Rapid consumer-based sensory characterization of requeijão cremoso, a spreadable processed cheese: Performance of new statistical approaches to evaluate check-all-that-apply data

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ABSTRACT

We investigated the performance of multidimensional alignment analysis and multidimensional scaling on phi coefficient values to evaluate check-all-that-apply questionnaire data. We evaluated 6 dairy foods belonging to the category of requeijão cremoso processed cheese (traditional, with starch, or with starch and vegetable fat). We obtained sensory descriptors using trained assessors in descriptive analysis for comparison. A check-all-that-apply questionnaire used with 121 consumers (77 women and 44 men; 18 to 57 yr old) proved to be a suitable alternative for sensory profiling, providing descriptions similar to descriptive analysis and discriminating between products. Multidimensional alignment analysis and multidimensional scaling were efficient and logical approaches for obtaining a deeper understanding of the data, allowing us to clarify the relationships between sensory descriptors and products and contribute to optimizing the different formulations of requeijão cremoso.

Key words: check-all-that-apply, multidimensional alignment, multidimensional scaling, requeijão cremoso

INTRODUCTION

Sensory perception is one of the keys to the flavorful and wholesome image that dairy foods continue to enjoy with consumers. In some cases, gross measurement of product quality or consistency may be all that is required, but for most products and market research, more detailed and complex information about sensory properties is needed (Drake, 2007).

Descriptive tests provide sensory descriptors of the product, allowing for comparisons between products (Stone et al., 2012). Outlining the sensory characteristics of products is a common practice in the dairy industry, contributing to business decisions and the development of products according to consumer needs; developing reference products; and investigating the effects of ingredients or processes and sensory changes during storage (Varela and Ares, 2012).

Descriptive analysis is a recognized and established method used by the dairy industry. It employs a trained panel to identify and quantify the intensity of each sensory descriptor, providing a complete sensory profile (Drake, 2007). Several studies on the descriptive analysis (DA) of dairy products have been published (Cadena et al., 2012; Albenzio et al., 2013; Murtaza et al., 2013; Pimentel et al., 2013; Aquino et al., 2014; Gaze et al., 2015; Janiaski et al., 2016; Kwab et al., 2016). However, DA requires a considerable amount of time, because a series of training sessions is necessary to ensure reliable results. Faster and more flexible sensory methodologies using consumers are needed (Valentin et al., 2012).

Of the descriptive sensory methods that use consumers, the check-all-that-apply (CATA) questionnaire has been evaluated by several studies (Ares et al., 2010; Dooley et al., 2010; Cruz et al., 2013; Varela et al., 2014; Santos et al., 2015; Antunes et al., 2017). The CATA questions consist of a list of attributes (words or phrases) from which assessors can select those they consider appropriate for describing a product (Ares and Jaeger, 2013). However, when the samples to be evaluated are very similar, or if they are complex from a sensory point of view, traditional statistical methods such as Cochran's Q test and correspondence analysis may not be suitable for assessing the many the differences or correlations between products (Ares et al.,

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2014); new approaches that improve the interpretation of results are needed. Multidimensional alignment and multidimensional scaling are options for the interpretation of CATA findings. Multidimensional alignment is a numerical tool that allows researchers to identify associations between samples and attributes by measuring the cosine angles between them (Carr et al., 2009). Multidimensional scaling can be used with phi coefficient values to determine which attributes are usually checked together and which are chosen independently, measuring the distance to specific locations in a special configuration (Jaworska and Chupetlovska-Anastasova, 2009).

Requeijão cremoso is a typical Brazilian processed cheese manufactured using a variety of ingredients and technologies (Oliveira et al., 2016). It is a typical dairy food manufactured by most Brazilian dairy enterprises regardless of their size, and recently, products similar to traditional requeijão cremoso have been developed that contain starch or vegetable fat or both. Given these differences, we wanted to obtain a deep understanding of the characteristics of the different cheeses, and to suggest improvements from a sensory perspective.

This study had 2 purposes: (1) to investigate the performance of a CATA questionnaire to provide a sensory profile of different requeijão cremoso products (requeijão containing starch; starch and vegetable oil; and a traditional formulation without these ingredients); and (2) to evaluate the use of multidimensional alignment and multidimensional scaling on phi coefficient values as a way of obtaining a deeper, complementary interpretation of the findings, which could be useful for the dairy industry. For comparison, we also performed DA using a trained panel.

