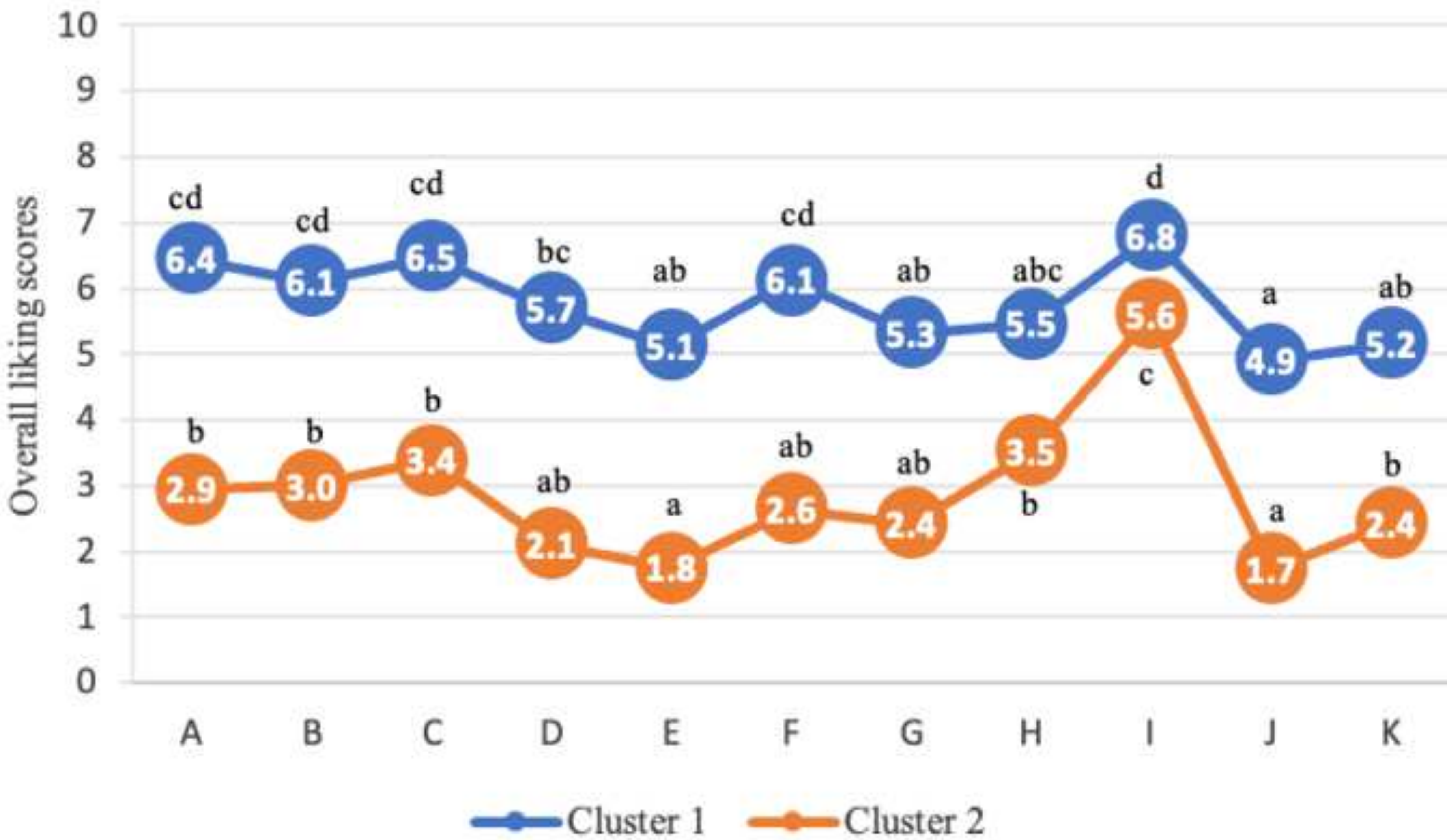

10
9
8
7
6
5
4
3
2
1
0
Overall liking scores
cd
cd
cd
bc
ab
cd
ab
abc
d
a
ab
6.4
6.1
6.5
5.7
5.1
6.1
5.3
5.5
6.8
4.9
5.2
b
b
b
ab
a
ab
ab
b
c
a
b
2.9
3.0
3.4
2.1
1.8
2.6
2.4
3.5
5.6
1.7
2.4
A
B
C
D
E
F
G
H
I
J
K
Cluster 1
Cluster 2

