Consumer-based product characterization using Pivot Profile, Projective Mapping and Check-all-that-apply (CATA): A comparative case with Greek yogurt samples

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ABSTRACT

Product characterization has been a primary concern for the food industry, and methodologies based on consumers' perceptions have become popular and widely used by industries to replace classical methods. Although there are several studies on other methods, the potential of reference-based one such as Pivot Profile is still little explored. Therefore, the aims of this study were to characterize Greek yogurt samples according to consumers' perceptions using three different methodologies: Pivot Profile (PP), Check-all-that-apply (CATA), and Projective Mapping (PM), and to assess which method is easier for consumers to describe products. The rapid methodologies assessed were equally effective in characterizing the different samples; however, some drawbacks evidenced in the study can help in targeting and choosing the best method to perform the sensory characterization. Pivot Profile showed some advantages, bypassing some limitations presented by the other methods. In addition, its experimental versatility also allows for broad applications evidencing the PP technique as a promising tool for routine use. Some implications of using it were also discussed. We suggest the supplemental use of Multidimensional Alignment (MDA) as it shows more accurately the correlations between attributes and samples, especially in the case of PP data.

1. Introduction

Consumers have been bombarded with a wide range of new food products, which has led the food industry to use sensory profiling tools to develop more attractive products and meet consumers' expectations (van Kleef, van Trijp, & Luning, 2005). Descriptive Analysis (DA) is recognized as an adequate technique to determine the sensory profile of processed foods, thus providing detailed, robust, and reproducible results. However, it has been criticized for being expensive and very time-consuming (Moussaoui & Varela, 2010), which can impair its application in small companies, besides being logistically impractical for large companies due to their great diversity of products (Cruz et al., 2013). Furthermore, trained assessors tend to perceive attributes that may not be important or perceptible to consumers (Moussaoui & Varela, 2010).

In response to this demand, sensory methodologies based on consumers' perceptions have become popular and widely used by industries in recent years to replace the classical methods (Ares, 2015). These methods do not require training, have a low financial impact, optimize time and resources in companies, and provide information highly correlated with traditional methods (Varela & Ares, 2012). Among the rapid methods used to capture consumers' perceptions, verbal-based tasks (intensity scales, CATA, Flash Profiling), similarity-based methods (Projective Mapping and Sorting), and reference-based methods (Polarized Sensory Positioning - PSP, Polarized Projective Mapping - PPM and Pivot Profile) have stood out (Valentin, Chollet, Lelièvre, & Abdi, 2012; Varela & Ares, 2012).

Projective Mapping (PM) is one of the most popular holistic methods (Savidan & Morris, 2015), with an emerging number of studies in the past several years (Vidal et al., 2014). As the main advantage, PM provides a global judgment about products, integrating all the sensory characteristics (Dehlholm, Brockhoff, Meinert, Aaslyng, & Bredie, 2012; Perrin et al., 2008; Risvik, McEwan, & Rødbotten, 1997). Check-all-that-apply (CATA) questions consist of a list of words or phrases from which respondents should select all of the words they consider

appropriate to describe the sample (Dooley et al., 2010). It is considered a practical approach to provide information about sensory perceptions, with high correlations to the sensory profiles generated by trained assessors (Ares & Jaeger, 2015; Jaeger et al., 2014).

Recently, Pivot Profile (PP) has been proposed as a new approach for a rapid and comparative description of food products (Lelièvre-Desmas, Valentin, & Sylvie Chollet, 2017; Thuillier, Valentin, Marchal, & Dacremont, 2015). PP has as a main strategy capturing the differences between two samples through free comments: a product under examination and a reference one, which is called a pivot (Valentin et al., 2012). Although promising, Pivot Profile has been little explored, with no studies on the comparative use of PP with other sensory methods based on different efforts such as PM and CATA.

The comparison of consumer profiling methodologies based on product's similarities according to consumers' perception and the difficulty in performing the tasks can provide useful information for food companies to select the most suitable methodology (Ares, Varela, Rado, & Giménez, 2011). Studies on the performance of consumer-based methodologies are still hot topics (Antúnez, Vidal, Saldamando, Giménez, & Ares, 2017; Ares et al., 2013; Bruzzone et al., 2015; Cadena et al., 2014; Fonseca et al., 2016; Reinbach, Giacalone, Ribeiro, Bredie, & Frøst, 2014), which demonstrate the importance of this theme to encourage new studies.

In this context, the present study aimed to evaluate the performance of Pivot Profile to describe the sensory characteristics of a food product category, when compared to other consumer-based sensory methodologies (Projective Mapping and Check-all-that-apply) and assess which one of the three methods is easier for consumers describing products. Greek yogurt was chosen for this study mainly due to its increased popularity. Although they became the flagship of the dairy industry occupying more space on market shelves, reports on the sensory profiling of them are still scarce, and based on consumer perception, they are non-existent. Information about product formulation that is aligned as much as possible with consumer preferences can help product optimization and increase competitiveness in today's competitive global market.

2. Material and methods

2.1. Samples

A wide range of products belonging to Greek yogurt category are available in the market, and they are consumed by different groups of consumers. In this sense, seven commercial Greek yogurt samples were purchased at local supermarkets in the city of Campinas (São Paulo, Brazil), as follows: traditional Greek yogurts (GKY1, GKY2, GKY3, GKY4, and GKY5) and Greek yogurts labeled as light (GKYL1 and GKYL2). For each test, approximately 30 g of sample was served at 10 °C in 50-mL disposable cups coded with three random digits. All samples were approved by the Federal Inspection Service (SIF) and marketed throughout the Brazilian territory.

2.2. Consumers

Participants were recruited from the University of Campinas (UNICAMP) among students, staff, and visitors, through emails, posters, and invitations via social networks. They were selected according to their Greek yogurt consumption habits (at least once a week), interest in the study, and availability to participate in the study. One hundred consumers (gender and aged-balanced - 55% female and 45% male, aged from 18 to 65 years) participated in each test, being restricted the participation in only one sensory test to avoid the learning effect.