MATERIALS AND METHODS

Samples

We used a convenience sample for this study (Felicio et al., 2013). We acquired 6 samples from supermarkets in the city of Rio de Janeiro, Brazil, and kept them in the refrigerator at 9°C ($\pm 1^\circ\text{C}$) until analysis. The samples were traditional requeijão cremoso (1 sample), requeijão cremoso containing starch (3 samples), and requeijão cremoso containing starch and vegetable fat (2 samples), and were numbered I, II, III, IV, V, and VI, respectively. We used the traditional requeijão cremoso as a reference. We used only samples submitted to federal sanitary inspection that could be marketed throughout Brazil. For all sensory analyses, samples were presented in white 50-mL plastic cups identified with 3-digit numbers at a temperature of approximately 5°C.

Descriptive Analysis

Descriptive analysis (DA) was performed in the Sensory Analysis Laboratory of the Federal Fluminense University, according to the principles described by Stone et al. (2012). The assessors defined attributes of appearance, aroma, flavor, and texture that characterized the samples, and standards to anchor the ends of the perceived intensity scale shown in Table 1. The sensory descriptors were divided into 5 groups: appearance (color, brightness), aroma (artificial requeijão cremoso aroma, natural requeijão cremoso aroma, buttery aroma, sweet aroma, acid aroma), flavor (sweet taste, bitter taste, acid taste, salty taste, buttery flavor, artificial requeijão cremoso flavor, natural requeijão cremoso flavor, oil film), visual texture (consistency, adhesiveness, spreadability, gelatinous quality, homogeneity, forming wire) and oral texture (consistency, adhesiveness).

To memorize the anchors, assessors went through 18 sessions, totaling 27 h of training. After training, assessors were asked to evaluate 3 samples in 4 replicates, using the definitive sheet for DA. All attributes were evaluated using an unstructured 15-cm line scale, anchored at the extremes by “none/weak” and “very strong” (McMahon et al., 2017). The results were evaluated by 2-way ANOVA and assessors who had discriminatory capacity ($pF_{\text{sample}} \leq 0.50$) and good repeatability of the results ($pF_{\text{replicate}} \geq 0.05$) for all attributes were selected for the final stage (Cadena et al., 2013). The final evaluation was performed in 4 replicates, with 11 selected assessors in sensory booths. All samples were presented in monadic and balanced form, according to the methodology described by Macfie et al. (1989).

CATA

A CATA questionnaire was completed by 121 consumers (77 women and 44 men, aged 18 to 57 yr) who were randomly recruited at the Veterinary School of Federal Fluminense University. Prior to testing, each participant signed a consent form. Consumers who were allergic to milk or lactose intolerant and consumers who consumed dairy products <1 time/week were excluded. Mineral water and unsalted crackers were used to cleanse the palate.

The selection of attributes for the CATA questionnaire was based on the list from the DA, removing terms that showed low mean values or no significant difference. A similar approach has been used in recent studies evaluating dairy foods such as yogurts (Cruz et al., 2013; Tarrega et al., 2016), dairy desserts (Bruzzone et al., 2015), and ice creams (Dooley et al., 2010). Based on these criteria, buttery aroma, sweet aroma, and acid aroma were removed. Color and homogeneity

Table 1. Attributes used for descriptive analysis of queijoão cremoso samples: definitions and references

