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A sensometric approach to the development of mortadella with healthier fats☆

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ABSTRACT

The aim of this study was to evaluate the sensory characteristics of mortadellas with different fat contents using Descriptive Analysis (DA) and Check-all-that-apply (CATA) questions and their relationship with overall liking (OL). Five mortadella samples were studied. Sample 1, containing 16% fat. Sample 2 was formulated with 8% fat. Samples 3 and 4 were prepared by replacing 50% fat by a pre-emulsion composed of fish, canola and olive oil. A commercial fat-reduced sample was also studied. The sensory characteristics of the samples were evaluated by DA. Besides, eighty-four consumers evaluated their OL using a 9-point scale and answered the CATA questions. Replacement or reduction of fat caused changes in the sensory characteristics of the samples. Commercial mortadella was the most liked. CATA questions along with penalty analysis and partial least squares regression (PLSR) of dummy variables on the OL helped to identify the attributes to be changed in the mortadella formulations.

1. Introduction

Meat products are fundamental constituents in the diet of several populations, providing essential nutrients such as protein, vitamins and minerals. However, these products are among the major contributors to saturated fat intake, which has been associated with several health problems. For this reason, there is an increasing interest in reducing the saturated fat of these products, while preserving their sensory quality.

The use of pre-emulsions (oil in water) as an animal fat substitute is a good technological alternative to obtain a healthier mortadella (Delgado-Pando, Cofrades, Ruiz-Capillas, & Jiménez-Colmenero, 2010), since it can be enriched with some beneficial fatty acids, such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), in addition to minimize the possibility of oil physically separating from the meat structure. However, the content and type of fat are key factors for the food product quality, being responsible for texture and flavor characteristics (Laguna, Primo-Martín, Varela, Salvador, & Sanz, 2014). Changes in the type and amount of fat used in the preparation of this type of product have important implications on sensory characteristics, leading to a decrease in consumers' acceptance (Santos et al., 2013).

For new product development and nutritional improvement reformulations, food companies need information on how consumers perceive the sensory characteristics of the products. These data are important to identify the drivers of liking (DL) in order to design products that meet consumers' expectations (Tarancón, Salvador, Sanz, Fiszman, & Tárrega, 2015). Generally, the relationship between liking and sensory characteristics of a food product is performed by comparing the data of DA and OL, using the external preference mapping (PREFMAP) (MacFie, 2007). Even DA, widely used as a reference for sensory profiles (Selani et al., 2016), is faced with some limitations, such as the difficulty of measuring perceptions and the high cost required to train and maintain a trained panel (Varela & Ares, 2012). These considerations have led sensory scientists to develop rapid sensory techniques, which are suitable for situations where the uses of conventional approaches are limited.

In this sense, the use of CATA questions may be useful to gather

☆ The application of statistics and data analysis in sensory and consumer data is called sensometrics.

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information on consumers' perceptions of food products by selecting a list of attributes that consumers consider appropriate to describe a food product (Varela & Ares, 2012). CATA questions have been used for sensory characterization of a wide range of food products, obtaining similar results to those provided by DA. Among those food products included are: apple and strawberry (Ares & Jaeger, 2013), vanilla ice cream (Dooley, Lee, & Meullenet, 2010), and citrus-flavored sodas (Plaehn, 2012). However, in the Meat Science and Technology area, there are few studies using CATA questions to evaluate consumer-based sensory characteristics. Henrique, Deliza, and Rosenthal (2014) performed a consumer sensory characterization of cooked ham using CATA questions. Dos Santos et al. (2015) studied the sensory profiling of low sodium salamis by QDA, CATA questions, and free listing. CATA questions were applied to sensory characterize turkey ham with reduced sodium content (Galvão, Moura, Barretto, & Pollonio, 2014). Choi et al. (2015) used CATA questions to identify the DL of barbecue sauce. Finally, Jorge et al. (2015) used CATA questions to evaluate mortadella.

In this context, this study aimed to evaluate the sensory characteristics of mortadellas with healthier fats using DA and CATA questions, and to determine their relationship with the OL, using partial least squares regression and penalty analysis. In addition, the ideal mortadella was used to recommend changes on the mortadella formulation.