2.3. Sensory evaluation

Sensory evaluation was carried out during three different days, with one session for each test and 1-week interval between tests. The tests were conducted in individual booths with adequate temperature and lighting, ensuring the comfort and privacy of panelists (Stone, Bleibaum, & Thomas, 2012). Panelists were also provided with water and unsalted crackers for palate cleansing. The sessions were conducted in the Sensory Analysis Laboratory of the Department of Food and Nutrition. Approval for the study was obtained from the Ethics Committee of the State University of Campinas, and a free and informed consent form was signed by all volunteers.

2.3.1. Projective Mapping

One hundred consumers were asked to try seven Greek yogurt samples (coded with three random digits), and to place them on an A4 white sheet of paper (210 × 297 mm) according to their similarities or dissimilarities. Consumers were instructed to perform the task according to their own criteria, and there were no right or wrong answers. They were also informed that two samples close together on the sheet correspond to very similar samples, while different samples should be placed very distant from each other (Cadena et al., 2014; Valentin et al., 2012). After positioning the samples on the evaluation sheet, consumers were asked to provide 3 to 5 words to describe the sensory characteristics of each sample or group of samples.

2.3.2. Check-all-that-apply - CATA

One hundred consumers answered CATA questions containing 24 sensory attributes, as follows: white, yellow, homogeneous appearance, bright, firm, sweet aroma, vanilla aroma, acidic aroma, cheese aroma, sweet taste, vanilla flavor, salty, fat flavor, milk flavor, cheese flavor, sour, bitter, astringent, sweet aftertaste, bitter aftertaste, viscous, creamy, and fluid. The terms were selected based on previous studies (Akalın et al., 2012; Desai, Shepard, & Drake, 2013), and the descriptors raised using the Projective Mapping. The presentation order of the terms of the CATA question was balanced between and within participants following a Williams' Latin square experimental design (Ares, Antúnez, Giménez and Jaeger, 2015b). Consumers were asked to check all attributes they considered appropriate to describe each sample in digital forms using Fizz Sensory Analysis Software (Biosystèmes, France) (Ares, Antúnez, Bruzzone, et al., 2015a). The samples were coded with three random digits and served in sequential monadic order, taking care to avoid carry-over effects (Macfie et al., 1989).

2.3.3. Pivot Profile

The simulations with different pivot products have demonstrated that the choice of pivot exerted slight changes in the settings generated, and it is not a critical issue for the good performance of the method (Thuillier et al., 2015). As noted by Lelièvre-Desmas et al. (2017), the selection of pivot does not highly affect the product positioning, as well as the number of terms used to describe them. Considering that the pivot should represent the diversity of the products under study, being an appropriate choice when it is a "central product", the sample GKY5 was chosen as a pivot, as it had intermediate protein and fat levels among all samples, resulting in an intermediate texture, which it is an important characteristic for consumers when ingesting Greek yogurt.

One hundred consumers of Greek yogurt were asked to try six pairs of samples (one pair at a time), consisting of the pivot, marked as *P* (sample GKY5), and a coded sample. The samples were coded with three random digits and served in sequential monadic order, taking care to avoid carry-over effects (Macfie et al., 1989). Consumers were asked to try both samples (coded sample and pivot) and answer two open questions, using the Fizz Sensory Analysis Software (Biosystèmes, France). First, they were asked to report which attributes the coded sample had greater intensity than the pivot and then which attributes the coded sample had lesser intensity than the pivot. The definition of sensory descriptors was not mandatory, and consumers were free to describe the characteristics of each sample and were instructed to avoid hedonic terms and negative forms (Fonseca et al., 2016; Lelièvre-

Desmas et al., 2017).

2.4. Ease in performing the tests

At the end of each test, consumers were asked to indicate the ease in performing the tasks (Ares et al., 2013; Schouteten et al., 2015). Data were obtained through a structured 9-point scale (Esmerino et al., 2015), anchored on its left end by "it was very difficult to perform", central point as "more or less difficult to perform," and on its right end by "it was not difficult to perform". A designated space for free comments about each test was also available.

2.5. Statistical analysis

2.5.1. Projective Mapping

Data were obtained from the Cartesian coordinates X and Y for each sample, as was their position in the A4 sheet paper. For descriptive data, textual analysis was necessary and carefully performed. The terms and words were analyzed according to the following criteria: (a) Verifying typing and grammatical errors; (b) Removing connectors; (c) Reducing derivatives to a single word, and (d) Grouping synonyms or terms referring to the intensity level. The refinement of data was always based on the dictionary to identify synonyms (Fonseca et al., 2016; Symoneaux, Galmarini, & Mehinagic, 2012). The grouping of terms was performed independently by three researchers, and a meeting between researchers was held after the evaluation of the words to determine the final descriptors (Guerrero et al., 2010).

The frequency of each sensory descriptor was determined by counting the number of consumers who used the term to describe the sample, and the descriptions were considered as a group of supplementary variables. Only the descriptions cited by at least 10% of the panelists were considered. After assembling the data matrix, Multiple Factor Analysis (MFA) was applied obtaining a sensory map with the spatial arrangement of the samples according to their characteristics (Pagès, 2005; Vidal et al., 2014).

2.5.2. Check-all-that-apply (CATA)

As recommend by Meyners, Castura, and Carr (2013), the data was submitted to randomization and a pairwise comparison test confirming the interpretability of data in detail. The citation frequency of each sensory attribute was determined by counting the number of consumers who used the term to describe the sample. To obtain the sensory map of the samples, Correspondence Analysis (CA) was applied to the contingency table (Bruzzone et al., 2015). CA is a descriptive/exploratory technique designed to examine contingency tables with two entries containing correspondence measures between samples and attributes, generating a bidimensional visual representation of data.