Attribute	Definition	Reference ¹
Artificial queijoão cremoso aroma	Aroma associated with Parmesan cheese	None: UHT whole milk, Itambé Strong: cheese essence, Mane, prepared in the proportion of 12 g of essence to 40 mL of water
Buttery aroma	Aroma associated with unsalted butter	Low: UHT whole milk, Itambé Strong: unsalted butter, Elegê
Sweet aroma	Typical carbohydrate aroma (e.g., sucrose, glucose, lactose)	None: UHT whole milk, Itambé Strong: 5 g of Ninho milk powder diluted in 10 mL of Itambé UHT whole milk
Acid aroma	Typical aroma related to the formation of fatty acids by hydrolysis of triglycerides	None: UHT whole milk, Itambé Strong: natural yogurt, Paulista
Natural queijoão cremoso aroma	Milk aroma with mild salty perception	Low: UHT whole milk, Itambé High: creamy queijoão cremoso, Poços de Caldas
Sweet taste	Taste perceived by stimulus sugars sucrose, glucose, and lactose	None: UHT whole milk, Itambé Strong: 5 g of milk powder, Ninho, diluted in 10 mL of UHT whole milk, Itambé
Bitter taste	Taste perceived by stimulating alkaloid chemical compounds	None: UHT whole milk, Itambé Strong: cream cheese, Polenghi
Acid taste	Taste perceived by stimulus ions released by organic acids	None: UHT whole milk, Itambé Strong: cream cheese, Philadelphia
Salty taste	Taste perceived by soluble salts such as sodium chloride	Low: 0.1 g of Na Cl + 40 mL of water solution High: 0.4 g of Na Cl + 40 mL of water solution
Buttery flavor	Flavor associated with unsalted butter	Low: UHT whole milk, Itambé Strong: unsalted butter, Elegê
Artificial queijoão cremoso flavor	Flavor caused by the substance that gives cheese flavor to food	None: UHT whole milk, Itambé Strong: queijoão sabor 4 queijos, Pura nata
Natural queijoão cremoso flavor	Taste associated with dairy product, combined with light perception of salty and acid tastes	Low: cream cheese, Polenghi High: creamy queijoão cremoso, Poços de Caldas
Oil film	Fatty sensation in the oral mucosa and lips	None: UHT whole milk, Itambé Strong: unsalted butter, Elegê
Oral adhesiveness	Adherence to the palate when pressed against the roof of the mouth by the tongue	Low: UHT cream, Nestlé High: UHT cream, Polenghi
Oral consistency	Speed at which the sample melts in the mouth; faster = less consistent	None: UHT cream, Nestlé High: UHT processed cheese, Polenghi
Color	Queijoão characteristic generated from the light reflectance of the resulting product and staining	White: natural yogurt, Paulista Yellow: sweetened condensed milk, Leite Moça
Brightness	Intensity of light reflection	Low: cream cheese, Polenghi High: sweetened condensed milk, Leite Moça
Consistency	By dividing the product in half with a trowel and speed with which the parties reunite	Low: sweetened condensed milk, Leite Moça High: cream cheese, Polenghi
Adhesiveness	Power joining the spoon when lying on the surface of the product, using only its own weight, and manually raised at an angle of 90°	Low: sweetened condensed milk, Leite Moça High: pastry Dulce de leite, Elegê
Gelatinous quality	Feature that the product has when its consistency resembles gelatin	None: UHT cream, Nestlé High: Royal Vanilla flan prepared according to manufacturer's instructions
Homogeneity	Feature that the product has when its composition or its appearance is completely equal	Low: Strawberry jam, Turma da Mônica High: UHT cream, Nestlé
Forming wire	Product features to form long strands to be handled with the spatula	None: natural yogurt, Paulista High: sweetened condensed milk, Leite Moça
Spreadability	The ease with which the product at 10°C is spread on toast with spatula	Low: strawberry jam, Turma da Mônica High: UHT cream, Nestlé

¹Itambé (Uberlândia, MG, Brazil), Mane (Rio de Janeiro, RJ, Brazil), Elegê (BRF Brasil, Poços de Caldas, MG, Brazil), Polenghi (Goatuba, GO, Brazil), Philadelphia (Kraft Foods, Sao Paulo, SP, Brazil), Pura nata (Alto da Boa Vista Frutal, MG, Brazil), Leite Moça (Nestlé, Ituiutaba, MG, Brazil), Royal (Mondelez International, Bauru, SP, Brazil), Turma da Mônica (Geleia Homemade, Itupeva, SP, Brazil).

attributes were adapted from the scale used in the DA. In the DA, color ranged from white to yellow, so we evaluated “yellowness” and “whiteness” in the CATA. In the DA, the score for homogeneity varied from low to high, so for the CATA, we revised these extremes to be “homogeneous” and “heterogeneous.” Furthermore, other attributes were revised to be more easily understood by consumers: fatty (oil film), ease of melting in the mouth (oral consistency), viscosity (form wire), and creaminess (consistency).