2. Materials and methods

2.1. Samples preparation

The mortadella samples were manufactured at the Processing Plant of the Centro de Tecnologia de Carnes (CTC) of the Instituto de Tecnologia de Alimentos (ITAL) (Campinas, SP, Brazil) as reported by (Saldaña et al., 2015b), following a randomized block design with 3 blocks (each block corresponding to an independent mortadella processing). Four mortadella samples were manufactured with different fat contents based on Table 1 (Saldaña et al., 2017). In samples 3 and 4, pre-emulsions were prepared by stirring sodium alginate and milk protein concentrate with ultrapure water using a magnetic stirrer (IKA, model RH basic 1) at 500 rpm and 60 °C, until complete dissolution. After cooling to room temperature, the solution was emulsified with the mixture of oils at 500 rpm for 10 min at 30 °C (Delgado-Pando et al., 2010; Marchetti, Andrés, & Califano, 2014). Also, a commercial fat-reduced sample (11% fat content) was randomly selected from the local market. The samples of the present study were selected with the purpose of allowing the comparison of laboratory-formulated mortadellas in relation to their competitor in the market.

2.2. Microbiological analysis

Microbiological analysis was performed before the sensory analysis, in order to verify the hygienic quality of the mortadellas, according to the limits specified by the Agência Nacional de Vigilância Sanitária (Brazilian Health Surveillance Agency - BHSA) (BRASIL, 2001). Microbiological analyses were as follows: Sulphite-reducing clostridia (colony-forming units/g - CFU/g) (Labbe, 2001), thermotolerant coliforms (most probable number/g – MPN/g) (ISO, 2005), coagulase-positive staphylococcus (CFU/g) (Bennett, Hait, & Tallent, 2001), and *Salmonella sp.* (presence or absence in 25 g) (ISO, 2007a). All microbiological analyses were performed at CTC - ITAL.

2.3. Sensory analysis

Sensory analyses were performed at the Unidade Laboratorial de Referência de Análises Físicas, Sensoriais e Estatística (LAFISE) of the Centro de Ciência e Qualidade de Alimentos (CCQA) of ITAL in a sensory laboratory designed in accordance with ISO 8589 (ISO, 2007b). The data were collected using *Compusense Five* - version 5.4 – (Compusense Inc., Guelph, Canada). Samples were served in plastic containers, labeled with three-digit random numbers and presented in a sequential monadic way, following a balanced presentation order (Macfie, Bratchell, Greenhoff, and Vallis, 1989). Mineral water was used as rinsing between samples. Before sensory evaluation, both assessors and consumers read and signed the free and informed consent form.

2.3.1. Descriptive analysis

Descriptive analysis was developed in sixteen-1 h sessions, according to Stone, Bleibaum, & Thomas (2012) and Lawless & Heymann (2010) and was performed according to the following steps.

2.3.1.1. Recruitment and selection of the candidates. Candidates were recruited from LAFISE - CCQA - ITAL database and selected based on: (i) Non-existence of physical or physiological deficiencies that could limit their sensory perception; (ii) Interest in participating in the DA and to like to eat the product of interest; (iii) Sensory acuity, assessed by stimuli related to the basic tastes; and (iv) Discriminative ability, evaluated through sequential analysis of triangular tests.

2.3.1.2. Vocabulary development. Vocabulary was developed using Kelly's Repertory Grid Method (Moskowitz, 1983). Mortadella samples were compared in pairs regarding the differences and similarities between them, considering appearance, odor, texture and taste. After that, under the supervision of a panel leader, a group discussion was conducted in order to eliminate redundant descriptors, synonyms and little cited descriptors. Consensually, descriptors that best described the similarities and differences between samples were selected. The panel also suggested reference samples for each attribute, which were later used in the panel training. Afterwards, with the selected descriptors, an evaluation ballot of the samples was developed, presenting a non-structured 10 cm-long scale beside each descriptor, which was anchored at the ends with “minimal” on the left, and “maximum” on the right.

2.3.1.3. Panel training, panel performance, and final selection of assessors. The aim of the panel training was to provide the assessors a better understanding on how to measure all the descriptors of the five mortadella samples, and allow them to develop the same sensory memory. Panel performance and final selection of assessors were performed according to Saldaña et al. (2015), considering three

Table 1
Concentration of total fat, animal fat, pre-emulsion fat used in the mortadella formulation.