Figure 5

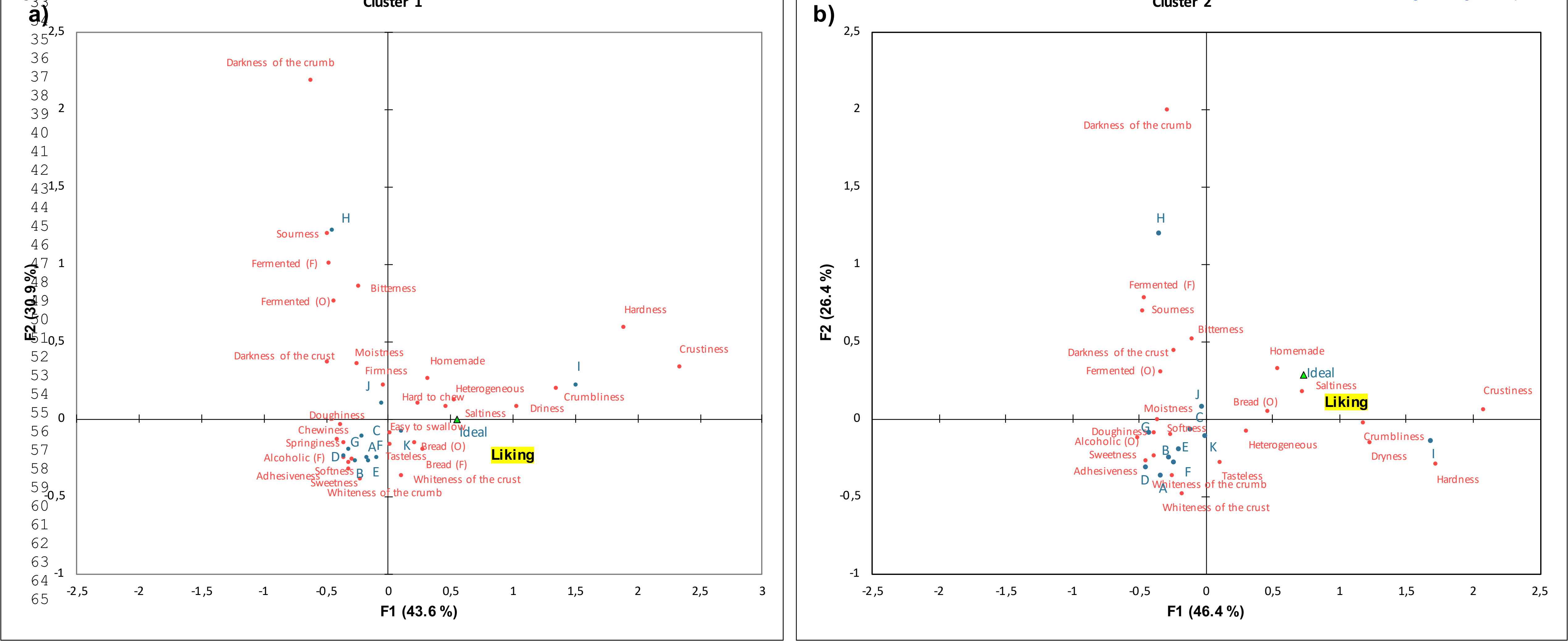

a)
Cluster 1
F1 (43.6 %)
F2 (30.9 %)
Darkness of the crumb
H
Sourness
Fermented (F)
Bitterness
Fermented (O)
Hardness
Crustiness
Darkness of the crust
Moistness
Homemade
Firmness
I
J
Heterogeneous
Hard to chew
Crumbliness
Driness
Doughiness
Saltiness
Chewiness
Easy to swallow
C
Ideal
Springiness
G
AF
K
Bread (O)
Liking
Alcoholic (F)
D
Tasteless
Bread (F)
Softness
B
E
Adhesiveness
Sweetness
Whiteness of the crust
Whiteness of the crumb
b)
Cluster 2
F1 (46.4 %)
F2 (26.4 %)
Darkness of the crumb
H
Fermented (F)
Sourness
Bitterness
Homemade
Darkness of the crust
Ideal
Fermented (O)
Saltiness
Crustiness
J
Bread (O)
Liking
Moistness
C
Softness
Doughiness
G
Alcoholic (O)
Heterogeneous
Crumbliness
B
E
K
Sweetness
Dryness
I
Adhesiveness
F
Tasteless
Hardness
D
Whiteness of the crumb
A
Whiteness of the crust

Figure legend.

Figure 1. Mean liking scores and standard error of the mean (SEM) of samples. Red line represents the middle of the scale (liking score = 5). Different letters indicate significant differences according to Tukey's Honest Significant Difference *post hoc* test.

Figure 2. Representation of the bread samples, the ideal product and the terms in the first and second dimensions of the CA of the CATA questionnaire. For ease of visualization and interpretation, all factor loadings less than ±0.3 were suppressed (Field, 2013; Tabachnick & Fidell, 2014).