Consumers were asked to select how many terms they considered appropriate to describe the samples. The position of the terms in the questionnaire was adapted according to recommended procedures from Ares and Jaeger (2013), who found that consumers had an easier time with a CATA questionnaire when terms were grouped (i.e., odor, taste, appearance). Therefore, descriptors were assembled into 3 major groups: appearance (brightness, yellowness, whiteness, homogeneity, gelatinous quality, heterogeneity, viscosity, creaminess, and spreadability), natural and artificial requeijão cremoso aroma, and oral perception (sweet taste, salty taste, acid taste, bitter taste, natural and artificial requeijão cremoso flavor, buttery flavor, oil film, and ease of melting in the mouth). Then, groups were arranged on the page so that each group occupied all positions the same number of times. Words within attribute groups always appeared in a fixed order. Thus, we obtained 6 different page models.

Statistical Analysis

We analyzed findings from the DA using 2-way ANOVA (samples and assessors and their interaction as sources of variation), followed by Tukey's test for comparison between means ($P < 0.05$) to check for significant differences between samples for each attribute (Gaze et al., 2015). We also applied principal component analysis to the mean values for sensory attribute intensity using correlation data (Cruz et al., 2013). For the CATA findings, we applied Cochran's Q test to each sensory descriptor to evaluate possible differences between treatments (samples) with binary responses. We calculated correspondence analysis using chi-squared distances on the frequency of each sample and attribute, obtaining a contingency table with orthogonal components and maximizing the sequential representation of variation of data (Vidal et al., 2015).

We tested multidimensional alignment (MDA) and multidimensional scaling (MDS) based on phi coefficient values (Meyners et al., 2013), new approaches recently suggested for evaluating CATA findings. We used MDA to evaluate the association of the sensory descriptors with each sample. By calculating the cosine

of the angle formed between each attribute and sample (range -1 to 1), it is possible to determine which attributes have a strong relationship with each sample and obtain complete information about the relationship between products and attributes. Absolute cosines below 0.707 [$= \cos(45^\circ) = -\cos(135^\circ)$] indicate very little relationship (Carr et al., 2009). We used the phi coefficient to check the correlation between attributes. When applied to all assessors, it allows us to determine which attributes typically appear together and which are used independently. The phi coefficients between pairs of attributes enabled us to construct a matrix of similarities that we submitted to metric MDS. The degree of correspondence among the distances between points implied by the MDS map and the matrix input by the user is measured (inversely) by a stress function. When the MDS map perfectly reproduces the input data, the stress is zero. Thus, the smaller the stress, the better the representation (Granato and Ares, 2014).

Finally, we used multiple factor analysis to compare both sensory configurations (samples and sensory descriptors) described by each methodology, assessing the sensory positioning of products in a single map. A 6-row matrix, in which each row corresponded to each sample data, was constructed with 2 blocks of columns, corresponding to the positions of the samples at the 2 first dimensions of each methodology. The similarity/correlation RV coefficient was used as a quantitative measure of this correspondence (Cruz et al., 2013; Santos et al. 2013; Pontual et al., 2017).

RESULTS AND DISCUSSION

Descriptive Analysis

The DA resulted in 23 sensory descriptors, more than the number obtained in a previous study (Garruti et al., 2003), and demonstrating the sensory complexity of the samples. Table 2 shows the results of the DA test. We observed significant differences for most attributes, indicating a wide variety of sensory characteristics for this group of products and providing evidence for the different procedures and formulations used by dairy companies to make requeijão cremoso. Sample I (traditional requeijão cremoso) was characterized by increased brightness and wire formation, more intense white color, and high homogeneity. Samples II and III exhibited similar profiles, with intermediate brightness, greater tendency to yellow, and a flavor similar to that of traditional requeijão cremoso. Sample III also had the highest sweetness and lower saltiness intensities. Sample IV had high saltiness intensity, lower brightness, and a strong buttery flavor. Sample V was different from the other samples with respect to the

Table 2. Attribute mean values for each sample of requeijão cremoso in the descriptive analysis using a 15-cm nonstructured intensity scale