Samples	Total fat (%)	Animal fat (%)	Pre-emulsion fat (%)	Composition of the pre-emulsion
1	16	16	0	–
2	8	8	0	–
3	16	8	8	30% oil mixture[a] + 0.5% sodium alginate + 0.5% milk protein concentrate + 69% water
4	16	8	8	30% oil mixture[a] + 0.75% sodium alginate + 1% milk protein concentrate + 68.25% water
5[b]	11	–	–	–

[a] Oil mixture composition: 20% fish oil, 50% canola oil, and 30% olive oil.
[b] Commercial sample available from local industry.

Table 2
Definitions and references of the descriptors used in DA.

Parameter	Attribute	Definition	Reference
Appearance	Pink color	Intensity of the characteristic pink color of the sausage.	**Light:** Slice of a light chicken mortadella (Ceratti). **Dark:** Slice of a light bologna mortadella (Ceratti).
	Seasoning particles	Amount of seasoning particles visually observed on the surface of the Mortadella slice.	**None:** Slice of a light chicken Mortadella (Ceratti). **A lot:** 0.002 g of black pepper spread on a slice of the sample 1.
	Homogeneity	Visual perception of the surface homogeneity of the mortadella slice.	**Slight:** Slice of the sample 1. **A lot:** Homogeneous appearance (chicken mortadella - Ceratti).
	Amount of holes	Amount of holes, also perceived as bubbles, by visual observation of the mortadella slice.	**Slight:** Slice of light chicken mortadella (Ceratti) **A lot:** Slice of a Mortadella with 80% of its area with holes.
	Size of holes	Visual perception of the size of holes of the mortadella slice, ranging from small (approximately 1 mm) to large (approximately 10 mm).	**Small:** Slice of a Mortadella with hole size of approximately 1 mm. **Large:** Slice of a Mortadella with hole size of approximately 10 mm.
	Brightness surface	Visual perception of the brightness surface (oiliness and moisture) of the mortadella slice due to light reflection.	**None:** Mortadella slice with the oiliness and moisture of the surface removed with absorbent paper **A lot:** 0.2 g glycerin over the slice of a traditional bologna mortadella (Ceratti).
Odor	Characteristic odor	Intensity of the characteristic odor of the mortadella, a mixture of meat and seasonings, such as garlic, onion and pepper.	**Slight:** Light chicken mortadella (Ceratti). **A lot:** Traditional bologna mortadella (Ceratti).
	Seasoning odor	Intensity of the odor of the seasonings, such as garlic and onion.	**Slight:** Light chicken mortadella. **A lot:** Commercial seasoning of garlic and onion.
	Pepper odor	Intensity of the odor of black pepper.	**Slight:** Light chicken mortadella. **A lot:** black pepper.
	Strange odor	Intensity of uncharacteristic odor of mortadella, such as mechanically deboned meat or lipid oxidation odors.	**Slight:** Traditional bologna mortadella (Ceratti). **A lot:** Mechanically deboned meat.
Texture	Firm texture	Oral perception of the firmness of the product. A little firm product does not present resistance to chewing, as opposed to a very firm product.	**Slight:** Slice of a light chicken mortadella (Ceratti). **A lot:** Slice of a salami Italian type (Ceratti).
	Gelatinous texture	Oral perception obtained by cutting the sample with teeth. A very gelatinous product makes noise when chewing and breaks into small pieces that do not come together to form a homogeneous mass.	**Slight:** Slice of a light chicken mortadella. **A lot:** Gummy bears.
	Succulent texture	Feeling of the moisture of the product. A very succulent product releases much liquid as the product is bitten and a little succulent product releases little liquid, giving the feeling of a dry product.	**Slight:** Slice of a light bologna mortadella (Ceratti) cut the day before. **A lot:** Slice of a traditional bologna mortadella (Ceratti).
Taste	Mortadella taste	Intensity of the characteristic taste of mortadella, a mixture of meat and seasonings, such as garlic, onion and pepper.	**Slight:** Light bologna mortadella (Ceratti). **A lot:** Traditional bologna mortadella (Ceratti).
	Seasoning taste	Intensity of the taste of seasonings, such as garlic and onion.	**Slight:** A 1% onion and garlic seasoning solution in mineral water at 40 °C. **A lot:** A 5% onion and garlic seasoning solution in mineral water at 40 °C.
	Pepper taste	Intensity of the taste of black pepper.	**Slight:** A 1% black pepper solution in mineral water at 40 °C. **A lot:** A 5% black pepper solution in mineral water at 40 °C.
	Salty taste	Describes the primary taste produced by an aqueous solution of sodium chloride.	**Slight:** A 0.25% sodium chloride solution in mineral water at 40 °C. **A lot:** A 1.2% sodium chloride solution in mineral water at 40 °C.
	Umami taste	Describes the primary taste produced by an aqueous solution of monosodium glutamate	**None:** mineral water **A lot:** A 1% monosodium glutamate solution in mineral water at 40 °C.
	Strange taste	Intensity of strange and uncharacteristic taste of mortadella, such as cereals, sour, citrus, fish, soap, and olive tastes.	**Slight:** Traditional bologna mortadella (Ceratti) **A lot:** cereal, orange, olive
	Strange after taste	Intensity of strange taste perceived in the mouth after swallowing, such as cereals, sour, citrus, fish, soap, and olive tastes.	**Slight:** Traditional bologna Mortadella (Ceratti) **A lot:** cereal, orange, olive