Figure 3. Mean drop chart obtained by the CATA-based penalty analysis. The 'must have' attributes are displayed in blue, the 'must not have' attributes are displayed in red.

Figure 4. Mean liking score by samples and clusters (Cluster 1 in blue; Cluster 2: in orange). Different letters indicate significant differences according to Tukey's Honest Significant Difference post hoc test.

Figure 5. Representation of the bread samples, the ideal product and the terms in the first and second dimensions of the CA of the CATA questionnaire according to both consumer clusters. For ease of visualization and interpretation, all factor loadings less than ±0.3 were suppressed (Field, 2013; Tabachnick & Fidell, 2014).

Supplemental materials

Identification of desirable mechanical and sensory properties of bread for the elderly

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Supplemental Table S1. Attributes (n=36) used to describe the bread samples.

Attributes	
Appearance	Homogeneous
	Heterogeneous
	Darkness of the crust
	Whiteness of the crust
	Darkness of the crumb
	Whiteness of the crust
	Firmness
	Porosity
	Homemade
Odors	Yeasty
	Alcoholic
	Fermented
	Bread
Taste	Saltiness
	Sweetness
	Bitterness
	Tasteless
Flavors	Yeasty
	Alcoholic
	Fermented
	Bread
Texture	Softness
	Hardness
	Dryness
	Moisture
	Doughiness
	Adhesiveness
	Crustiness
	Springiness
	Chewiness
	Crumbliness
Chewing properties	Easy to chew

Hard to chew

Easy to chew

Hard to swallow

Supplemental Table S2. Crumb and crust color parameters of different types of bread.

Sample		Lightness (L*)	Hue angle ($tan^{-1}b^*/a^*$)	YI ($b^*/L^*x142.86$)
Crumb	Sample A	$73.4^{ef} \pm 1.2$	$94.0^{c} \pm 0.2$	$25.6^{de} \pm 0.8$
	Sample B	$75.6^{e} \pm 0.4$	$93.9^{c} \pm 0.8$	$30.2^{bc} \pm 1.3$
	Sample C	$77.9^{bc} \pm 1.1$	$97.2^{a} \pm 0.5$	$42.4^{a} \pm 2.6$
	Sample D	$79.1^{b} \pm 1.8$	$93.7^{c} \pm 0.5$	$24.3^{e} \pm 0.9$
	Sample E	$77.6^{bc} \pm 0.3$	$95.5^{b} \pm 0.7$	$26.0^{de} \pm 1.6$
	Sample F	$76.9^{cd} \pm 1.4$	$93.3^{c} \pm 0.4$	$31.1^{b} \pm 1.4$
	Sample G	$82.1^{a} \pm 0.5$	$95.6^{b} \pm 0.7$	$30.7^{bc} \pm 0.6$
	Sample H	$55.4^{g} \pm 0.8$	$74.6^{d} \pm 1.1$	$44.3^{a} \pm 4.2$
	Sample J	$70.9^{f} \pm 3.0$	$95.5^{b} \pm 0.6$	$28.7^{cd} \pm 1.5$
	Sample K	$71.2^{f} \pm 2.8$	$93.6^{c} \pm 0.9$	$28.5^{cd} \pm 1.5$
Crust	Sample A	$57.8^{b} \pm 2.8$	$68.0^{bc} \pm 4.3$	$71.1^{bc} \pm 5.5$
	Sample B	$51.5^{c} \pm 1.4$	$66.5^{bc} \pm 0.8$	$91.2^{a} \pm 2.5$
	Sample C	$42.4^{d} \pm 2.2$	$63.4^{bc} \pm 2.8$	$74.2^{b} \pm 8.2$
	Sample E	$59.1^{b} \pm 3.9$	$67.1^{bc} \pm 5.6$	$65.5^{c} \pm 6.1$
	Sample F	$50.3^{c} \pm 3.7$	$67.8^{bc} \pm 2.5$	$83.3^{a} \pm 4.2$
	Sample G	$59.2^{b} \pm 7.5$	$68.4^{b} \pm 8.6$	$68.0^{bc} \pm 9.2$
	Sample H	$41.0^{d} \pm 1.8$	$42.3^{d} \pm 4.3$	$31.8^{e} \pm 3.3$
	Sample I	$79.1^{a} \pm 2.2$	$93.8^{a} \pm 1.9$	$50.5^{d} \pm 5.4$
	Sample J	$49.9^{b} \pm 2.3$	$63.4^{bc} \pm 2.1$	$70.2^{bc} \pm 0.6$
	Sample K	$49.4^{c} \pm 5.4$	$62.5^{c} \pm 7.2$	$52.7^{d} \pm 7.0$

Data points Means ± SD; $^{a–g}$ in the same column, crumb and crust, means indicated by different letters are significantly different ($p < 0.05$).