Attribute	Requeijão cremoso sample ¹					
	I	II	III	IV	V	VI
Brightness	13.28 ^a	9.69 ^b	10.76 ^b	10.76 ^b	6.65 ^c	10.79 ^b
Color	3.25 ^d	9.94 ^a	8.14 ^b	5.06 ^c	6.88 ^b	4.79 ^{cd}
Consistency	6.97 ^c	9.69 ^b	8.78 ^{bc}	12.49 ^a	12.29 ^a	13.10 ^a
Adhesiveness	8.50 ^b	9.06 ^b	8.74 ^b	13.36 ^a	10.04 ^b	13.07 ^a
Gelatinous quality	0.11 ^b	0.24 ^b	0.18 ^b	0.22 ^b	13.00 ^a	0.26 ^b
Homogeneity	14.03 ^a	13.02 ^a	12.98 ^a	12.91 ^a	4.71 ^b	13.71 ^a
Forming wire	9.03 ^a	6.08 ^b	3.63 ^c	0.96 ^d	0.17 ^e	2.76 ^{cd}
Spreadability	10.76 ^{ab}	14.21 ^a	11.45 ^a	9.81 ^{ab}	5.84 ^b	10.31 ^{ab}
Artificial requeijão cremoso aroma	1.10 ^c	2.61 ^b	1.4 ^{bc}	1.25 ^c	12.32 ^a	1.49 ^{bc}
Buttery aroma	5.91 ^a	6.17 ^a	6.05 ^a	7.24 ^a	5.41 ^a	6.58 ^a
Sweet aroma	3.40 ^a	3.21 ^a	5.12 ^a	3.49 ^a	0.73 ^a	5.18 ^a
Acid aroma	1.82 ^b	2.41 ^{ab}	2.10 ^b	1.77 ^b	3.45 ^a	2.22 ^{ab}
Natural requeijão cremoso aroma	7.76 ^a	8.41 ^a	9.37 ^a	7.69 ^a	2.92 ^b	6.88 ^a
Buttery flavor	7.20 ^b	7.23 ^b	6.55 ^b	10.03 ^a	6.61 ^b	8.17 ^{ab}
Artificial requeijão cremoso flavor	0.92 ^c	2.66 ^b	1.20 ^c	1.27 ^{bc}	11.77 ^a	0.833 ^c
Natural requeijão cremoso flavor	6.02 ^{bc}	7.84 ^{ab}	9.64 ^a	5.86 ^{bc}	2.69 ^d	4.48 ^{cd}
Salty taste	9.80 ^a	9.97 ^a	7.06 ^b	11.28 ^a	10.19 ^a	9.21 ^a
Sweet taste	1.23 ^c	3.89 ^b	6.74 ^a	0.86 ^c	0.44 ^c	0.66 ^c
Bitter taste	3.85 ^a	4.91 ^a	3.77 ^a	4.83 ^a	3.68 ^a	4.98 ^a
Acid taste	4.23 ^a	4.95 ^a	3.51 ^a	3.49 ^a	3.04 ^a	4.88 ^a
Oral adhesiveness	8.15 ^b	8.81 ^b	8.37 ^b	10.03 ^{ab}	10.87 ^a	10.94 ^a
Oral consistency	6.67 ^b	6.99 ^b	6.51 ^b	8.19 ^{ab}	9.51 ^a	9.43 ^a
Oil film	5.11 ^a	4.84 ^a	5.07 ^a	5.94 ^a	6.67 ^a	4.60 ^a

^{a-e}Means with different superscript letters in the same column differed ($P < 0.05$).

¹I = traditional requeijão cremoso; II, III, and IV = requeijão cremoso with added starch; V, VI = requeijão cremoso with added starch and vegetable fat.

following attributes: gelatinous quality, homogeneity, spreadability and wire formation, artificial requeijão cremoso aroma and artificial requeijão cremoso flavor, sweet aroma, and consistency in the mouth. Finally, sample VI showed a tendency to white and increased consistency, adhesiveness, homogeneity, and oral adhesiveness. We observed no significant differences ($P > 0.05$) between the samples for the following attributes: buttery aroma, acid taste, and oil film.

Principal component analysis explained approximately 76% of the variation when considering the 2 first dimensions (Figure 1). The first dimension was responsible for approximately 50% of the variation, characterized by natural requeijão cremoso aroma, homogeneity, and natural requeijão cremoso flavor. The second dimension was responsible for approximately 26% of the variation, characterized by adhesiveness, buttery flavor, buttery aroma, and bitter taste. Samples I, II, and III were characterized by natural requeijão cremoso aroma and flavor, sweet taste, sweet aroma, forming wire, brightness, homogeneity, and spreadability. Samples IV and VI were characterized by adhesiveness, buttery flavor, buttery aroma, and bitter taste. Sample V was characterized by artificial requeijão cremoso aroma and flavor, oil film, color, and gelatinous quality.