Ceratti is a Brazilian commercial brand of meat products.

criteria: discrimination, reproducibility, and consensus.

2.3.1.4. Final evaluation. The final evaluation was carried out in triplicate, according to the vocabulary developed by the trained panel (Table 2), using 3 mortadella samples per session. The panel consisted of 12 assessors, which evaluated 20 sensory attributes related to appearance, odor, texture, and taste.

2.3.2. Consumer study

Eighty-four consumers (21 male and 63 female, aged between 20 and 65 years) were recruited among students, researches and employees of ITAL. Consumers were asked to try the mortadella samples and to evaluate their OL using a structured 9-point hedonic scale, ranging from dislike extremely (1) to like extremely (9). Finally, they were asked about their socio-demographic information and the frequency of mortadella consumption.

2.3.2.1. CATA questions. Consumers answered the CATA questions composed of 41 sensory terms related to mortadella samples and presented by category (appearance, odor, texture, and taste), to avoid biases due to long terms list. Consumers were asked to select the terms that they considered appropriate to describe each mortadella and the terms they considered appropriate to describe their ideal mortadella. The selection of the sensory terms was based on a previous study (Jorge

Table 3
Assessing the global panel performance of the assessors.

Attributes	Sample (Sa)	Assessor (A)	Session (Se)	Sa*A	Sa*Se	A*Se
Pink color	< **0.001**	0.1136	0.2525	< **0.001**	**0.0189**	0.7203
Seasoning particles	0.3119	**0.0315**	0.4645	< **0.001**	0.1500	0.8635
Homogeneity	< **0.001**	< **0.001**	0.6783	< **0.001**	**0.2286**	0.0526
Amount of holes	< **0.001**	**0.0073**	0.0616	**0.0007**	**0.0201**	0.4640
Size of holes	< **0.001**	< **0.001**	0.4213	**0.0371**	**0.0291**	**0.0432**
Brightness surface	**0.0035**	< **0.001**	0.2307	< **0.001**	**0.0052**	0.8540
Characteristic odor	< **0.001**	< **0.001**	0.1364	< **0.001**	0.7509	0.4901
Seasoning odor	< **0.001**	< **0.001**	0.3795	< **0.001**	0.2718	0.4189
Pepper odor	< **0.001**	< **0.001**	0.8154	< **0.001**	0.8672	0.5172
Strange odor	< **0.001**	< **0.001**	0.6922	< **0.001**	0.7817	0.1400
Firm texture	**0.0012**	< **0.001**	**0.0417**	< **0.001**	0.8682	0.9203
Gelatinous texture	< **0.001**	< **0.001**	**0.0236**	< **0.001**	**0.0003**	0.7954
Succulent texture	**0.0404**	< **0.001**	0.3072	**0.0002**	0.6763	0.2749
Mortadella taste	< **0.001**	< **0.001**	0.1629	< **0.001**	0.5197	0.6925
Seasoning taste	< **0.001**	**0.0003**	0.4145	< **0.001**	0.3353	0.2867
Pepper taste	< **0.001**	< **0.001**	0.6148	< **0.001**	0.2702	0.9577
Salty taste	< **0.001**	< **0.001**	0.5641	< **0.001**	0.1572	0.8059
Umami taste	< **0.001**	**0.0001**	**0.0086**	< **0.001**	< **0.001**	0.1256
Strange taste	**0.0002**	< **0.001**	0.1299	< **0.001**	0.0849	0.7679
Strange after taste	< **0.001**	0.1122	0.3055	0.3569	0.8985	0.5423

Significant effects at 5% significance are highlighted in bold.