2.5.3. Pivot Profile

After textual analysis (similar as previously mentioned for PM), the number of times each attribute was quoted as "less than the pivot" (negative frequency) and "more than the pivot" (positive frequency) was automatically computed and summed. Subsequently, the negative frequency was subtracted from the positive one for each attribute. The resulting score was then translated by adding the absolute value of the minimum score to all the scores. Thus, the minimum score takes the value of zero and all other scores are positive, yielding a translated frequency table (Fonseca et al., 2016; Lelièvre-Desmas et al., 2017; Thuillier et al., 2015). Correspondence Analysis (CA) was applied to PP translated frequency table, obtaining a sensory bidimensional map for PP.

To improve interpretation of the results, the theoretical position of the pivot (GKY5) was obtained by adding the value of zero to all attributes in the frequency matrix (before translation) and then used as a supplementary variable. Thus, the position and characteristics of all samples are shown in the map generated by the Correspondence Analysis (CA).

2.5.4. Graphic analysis of CATA and Pivot Profile

Multidimensional Alignment (MDA), previously suggested for analysis of CATA test (Carr, Dzuroska, Taylor, Lanza, & Pansini, 2009; Dos Santos et al., 2015; Meyners et al., 2013) was pioneer used to interpret the graphs of the Correspondence Analysis (CA) in Pivot Profile. According to Carr et al. (2009), the determination of the angle between vectors (or their cosines) in the full dimensional space can provide relevant information to help investigate the association between products and their attributes. The cosine takes values between -1 and 1, and absolute values lower than 0.707 indicate almost no spatial relationships.

The results can be presented through bar charts (Carr et al., 2009), showing the reverse angle shots (Meyners & Castura, 2014), or by a circle or semi-circle to represent the attributes of each product (Meyners et al., 2013). In this study, the results of the CATA question and PP were numerically presented in individual tables to better understand the results.

2.5.5. Similarity between the sensory configurations

The RV coefficient using cross-reference matrices and Multiple Factor Analysis (MFA) based on the first two dimensions of the MFA on the PM, and Correspondence Analysis (CA) for CATA and PP, was used to compare and analyze the similarities between the configurations of the three methodologies for all samples. The RV is the correlation coefficient between two individual spaces, ranging from 0 (totally disagree) to 1 (perfect agreement) (Albert, Varela, Salvador, Hough, & Fiszman, 2011; Antúnez et al., 2017). The significance of the RV coefficient was determined using the standardized RV coefficient according to Josse, Pagès, and Husson (2008) and Dehlholm et al. (2012).

2.5.6. Hierarchical cluster analysis

Hierarchical cluster analysis (HCA) was performed on samples' coordinates in the first and second dimensions in the space defined by MFA (Projective mapping) and CA (CATA and Pivot Profile) to identify groups of samples with different sensory characteristics considering Euclidean distances (dissimilarity), Ward's aggregation criterion (agglomeration method), and automatic truncation. This approach has been used with success in previous studies to evaluate and determine similarities and differences among sensory methods (Ares et al., 2013; Cruz et al., 2013; Santos et al., 2013). In addition, the reliability of the dendrograms obtained was assessed using the Cophenetic Correlation Coefficient - CCC (Sokal & Rohlf, 1962). CCC is an analytical parameter that can be associated with the certainty of groups of samples obtained by the sensory methods. Its value ranges from 0 to 1, being zero (absence of concordance between dendrogram and original matrix data set) and 1 (total relationship among dendrogram and original data matrix set). Values above 0.7 indicate good agreement between groups in relation to the original data.

2.5.7. Analysis of variance (ANOVA)

Analysis of variance (ANOVA) was carried out to determine the ease of performing each methodology, using both the assessor and methodology as sources of variation (assessor random effect and sensory methodology fixed effect). The averages were calculated, and the significant differences were analyzed by Tukey's test at the $p \leq 0.05$ significance level.

All statistical analyses were performed using XLSTAT for Windows, version 2015.5 (Addinsoft, Paris, France).
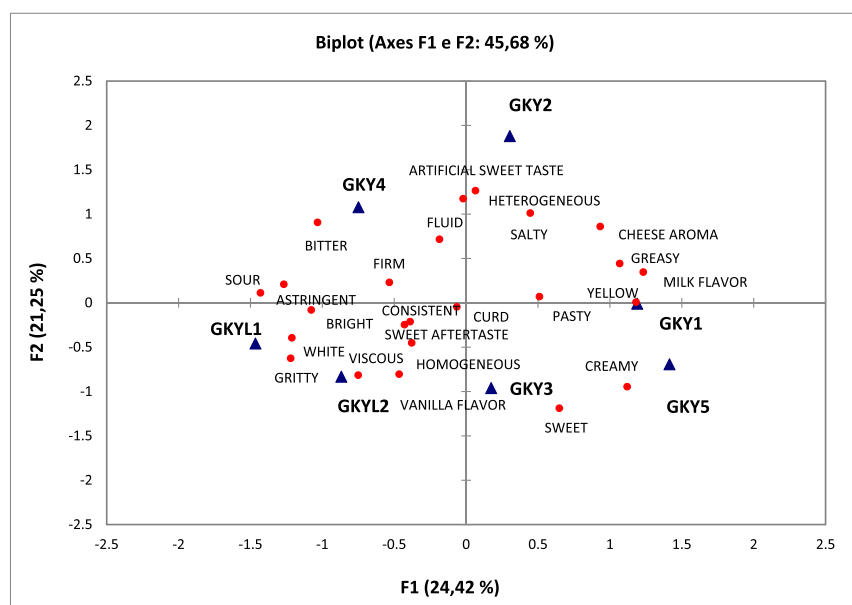
Fig. 1. Sample configuration in the first and second dimensions of the Multiple Factor Analysis (MFA) performed on Projective Mapping data. The main sensory attributes (circles) were projected as supplementary variables in the analysis.