We found no studies describing a DA of requeijão cremoso containing starch and vegetable in the literature,

so we used traditional requeijão cremoso for comparison. The attributes used to describe the samples were similar to those reported by Garruti et al. (2003), who studied 4 commercial samples of requeijão cremoso. When comparing those results with the ones obtained in the present study, we noted that forming wire, salty taste, consistency, adhesiveness, and yellow color were important characteristics of this type of processed cheese.

CATA

Cochran's Q test (Table 3) showed differences in all attributes among the samples, except for acid taste and viscosity, emphasizing the efficacy of consumer CATA questions in identifying sensory differences. The terms used in the CATA questionnaire were easy to understand, and some differences from the trained panel were due to intrinsic differences in the methods.

A correspondence analysis bidimensional map is shown in Figure 2. For correspondence analysis, we divided the samples into 3 groups: samples I, IV, and VI in the upper left quadrant; samples II and III in the lower left quadrant; and sample V in the upper right quadrant. Considering the frequency for each attribute, shown in Table 3, we were able to obtain a description of samples. Samples I and VI were in almost the same

Table 3. Frequency mention of sensory attributes associated with each sample of requeijão cremoso by consumers (n = 121) on check-all-that-apply questions

Attribute	Sample ¹						P-value ²
	I	II	III	IV	V	VI	
Sweet taste	9	31	42	9	10	4	<0.001
Salty taste	62	63	35	69	56	60	<0.001
Acid taste	18	18	19	13	25	12	0.125
Bitter taste	13	13	8	12	23	9	0.017
Natural requeijão cremoso flavor	56	23	30	38	6	58	<0.001
Artificial requeijão cremoso flavor	28	43	32	33	69	15	<0.001
Buttery flavor	22	36	37	33	23	24	0.028
Fatty	28	45	36	36	55	34	0.001
Easy melting on mouth	54	52	53	64	21	49	<0.001
Natural requeijão cremoso aroma	46	27	29	33	8	52	<0.001
Artificial requeijão cremoso aroma	17	27	19	13	56	11	<0.001
Brightness	72	41	44	46	19	60	<0.001
Yellow color	10	96	66	41	19	15	<0.001
White color	81	9	29	53	75	72	<0.001
Homogeneity	90	73	78	72	39	86	<0.001
Heterogeneity	2	6	3	6	38	6	<0.001
Gelatinous quality	3	5	1	5	60	10	<0.001
Viscosity	34	27	24	28	23	25	0.508
Creaminess	61	62	66	64	17	78	<0.001
Spreadability	37	28	44	36	11	23	<0.001

¹I = traditional requeijão cremoso; II, III, and IV = requeijão cremoso with added starch; V, VI = requeijão cremoso with added starch and vegetable fat.

²P-value greater than $\alpha = 0.05$ indicates no significant difference.

Figure 1. Principal component analysis of requeijão cremoso samples using descriptive analysis. I = traditional requeijão cremoso; II, III, and IV = requeijão cremoso with added starch; V, VI = requeijão cremoso with added starch and vegetable fat. F = factor. Color version available online.

Figure 2. Correspondence analysis of requeijão cremoso samples using check-all-that-apply findings. I = traditional requeijão cremoso; II, III, and IV = requeijão cremoso with added starch; V, VI = requeijão cremoso with added starch and vegetable fat. F = factor. Color version available online.

position and had the following properties: brightness, natural requeijão cremoso flavor, and natural requeijão cremoso aroma. These were also the attributes most likely to describe the samples. In the same quadrant, sample IV was homogeneous and creamy, and according to the attributes selected, it was also salty and melted easily in the mouth. Samples II and III had a yellow color, sweet taste, and buttery flavor. Finally, sample V was gelatinous, heterogeneous, and had an artificial requeijão cremoso aroma and flavor. Whiteness of requeijão cremoso was also frequently selected by consumers.