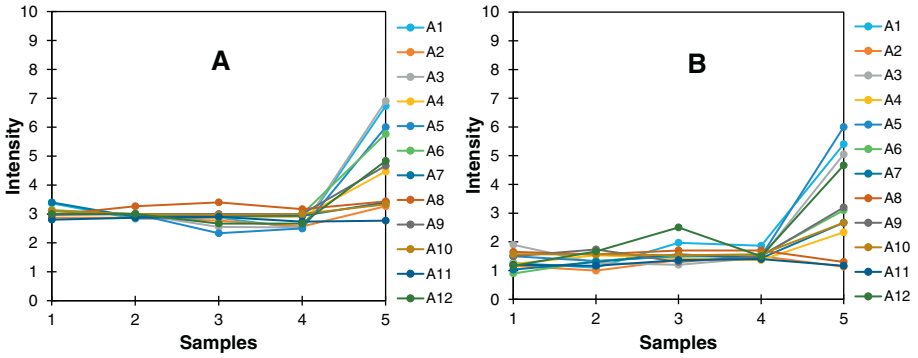

Fig. 1. Mean scores of the 12 assessors for the attributes: (A) Salty taste and (B) Pepper taste. A: Assessor. Sample 1: mortadella with 16% animal fat; Sample 2: mortadella with 8% animal fat; Sample 3: mortadella with 8% of animal fat + 8% pre-emulsion fat (30% oil mixture + 0.5% sodium alginate + 0.5% milk protein concentrate); Sample 4: mortadella with 8% of animal fat + 8% pre-emulsion fat (30% oil mixture + 0.75% sodium alginate + 1% milk protein concentrate); Sample 5: commercial mortadella.

et al., 2015), on the attributes obtained in the DA (Section 2.3.1).

2.4. Data analysis

2.4.1. Descriptive analysis

DA data were analyzed using the mixed analysis of variance (ANOVA) for the 20 attributes, 5 samples, 3 repetitions, 12 assessors and their double interactions as sources of variation. The source of variation "sample" was considered a fixed effect, while the others were considered random effects (Næs, Brockhoff, & Tomic, 2010). Tukey's HSD test was applied at a 5% significance level.

Principal component analysis (PCA) was performed on the Pearson's correlation matrix of the average scores of the sensory attributes that presented significant differences between samples. Confidence ellipses were also constructed using the parametric bootstrap considering 500 virtual assessors (Husson, Lê, & Pagès, 2005).

2.4.2. Overall liking

The OL data were analyzed by ANOVA, considering sample, consumer, and sample's presentation order as sources of variation. Tukey's HSD test was performed at a 5% significant level. Individual responses of the OL for each sample were analyzed through an internal preference mapping (MDPREF), using a PCA on the Pearson's correlation matrix (Macfie, 2007). The correlation between DA and OL data was performed by PLSR (Tenenhaus, Pagès, Ambroisine, & Guinot, 2005).

2.4.3. CATA questions

The frequency of mention of sensory attributes was determined by counting the number of consumers that used those terms to describe each mortadella (Meyners, Castura, & Carr, 2013). Afterward, a non-parametric Cochran's Q test was carried out to identify significant differences between mortadellas for each term.

Correspondence analysis (CA) was performed on the frequency of mention of the terms that presented significant differences between mortadellas, considering the Chi-square distances (Vidal, Tárrega, Antúnez, Ares, & Jaeger, 2015). The frequency of mention of the ideal mortadella was considered a supplementary variable in the CA.

Penalty analysis (PA) was carried out on consumer responses to determine the mean drop in OL associated with the deviation from the ideal mortadella for each term of the CATA questions. For each sample, the percentage of consumers who used a different attribute to describe the ideal mortadella was determined, as well as the mean variation in OL associated with this deviation.

According to the recommendation of Ares, Dauber, Fernández, Giménez, and Varela (2014), two dummy binary variables, identified as Z + and Z − (Z is the attribute analyzed) were considered. Thus, a value of 1 to Z +, and 0 to Z − was assigned when the attribute was present in the ideal mortadella and absent in the mortadella. On the other hand, a value of 0 to Z + and 1 to Z − was assigned when the attribute was absent in the ideal mortadella and present in the mortadella. If the attribute was present in both the ideal mortadella and the mortadella, a value of 0 to Z + and Z − was assigned. A PLSR on these dummy variables was performed to model the relationship between OL and the dummy variables generated for each term, following a similar approach to that performed by Xiong & Meullenet (2006).