3. Results and discussion

3.1. Projective Mapping

The first two dimensions of MFA accounted for approximately 45.7% of the variance of the experimental data. According to Fig. 1, the first dimension was represented by the positively valued attributes "yellow", "milk flavor", and "greasy" and the negatively valued attributes "white", "sour", "bitter", "astringent", "bright" and "gritty". These descriptors were responsible for sorting the samples GKY1 and GKY5, and the light samples GKYL1 and GKYL2, and the regular sample GKY4. The second dimension was positively correlated with "artificial sweet taste", "heterogeneous", "salty", and "fluid", characterizing the samples GKY2 and GKY4, while the second dimension was negatively related to the attributes "sweet", "vanilla flavor", "creamy" and "viscous", characterizing mainly the sample GKY3.

3.2. Check-all-that-apply (CATA)

Significant differences were observed between CATA data ($p = 0.001$) in the randomization test and pairwise comparison, suggesting that the methodology could detect differences between the attributes and samples in accordance with consumers' perceptions (Ares, Barreiro, Deliza, Giménez, & Gámbaro, 2010; Meyners et al., 2013). The Correspondence Analysis (CA) was applied to the contingency table of CATA, and a bidimensional map was derived from CA results. The first and second dimensions accounted for approximately 71.5% of the variance of the experimental data, with 44.36% and 27.11%, respectively.

As shown in Fig. 2, the first dimension was positively represented by attributes "vanilla flavor" and "vanilla aroma" and negatively mainly by "cheese flavor", "cheese aroma", and "salty". On the other hand, the second dimension was positively correlated with the descriptors "gritty", "astringent" and "bitter", and negatively correlated with the descriptor "yellow". Most of the remaining terms were correlated with the bisectors of the first and second quadrant.

The sensory maps generated by CA represent the relationship between the sensory attributes and products and exhibit only two (rarely three) dimensions. Depending on the experimental variance explained, and because of statistical drawbacks (distortions by data compression), the true relationship between samples and attributes can be visually misunderstood, and the attribute may be more or less related to the
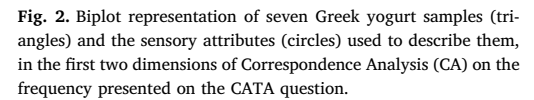
product in the multidimensional space when compared to the bi-dimensional display (Meyners et al., 2013). As recently reported by Dos Santos et al. (2015), to evaluate the data of descriptive analyses such as CATA, Multidimensional Alignment (MDA) can constitute a practical and quantitative way to express the associations between attributes and products. It measures the cosine of the angle between the sample and descriptors, and the cosine interpretation is performed in a similar manner as a correlation coefficient.

Thus, MDA was applied to determine the cosine values between vector pairs (product vector × descriptors vectors) originating in the CA of CATA questions. The values in Table 1 highlight the descriptors that are positively and negatively correlated with the samples using the first two dimensions of the CA bidimensional map. It can be noted that GKY1 was mainly positively correlated with the descriptors "yellow" (0.90), "greasy" (0.92), and "milk flavor" (0.91), and negatively correlated with "gritty" (− 0.98) and "sour" (− 0.98), which is consistent with Fig. 2. Sample GKY2 presented highly positive correlation with the descriptors "cheese aroma" (1.00), "salty" (0.99), "greasy" (0.99) and "cheese flavor" (1.00), and a negative correlation with "sweet aroma" (− 0.92) and "vanilla aroma" (− 0.97).

Among the light samples, the sample GKYL1 was mainly positively correlated with "white", "firm", "astringent", and "bitter aftertaste", and negatively correlated with "bright", "homogeneous appearance", "sweet aftertaste", and "creamy". The descriptors "cheese flavor", "salty", "greasy", and "cheese aroma" were negatively correlated with the sample GKYL2. These relationships were not visible only by looking at the CA bidimensional map, so once again, the use of MDA is strongly recommended to evaluate CATA data as previously reported by Dos Santos et al. (2015).

3.3. Pivot Profile

After determining the subtraction between negative and positive frequency, the lowest value was − 48 for all attributes, which was associated with the attribute "sweet" in the sample GKYL1. The theoretical position of the pivot (GKY5) was obtained through the addition of the value of zero to all attributes, and the sum of the absolute value of the lowest result (48) was added to all scores. Thus, the values became positive, all descriptors of the sample GKY5 assumed the value of 48, and the frequency of the descriptor "sweet" for the sample GKYL1 assumed a value of zero, creating a contingency table, which was analyzed by Correspondence Analysis (CA).

Fig. 2. Biplot representation of seven Greek yogurt samples (triangles) and the sensory attributes (circles) used to describe them, in the first two dimensions of Correspondence Analysis (CA) on the frequency presented on the CATA question.

As shown in Fig. 3, the first two dimensions of CA accounted for 83.0% of the variance of the data. The first dimension was positive and strongly characterized by the descriptor "sweet" and negatively correlated with descriptors such as "white" and "consistent". It is reasonable to say that because of the ease of recognition, and the different intensities in the sweet taste between samples and the pivot, the term "sweet" was often used, increasing the number of citations and driving the upper right quadrant space. The second dimension was positively correlated with the descriptor "sour" and negatively correlated with the descriptors such as "cheese flavor" and "bright". Most of the remaining attributes were distributed over the quadrants of both dimensions, and the identification of the correct correlation between descriptors and samples was not possible by only visual inspection.

According to Lelièvre-Desmas et al. (2017), PP is appropriate to evaluate sample sets with different degrees of similarity, but in homogeneous groups, although the total number of terms generated decreases, the product dispersion and term projections increase and CA maps are scattered, differently than in other consumer-based descriptive methods. It can be explained by the efforts in the performance of the test: in a high similarity set, participants strive harder to find out detailed information about the products while in low similarity they look for more obvious one. As in the present study, in many stages of development and reformulation, the use of samples already on the market is necessary, and a homogeneous set of samples cannot always be achieved. In this sense, the MDA helped to identify the attributes that were more and less correlated with each sample, leading to a proper interpretation of the sensory map. As far as we know, this is the first application of MDA in Pivot Profile data, and its outcome shows

Table 1
Table containing the values of the cosine between vectors pairs (product vector vs sensory terms used to describe the samples vector) obtained by Correspondence Analysis (CA) for seven Greek yogurt samples in CATA questions.