After developing the correspondence analysis map, we applied MDA to the coordinates of each sample and sensory descriptors. Table 4 shows the relationship between attributes and samples using MDA (cosine values >0.707 suggesting a strong relationship between samples and the attributes). Positive values indicate that the product is strongly characterized by the attribute, and negative values indicate that the product is not characterized by the attribute. Sample I was correlated with viscosity, homogeneity, brightness, and natural requeijão cremoso aroma/flavor (cosines 1.00, 0.74, 0.92, 0.93, and 0.96, respectively); it was not correlated with sweet taste, acid taste, artificial requeijão cremoso flavor, or fatty (-0.71 , -0.78 , -0.79 , and -0.82 , respectively). In contrast, samples II and III

were characterized as yellow and had a buttery flavor and a sweet taste. The terms spreadability, creaminess, viscosity, homogeneity, brightness, natural requeijão cremoso aroma, easily melted in the mouth and natural requeijão cremoso flavor were the main attributes of sample IV. Sample V was correlated with gelatinous quality, fatty, heterogeneity, artificial requeijão cremoso aroma/flavor, bitter taste, and an acid taste. Sample VI was correlated with viscosity, homogeneity, brightness, and natural requeijão cremoso aroma/flavor. These findings could be interesting for dairy processors, because they can evaluate the attributes that were strongly related to the traditional sample, which did not contain starch and vegetable fat, and use it as a guideline for developing similar products. For example, sample VI, which does contain starch and vegetable fat, had a strong correlation with the same attributes (homogeneity, brightness, and natural requeijão aroma/flavor) as sample I.

The clear and complete relationship between attributes and samples that can be assessed by MDA is not always available using the bidimensional map obtained by correspondence analysis (Meyners et al., 2013). For instance, sample V did not present a clear association with bitter taste, salty taste, and sour taste when assessed by correspondence analysis bidimensional map. Use of MDA to analyze CATA findings is advantageous

Table 4. Cosine values between vector pairs (product vector vs. main sensory terms) in the characterization of samples obtained by multidimensional alignment for requeijão cremoso samples

Attribute	Sample ^{1,2}					
	I	II	III	IV	V	VI
Sweet taste	-0.71	1.00	0.92	-0.06	-0.26	-0.73
Salty taste	0.54	-0.98	-0.98	-0.15	0.46	0.57
Acid taste	-0.78	0.10	-0.30	-1.00	0.93	-0.76
Bitter taste	-0.50	0.27	-0.63	-0.95	1.00	-0.46
Natural requeijão cremoso flavor	0.96	-0.48	-0.09	0.90	-0.72	0.95
Artificial requeijão cremoso flavor	-0.79	0.12	-0.28	-1.00	0.92	-0.77
Buttery flavor	-0.66	1.00	0.94	0.01	-0.33	-0.68
Fatty	-0.82	0.17	-0.23	-0.99	0.90	-0.80
Easy melting on mouth	0.47	0.30	0.65	0.94	-1.00	0.43
Natural requeijão cremoso aroma	0.93	-0.38	0.01	0.94	-0.79	0.91
Artificial requeijão cremoso aroma	-0.70	-0.02	-0.41	-1.00	0.97	-0.67
Brightness	0.92	-0.37	0.02	0.95	-0.79	0.91
Yellow color	-0.70	1.00	0.92	-0.05	-0.27	-0.72
White color	0.57	-0.98	-0.97	-0.12	0.43	0.60
Homogeneity	0.74	-0.04	0.35	1.00	-0.95	0.72
Heterogeneity	-0.51	-0.26	-0.62	-0.95	1.00	-0.48
Gelatinous quality	-0.44	-0.33	-0.68	-0.92	1.00	-0.41
Viscosity	1.00	-0.67	-0.33	0.78	-0.53	1.00
Creaminess	0.59	0.16	0.53	0.98	-0.99	0.56
Spreadability	0.27	0.49	0.79	0.84	-0.97	0.24

¹I = traditional requeijão cremoso; II, III, and IV = requeijão cremoso with added starch; V, VI = requeijão cremoso with added starch and vegetable fat.

²Bold values indicate correlation of the sensory attributes with the respective sample. Positive values indicate positive correlation, and negative values indicate negative correlation.

and confirms recent observations from a study evaluating low-sodium dry fermented sausages (Santos et al., 2015).