Table 4
Descriptive analysis scores of mortadella samples (mean ± standard deviation).

Attribute	Samples				
	1	2	3	4	5
Pink color	4.8 ± 0.4^{bc}	5.0 ± 0.2^{b}	4.5 ± 0.6^{c}	3.9 ± 0.7^{d}	6.8 ± 0.8^{a}
Seasoning particles	3.0 ± 0.3^{b}	3.0 ± 0.5^{b}	3.1 ± 0.5^{ab}	3.4 ± 0.6^{a}	2.9 ± 1.2^{b}
Homogeneity	2.8 ± 0.5^{c}	3.1 ± 0.4^{b}	2.9 ± 0.7^{bc}	3.1 ± 0.7^{b}	5.1 ± 1.6^{a}
Amount of holes	5.5 ± 1.1^{a}	5.9 ± 0.4^{a}	5.6 ± 0.8^{a}	6.0 ± 0.7^{a}	2.5 ± 1.4^{b}
Size of holes	3.0 ± 0.8^{ab}	3.2 ± 0.9^{a}	2.8 ± 0.6^{b}	3.0 ± 0.8^{ab}	2.2 ± 1.3^{c}
Brightness surface	3.0 ± 0.5^{b}	3.0 ± 0.3^{b}	2.9 ± 0.5^{b}	3.1 ± 0.6^{b}	3.9 ± 1.6^{a}
Characteristic odor	6.6 ± 0.5^{a}	6.9 ± 0.3^{a}	6.4 ± 0.7^{b}	6.3 ± 0.5^{b}	5.2 ± 1.0^{c}
Seasoning odor	5.8 ± 0.5^{a}	5.9 ± 0.2^{a}	5.4 ± 0.7^{b}	5.5 ± 0.5^{b}	4.2 ± 1.0^{c}
Pepper odor	2.5 ± 0.3^{b}	2.5 ± 0.2^{b}	2.3 ± 0.3^{b}	2.4 ± 0.5^{b}	3.7 ± 1.6^{a}
Strange odor	1.6 ± 0.7^{c}	1.4 ± 0.3^{c}	1.8 ± 0.7^{bc}	2.0 ± 0.8^{b}	3.1 ± 1.5^{a}
Firm texture	6.0 ± 0.5^{a}	6.0 ± 0.3^{a}	6.1 ± 0.4^{a}	5.9 ± 0.5^{a}	5.1 ± 1.3^{b}
Gelatinous texture	6.8 ± 0.5^{a}	7.0 ± 0.2^{a}	7.0 ± 0.4^{a}	7.0 ± 0.6^{a}	4.4 ± 1.7^{b}
Juiciness texture	4.7 ± 0.6^{ab}	5.0 ± 0.3^{a}	4.5 ± 0.7^{bc}	4.7 ± 0.7^{ab}	4.3 ± 1.2^{c}
Mortadella taste	6.3 ± 0.4^{a}	6.4 ± 0.3^{a}	5.9 ± 0.7^{b}	5.8 ± 0.6^{b}	5.3 ± 0.9^{c}
Seasoning taste	5.7 ± 0.5^{ab}	6.0 ± 0.3^{a}	5.4 ± 0.6^{b}	5.4 ± 0.6^{b}	4.3 ± 1.2^{c}
Pepper taste	1.6 ± 0.4^{b}	1.5 ± 0.2^{b}	1.3 ± 0.4^{b}	1.4 ± 0.4^{b}	3.2 ± 1.8^{a}
Salty taste	3.1 ± 0.3^{b}	3.0 ± 0.2^{bc}	2.8 ± 0.4^{bc}	2.8 ± 0.4^{c}	4.6 ± 1.5^{a}
Umami taste	4.9 ± 0.3^{a}	4.9 ± 0.3^{a}	4.9 ± 0.6^{a}	4.9 ± 0.4^{a}	3.5 ± 1.4^{b}
Strange taste	1.4 ± 0.6^{c}	1.4 ± 0.3^{c}	2.2 ± 1.1^{b}	2.7 ± 1.3^{ab}	2.8 ± 1.3^{a}
Strange after taste	0.1 ± 0.2^{b}	0.1 ± 0.1^{b}	0.3 ± 0.6^{ab}	0.5 ± 0.6^{a}	0.6 ± 0.8^{a}

Values followed by different letters in the same row are significantly different ($p < 0.05$) according to Tukey's test.