Attributes	GKY1	GKY2	GKY3	GKY4	GKY5	GKYL1	GKYL2
White	− 0.74[b]	− 0.30	− 0.33	0.37	− 0.75[b]	0.96[a]	0.52
Yellow	0.90[a]	0.56	0.06	− 0.09	0.54	− 0.85[b]	− 0.74[b]
Gritty	− 0.98[b]	− 0.75[b]	0.20	− 0.17	− 0.30	0.68	0.89[a]
Bright	0.53	0.03	0.58	− 0.61	0.90[a]	− 1.00[b]	− 0.26
Homogeneous appearance	0.50	0.00	0.60	− 0.63	0.92[a]	− 1.00[b]	− 0.23
Firm	− 0.62	− 0.14	− 0.48	0.51	− 0.85[b]	0.99[a]	0.37
Sweet aroma	− 0.61	− 0.92[b]	0.97[a]	− 0.96[b]	0.72[a]	− 0.35	0.81[a]
Vanilla aroma	− 0.73[b]	− 0.97[b]	0.91[a]	− 0.90[b]	0.59	− 0.19	0.89[a]
Acid aroma	0.20	0.66	− 0.98[b]	0.99[a]	− 0.95[b]	0.73[a]	− 0.47
Cheese aroma	0.85[a]	1.00[a]	− 0.82[b]	0.80[a]	− 0.43	0.01	− 0.96[b]
Sweet	− 0.12	− 0.60	0.96[a]	− 0.97[b]	0.97[a]	− 0.78[b]	0.39
Vanilla	− 0.42	− 0.82[b]	1.00[a]	− 1.00[b]	0.85[a]	− 0.55	0.66
Salty	0.79[a]	0.99[a]	− 0.87[b]	0.85[a]	− 0.52	0.11	− 0.93[b]
Greasy	0.92[a]	0.99[a]	− 0.71[b]	0.69	− 0.27	− 0.16	− 0.99[b]
Milk flavor	0.91[a]	0.59	0.02	− 0.06	0.51	− 0.83	− 0.76[b]
Cheese flavor	0.81[a]	1.00[a]	− 0.85[b]	0.83[a]	− 0.49	0.07	− 0.94[b]
Sour	− 0.98[b]	− 0.74[b]	0.18	− 0.15	− 0.33	0.70[a]	0.88
Bitter	0.04	0.54	− 0.94[b]	0.95[a]	− 0.99[b]	0.83[a]	− 0.32
Astringent	− 0.81[b]	− 0.41	− 0.22	0.26	− 0.67	0.92[a]	0.61[a]
Sweet Aftertaste	0.28	− 0.24	0.78[a]	− 0.80[b]	0.99[a]	− 0.96[b]	0.00
Bitter aftertaste	− 0.74[b]	− 0.31	− 0.33	0.36	− 0.75[b]	0.96[a]	0.52
Viscous	0.24	0.69	− 0.99[b]	0.99[a]	− 0.94[b]	0.70[a]	− 0.50
Creamy	0.32	− 0.20	0.75[a]	− 0.77[b]	0.98[a]	− 0.97[b]	− 0.04
Fluid	0.75[a]	0.31	0.33	− 0.36	0.75[a]	− 0.96[b]	− 0.52

[a] Values indicate high positive correlation of the sensory attribute with respective sample.
[b] Values indicate high negative correlation of sensory attribute with the respective sample.
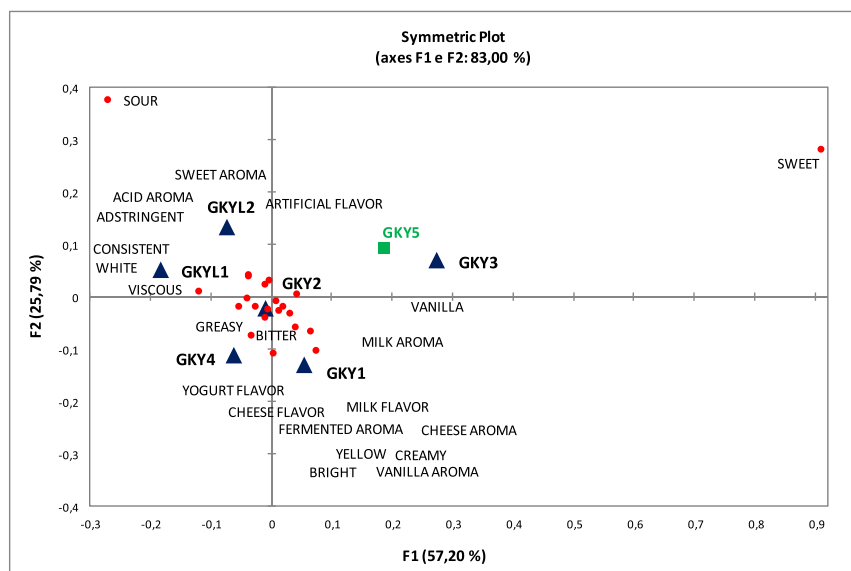
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Fig. 3. Biplot projection of six Greek yogurt samples (triangles), the pivot sample as supplementary variable (square) and the main sensory attributes (circles) used to describe them in the first two dimensions of the sensory map generated by Correspondence Analysis (CA) to the Pivot Profile data.

the appropriation of the technique for this type of data, as it is a quantitative measure and can be more easily interpreted.