We performed MDS using phi coefficients between attributes (Figure 3). Multidimensional scaling provides a map in which terms are distributed in 2 dimensions. The proximity of terms in the bidimensional map indicates their similarity with respect to sensory properties. The results showed a stress value of 0.162 and high validity; according to Granato and Ares (2014), values below 0.1 are considered fair and those up to 0.20 are acceptable. As shown in Figure 3, it is possible to observe a correlation between natural requeijão cremoso flavor/aroma, spreadability, homogeneity, creaminess, easily melted in the mouth and brightness, which were coherent and desirable in a typical processed cheese. We also observed a good correlation for artificial requeijão cremoso flavor/aroma, fatty, viscosity, heterogeneity, gelatinous quality, and bitter taste. These characteristics are not desirable in traditional requeijão cremoso and may have been associated with the vegetable fat and other additives (i.e., flavorings, thickeners) used to mimic the characteristics of the traditional product (Van Dender, 2014). In addition, we observed an association between yellow color, buttery flavor, sweet taste, and acid taste in the upper left quadrant. The sweet and acid tastes may have been seen as similar by consumers because of a cross-modal interaction. Cross-

modal taste and aroma interactions have been reported in the perception of cheese flavor (Niimi et al., 2016), and they should be taken in account in developing processed cheese.

These findings may be useful as a guideline for the processed cheese industry. Although one of the principal attributes of this processed cheese is natural requeijão cremoso natural flavor and aroma, it may also present with brightness, spreadability, homogeneity, creaminess, and easy melt in the mouth. Similar products should be formulated to achieve these characteristics. For example, the starch level will affect the texture of the sample, because starch interacts with the water in the cheese, forming a gel and making it firmer (Mounsey and O'Riordan, 2001; Ferrão et al., 2016). Vegetable fat levels will result in insufficient emulsification, illustrated by a highly hydrophobic character and more primary bonds, with a direct effect on fat globule structure (increased diameter). This in turn causes a decrease in protein-protein and protein-fat interactions in the processed cheese matrix, lowering the elasticity of the product and affecting its spreadability and ease of melting in the mouth (Cunha et al., 2010).

Comparison Between CATA and Descriptive Analysis

We used multiple factor analysis to analyze the consensus configuration between DA and CATA. Multiple

factor analysis explained 75% of the variability using 2 dimensions, in which the first dimension accounted for approximately 52% and the second dimension explained 23%. The RV coefficient values ranged from 0 to 1, with values closer to 1 suggesting adequate correlation between the methods (Fonseca et al., 2016). In this study, the RV coefficient was 0.843 ($P < 0.001$), indicating that both methodologies provided similar information about the sensory characteristics of the samples.

Figure 4 shows the consensus configuration of the samples associated with different colors according to each sensory methodology. The different positions show clear differences among samples, suggesting that consumers were able to discriminate appropriately between samples. The points corresponding to the 2 methods (CATA and DA) were close, suggesting that sample configurations were very similar for both methods, and that trained assessors and consumers perceived the samples similarly. Overall, our findings reinforced the use of descriptive methodologies with consumers—particularly CATA, because it is useful for small and medium dairy producers to obtain information about the sensory characteristics of their products that belong to the requeijão cremoso category. However, CATA, as with any other descriptive methodology using consumers, cannot be used as a replacement for DA; the latter is more accurate because assessors are extensively trained in the identification and quantification of sensory at-

tributes, enabling them to detect minor differences in formulation (Varela and Ares, 2012).

Standardized formulation of products in the requeijão cremoso category is lacking in the Brazilian dairy industry. For this reason, CATA can be a valuable, reliable, and economic sensory method of establishing a sensory profile for requeijão cremoso formulations. The use of MDS and MDA based on phi coefficient values allowed us to develop an adequate understanding of the sensory profile of requeijão cremoso samples with added vegetable fat and starch, possibly serving as a guideline for dairy processors who wish to improve the formulation of their products in accordance with consumer perceptions.

CONCLUSIONS

The CATA questionnaire proved to be an effective tool for characterizing different samples of requeijão cremoso, showing results that correlated well with conventional descriptive analysis by trained assessors. Multidimensional alignment and multidimensional scaling based on phi coefficient values were important and useful alternatives for obtaining a deeper understanding of the CATA findings, adding information to the traditional analysis. Adoption of these methods should be encouraged for the processed cheese industry when it conducts sensory profiling with consumers and using a CATA questionnaire. Overall, the findings of the

Figure 3. Multidimensional scaling of phi coefficients using check-all-that-apply findings. Dim = dimension. Color version available online.

Figure 4. Consensus configuration between descriptive analysis (DA) and check-all-that-apply (CATA) findings for requeijão cremoso samples using multiple factor analysis. I = traditional requeijão cremoso; II, III, and IV = requeijão cremoso with added starch; V, VI = requeijão cremoso with added starch and vegetable fat. F = factor. Color version available online.

present study may useful for companies that manufacture dairy foods with similar or complex sensory characteristics.

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