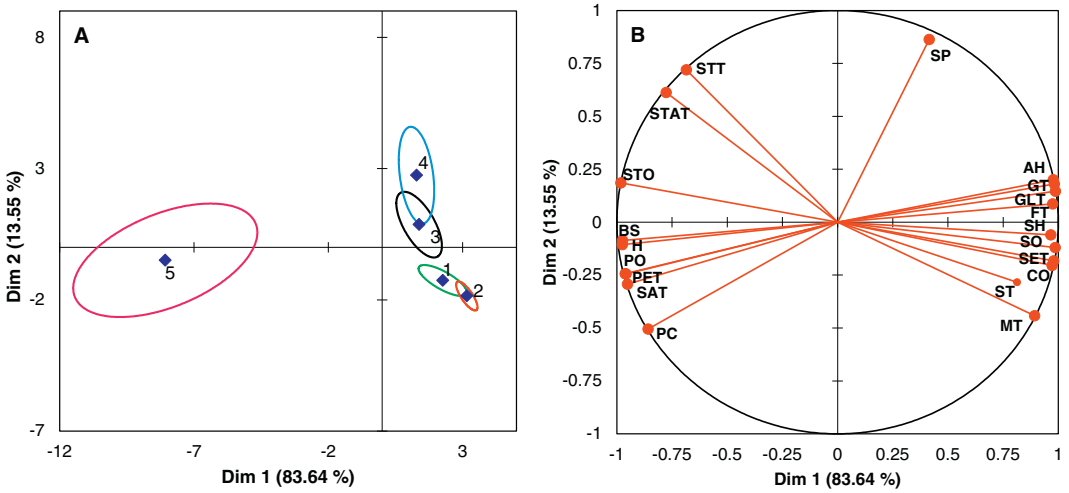

Fig. 2. PCA on the correlation matrix of the mean attributes: (A) Representation of the samples and (B) Representation of the attributes. PC: Pink color; SP: Seasoning particles; H: Homogeneity, AH: Amount of holes, SH: Size of holes, SB: Brightness surface, CO: Characteristic odor, SO: Seasoning odor, PO: Pepper odor, STO: Strange odor, FT: Firm texture, GT: Gelatinous texture, ST: Succulent texture, MT: Mortadella taste, SET: Seasoning taste, PET: Pepper taste, SAT: Salty taste, GLT: Umami taste, STT: Strange taste, SATA: Strange after taste.

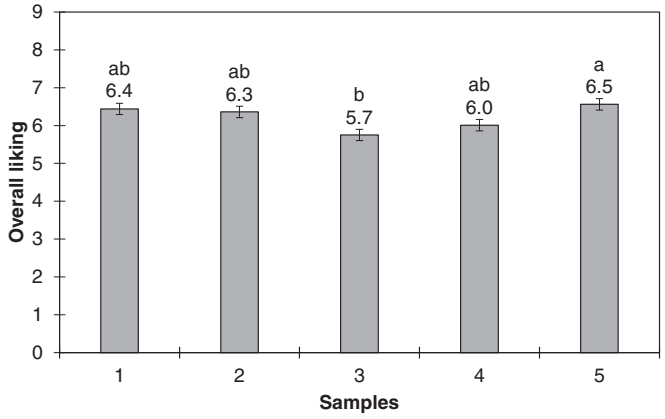

Fig. 3. Averages of the overall liking scores of the mortadella samples using a hedonic scale of 9 points. Different letters indicate significant differences according to the Tukey's test ($P < 0.05$).

2.4.4. Software

All analyses were carried out in XLSTAT 2015 (Addinsoft, New York, USA) and R (R Core Team, 2017), using SensoMineR (Lê & Husson, 2008) and FactoMineR (Lê, Josse, & Husson, 2008).