According to Table 2, the sample GKY1 stood out for presenting high positive correlation with some descriptors such as "milk flavor" (0.98), "cheese flavor" (0.93), "creamy" (0.98) and "bright" (1.00), and was negatively correlated with the descriptors "sweet aroma" (-0.94), "sour" (-0.98), "consistent" (-0.94), "astringent" (-0.95) and "artificial flavor" (-1.00). Sample GKY2 presented a positive correlation with the descriptors "bitter taste" (0.99), "yogurt flavor" (0.97), "milk aroma" (0.84), "cheese flavor" (0.92) and "greasy" (1.00), and was negatively correlated with "sweet aroma" (-0.91) and "artificial flavor" (-0.73). Finally, the sample GKY3 presented positive correlations with the descriptors "sweet" (1.00), and "vanilla flavor" (0.99), and was negatively correlated with "white" (-0.95), "acid aroma" (-0.98), "milk aroma" (-0.93) and "viscous" (-1.00).

The light Greek yogurts exhibited very close sensory characteristics, with positive correlations for the descriptors "consistent", "sour", and "astringent", while the descriptors "yellow", "creamy", "fermented aroma", "vanilla flavor", and "cheese flavor" were negatively correlated with these samples. As the speculative position of the sample GKY5 was achieved by adding the value of zero to all the sensory descriptors before the translation process (Thuillier et al., 2015), it was also possible to visualize the theoretical correlations between the sample and the attributes cited in the Pivot Profile (Table 2). However, it is worth mentioning that the positioning of the sample GKY5 was given theoretically; thus, conclusions using the Pivot Profile may be distinct for this sample.

3.4. Similarity between the sensory configurations

According to Fleming, Ziegler, and Hayes (2015), the configurational congruence and discriminative power can be determined by different methodologies using three criteria: (1) dendrograms generated via hierarchical cluster analysis (HCA); (2) visual plots generated by

Table 2
Table containing the values of the cosine between vectors pairs (product vector vs main sensory terms in the characterization of samples vectors) obtained by Correspondence Analysis (CA) for seven Greek yogurt samples in Pivot Profile test.

Attributes	GKY1	GKY2	GKY3	GKY4	GKY5	GKYL1	GKYL2
Sweet	0.10	-0.62	1.00[a]	-0.72[b]	0,99[a]	-0.84[b]	-0.19
Sweet aroma	-0.94[b]	-0.91[b]	0.19	-0.84[b]	0,40	0.33	0.91[a]
Sour	-0.98[b]	-0.54	-0.36	-0.43	$-0,15$	0.78[a]	0.99[a]
Acid aroma	-0.33	0.43	-0.98[b]	0.55	$-0,92$[b]	0.94[a]	0.42
Bitter	0.79[a]	0.99[a]	-0.48	0.97[a]	$-0,66$	-0.03	-0.74[b]
Yogurt flavor	0.85[a]	0.97[a]	-0.39	0.94[a]	$-0,58$	-0.13	-0.80[b]
Milk flavor	0.98[a]	0.54	0.37	0.42	0,16	-0.79[b]	-0.99[b]
Milk aroma	0.22	0.84[a]	-0.93[b]	0.91[a]	$-0,99$[b]	0.62	-0.13
Cheese flavor	0.93[a]	0.92[a]	-0.21	0.85[a]	$-0,42$	-0.31	-0.90[b]
Creamy	0.98[a]	0.55	0.35	0.43	0,14	-0.78[b]	-0.99[b]
Viscous	-0.07	0.65	-1.00[b]	0.75[a]	$-0,99$[b]	0.82[a]	0.16
Consistent	-0.94[b]	-0.42	-0.49	-0.29	$-0,29$	0.86[a]	0.96[a]
Greasy	0.69	1.00[a]	-0.61	0.99[a]	$-0,76$[b]	0.12	-0.63
Yellow	0.93[a]	0.40	0.50	0.28	0,31	-0.87[b]	-0.96[b]
Bright	1.00[a]	0.65	0.24	0.54	0,02	-0.69	-1.00[b]
Fermented aroma	0.93[a]	0.41	0.50	0.29	0,30	-0.87[b]	-0.96[b]
White	-0.47	0.29	-0.95[b]	0.42	$-0,85$[b]	0.98[a]	0.55
Astringent	-0.95[b]	-0.45	-0.46	-0.33	$-0,26$	0.84[a]	0.97[a]
Vanilla aroma	0.90[a]	0.34	0.56	0.21	0,37	-0.90[b]	-0.94[b]
Cheese aroma	0.90[a]	0.33	0.57	0.20	0,38	-0.91[b]	-0.93[b]
Vanilla	0.30	-0.45	0.99[a]	-0.57	0,93[a]	-0.93[b]	-0.39
Artificial flavor	-1.00[b]	-0.73[b]	-0.12	-0.63	0,09	0.61	0.99[a]

[a] Values indicate high positive correlation of the sensory attribute with respective sample.
[b] Values indicate high negative correlation of sensory attribute with the respective sample.
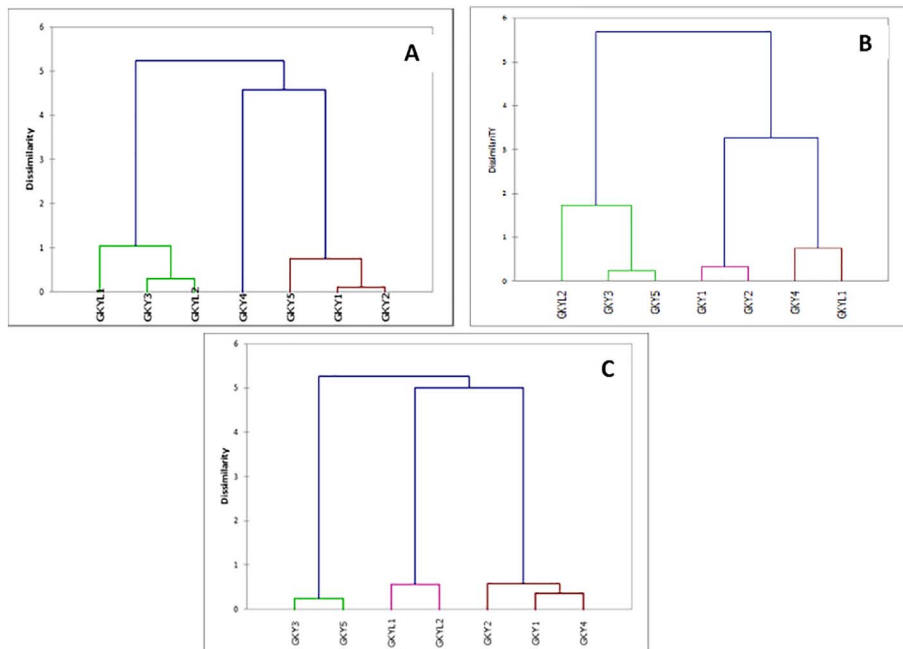
Fig. 4. Dendrogram obtained from hierarchical cluster analysis (HCA) on the representation of seven Greek yogurt samples: (a) in the first and second dimensions of the Multiple Factor Analysis performed on data from Projective Mapping, (b) in the first and second dimensions of the Correspondence Analysis performed on data from Check-all-that-apply, (c) in the first and second dimensions of the Correspondence Analysis performed on data from Pivot Profile.

MFA; and (3) use of RV coefficients comparing these plots for significance. Thus, we adopted the same criteria for evaluation of the methodologies of the present study.

The dendrogram obtained by HCA (Fig. 4) identified the existence of 2–3 groups depending on the sensory approach (Ares et al., 2013; Santos et al., 2013). (a) In Projective Mapping, we observe the existence of three groups: the first group (GKYL1, GKY3, and GKYL2), the second group containing the sample GKY4, and the third group (GKY5, GKY1 and GKY2). For (b) Check-all-that-apply, only two groups were observed, the first group with the samples GKYL2, GKY3 and GKY5, and the second group with GKY1, GKY2, GKY4 and GKYL1. Finally, the dendrogram obtained from (c) Pivot Profile showed the existence of three groups: the first group with GKY3 and GKY5, the second group with the samples GKYL1 and GKYL2, and the third group with the samples GKY2, GKY1 and GKY4.

The cophenetic correlation coefficients (CCC) for Projective Mapping, CATA, and Pivot Profile were 0.852, 0.794, and 0.910, respectively, indicating the reliability of the dendrogram. Although all methods have presented adequate values, Pivot Profile presented a more stable grouping of samples, being superior to the other methods. Thus, the strategy used in the description of the products using PP showed robustness when compared to CATA and PM, confirming the potentiality of the method for sensory characterization.

The differences in dendrograms of each sensory methodology may be due to different cognitive strategies encouraged in the sensory characterization tasks, leading to different forms of activation of neural activity, recognition, and recall during the tests (Lazo, Claret, & Guerrero, 2016). Projective Mapping has a holistic nature, being described as an intuitive method, based on the global perception of the participant, which identifies only the main attributes that distinguish samples. On the contrary, CATA questions are based on recognition activities, the information is already available, and the answers are chosen from a list containing different alternatives (Varela & Ares, 2012; Veinand, Godefroy, Adam, & Delarue, 2011).

The groups of samples obtained in Pivot Profile present similarity with both groups of PM and CATA, which suggests that the cognitive strategy used by consumers in this methodology has some characteristics already present in CATA and PM. PP shows answers consistent with the dominance of a rational-analytic information processing style (Fonseca et al., 2016; Stanovich & West, 2000), and according to Lelièvre-Desmas et al. (2017), the performance of PP is closer to

similarity-based methods as PM than verbal-based approaches as CATA, suggesting that it would be an appropriate technique for obtaining global information.

In summary, the ability to identify the main sensory characteristics for each product was similar for the three sensory profiling techniques although they somewhat have disagreed. While in PM and PP consumers use free elicitation, and limited sensory attributes to cover main relevant dimensions responsible for the discrimination of samples, providing a partial overview of the sensory space, CATA questions provided a summarized positioning of samples built by giving the same relative importance to all the sensory descriptors considered in the list (Antúnez et al., 2017; Reinbach et al., 2014).

Visualization of each product was achieved through the application of Multiple Factor Analysis (MFA) on the cross-tabulation matrix for all methods studied. The RV coefficients were calculated for all possible combinations, in two dimensions, and used to compare the results of the three descriptive methods based on consumers' perceptions (Antúnez et al., 2017; Cruz et al., 2013). As shown in Fig. 5, the first two dimensions of MFA accounted for approximately 96% of the variance explained. Each Greek yogurt sample was visualized by the distinct color and positions on the map, thus demonstrating that consumers were able to differentiate the samples. The points at the end of each representation show the position according to the sensory method, while the central point (average) represents a consensus position between the methods. By visual inspection of it, the samples presented similar positions for all methodologies.

When using the RV coefficient to compare sample configurations, a great similarity was observed between the methodologies. The significance of it was also tested and significant values ($p \leq 0.05$) were obtained for all consumer-based methods. Although lower, the RV coefficients between Pivot Profile and CATA, and CATA and Projective Mapping presented significant and high compatibility with similar values between them (PP and CATA - RV = $0.82/p = 0.013$) and (CATA and PM - RV = $0.83/p = 0.011$). However, the highest RV coefficient value (RV = $0.88/p = 0.001$) was observed between Pivot Profile and Projective Mapping. For all, it can be regarded as an indicator of good agreement between the sample configurations (Faye et al., 2004).

3.5. Ease in performing the tests

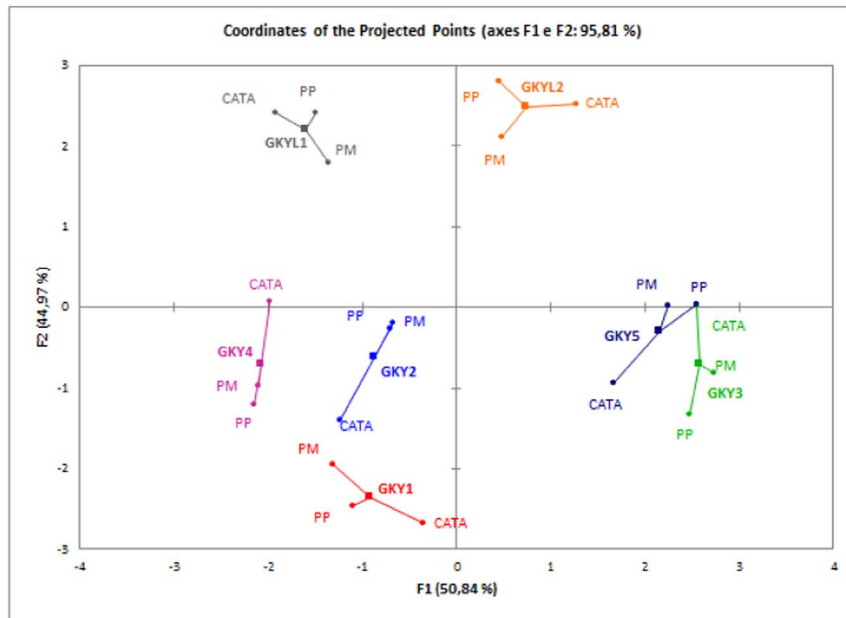Although all methods presented similar results, indicating a high

Fig. 5. Comparative configurational map generated by Multiple Factor Analysis (MFA) on the individual configuration of Projective Mapping, CATA and Pivot Profile for the seven Greek yogurt samples.

Table 3
Mean values in the assessment of the easiness in performing Projective Mapping, CATA and Pivot Profile in sensory characterization of Greek yogurt samples by consumers.

Methodology	Easiness
Projective Mapping	3.52[b]
CATA	6.55[a]
Pivot Profile	6.18[a]

Means with the same letter do not differ statistically according to Tukey's test ($p \leq 0.05$).

discriminative capacity and similar sensory maps, different degrees of ease were found during the performance of the tests. According to Table 3, PM was regarded as the method with the lowest degree of ease, with an average value of 3.52, which was significantly different from the other methodologies ($p \leq 0.05$). CATA and Pivot Profile were perceived by consumers as easier to perform, with no significant difference ($p \leq 0.05$) between them, with scores of 6.55 and 6.18, respectively.

Although PM is a holistic, natural and intuitive technique to describe products (Carrillo, Varela, & Fiszman, 2012), some problems in the performance were described at the end of the tests through casual and anecdotal reports. The difficulty in positioning the samples according to the similarities and dissimilarities was raised by some participants as a limiting factor. Previous studies have also shown that approximately 6–15% of consumers have problems during the performance of the method (Nestrud & Lawless, 2008; Pagès, 2005). One of the major limitation of PM is the number of products that can be tested simultaneously (Pagès, 2005), and because of the size of sample set, many consumers may have difficulty in discriminating between samples using a two-dimensional space. Sessions with practical examples, although time-consuming, may overcome these drawbacks (Risvik et al., 1997; Veinand et al., 2011; Louw et al., 2015). With respect to data analysis, it is worth noting the difficulty in accurately interpreting the descriptions provided by consumers, as they may use intensities related to descriptors at the time of differentiation (Thuillier et al., 2015; Varela & Ares, 2012).

CATA questions has gained popularity in the consumer research field mainly due to its simplicity (Antúnez et al., 2017; Jaeger et al., 2015; Reinbach et al., 2014), with high correlation with classical descriptive methods (Dooley et al., 2010). The main limitation using the method touches upon the list of descriptors used (Valentin et al., 2012). Although the list should have broad character, involving all samples, the responses are limited to the options of a pre-defined list (Thuillier et al., 2015). In this sense, some information may be lost, or important bias as halo dumping may occur (Jaeger, Cardello, & Schutz, 2013). There is always doubt with using long lists (better discrimination, characterization of products, fewer samples), or lists with a reduced number of terms (faster and easier).

According to ten Kleij and Musters (2003), one of the main advantages of using open questions such as Pivot Profile is the freedom of elicitation with richness and variety of responses. As observed in other reference-based methods, the number of products is not limited, filling the main methodological gap in PM. In addition, PP has shown to promote fast and direct description of samples, with the advantage of collecting spontaneous responses, unlike what occurs in CATA question with a pre-defined list. However, PP presents a drawback. The textual analysis may be a complex step, even if this process is simplified as in PP. Due to the nature of the responses of "more" or "less" than the pivot, data are less noisy and the analysis is more powerful, making data analysis easier and less time-consuming than other open-ended questions.

Although Pivot Profile has been little explored and underestimated, the present study reinforces its potential as a technique to assess consumers' perceptions of the sensory characteristics of products. PP presented good discriminative capacity, similar to CATA and PM, besides being considered very easy to perform according to consumers' responses, with a qualitative description of products. Finally, as previously mentioned for low-sodium sausages (Dos Santos et al., 2015), the Multidimensional Alignment (MDA) has proven to be a valuable analytical measure to evaluate CATA and now Pivot Profile data, once it helps the interpretation of results, with more precise associations between attributes and samples (expressed by numeric values), without relying on the subjective visual interpretations of the bidimensional maps.

4. Conclusions

According to our results, the three methods for sensory characterization have proven to be equally effective in describing the different Greek yogurt samples. However, some of the methodological limitations from each sensory approach previously discussed may serve as a guide for choosing the most appropriate method for determining

sensory profiles.

Pivot Profile (PP), a reference-based method, presented effective results for discrimination and sensory characterization of samples, being comparable with PM and CATA, two consecrated sensory methods widely studied. Although previous studies have addressed the practical aspects of PM and CATA for sensory characterization of samples, little is known about PP. The supplemental use of Multidimensional Alignment (MDA) is highly recommended as it shows more accurately the correlations between attributes and samples, especially in the case of PP data.

The present study has validity and can contribute to the dissemination of the method; however, further studies are required to establish the best PP procedures using different products' category. Finally, the assessment of robustness and repeatability of PP in comparison with data from trained assessors using classical descriptive analysis can be an interesting approach.

Acknowledgments

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