3. Results and discussion

3.1. Microbiological quality of mortadella

Microbiological counts of all treatments were < 10 CFU/g for sulphite-reducing clostridia, < 3 MPN for thermotolerant coliforms, and < 10^2 CFU/g for coagulase-positive staphylococcus. Salmonella was not detected in any of the samples. All treatments showed counts within the limits established by BHSA: sulfite-reducing clostridia: 5×10^2 CFU/g, thermotolerant coliforms: 10^3 MPN/g, coagulase-positive staphylococcus: 3×10^3 CFU/g, and Salmonella: absence/25 g. According to the microbial counts, the mortadellas developed in the given experimental conditions were safe and fit for consumption.

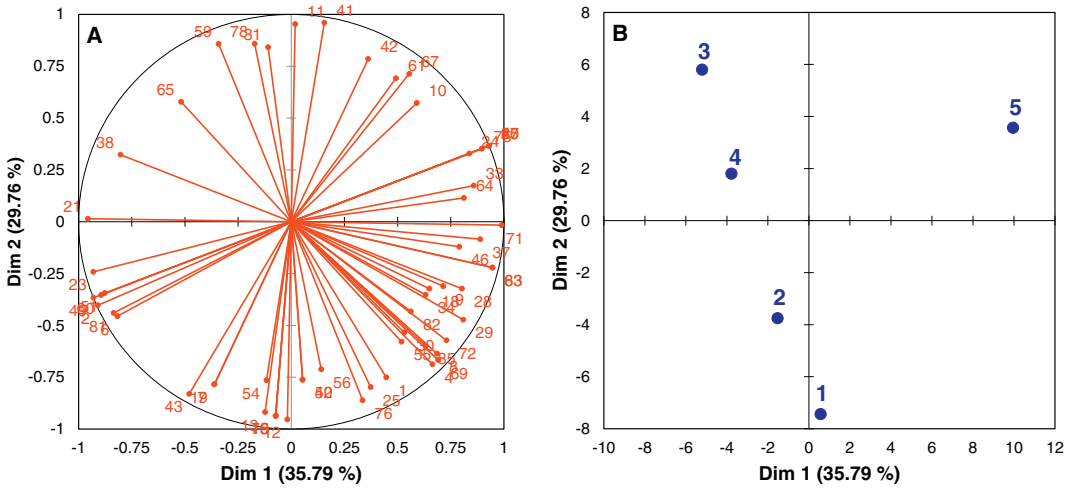

Fig. 4. Internal preference map: (A) consumers and (B) samples.

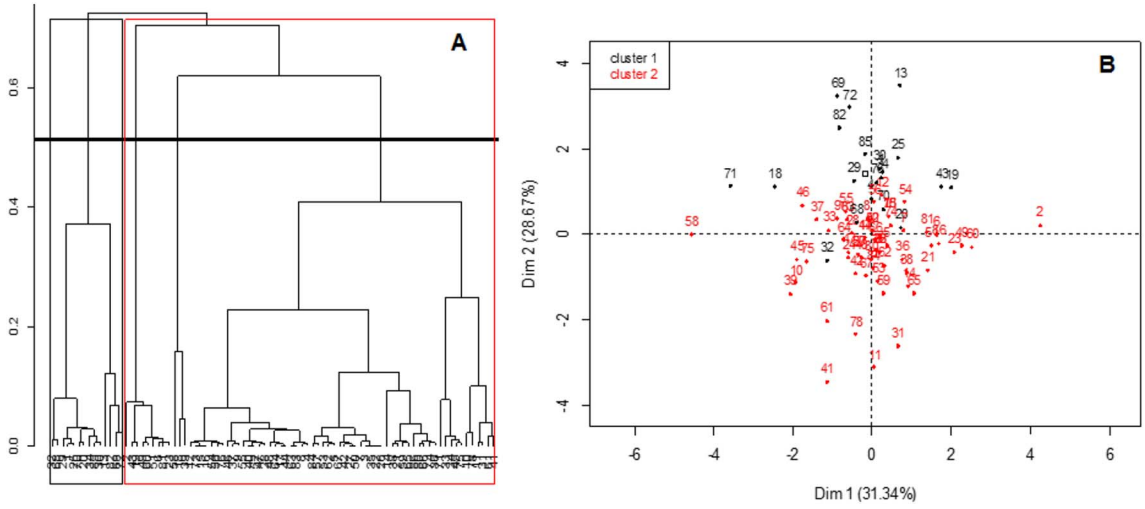

Fig. 5. Segmentation study: (A) Hierarchical Cluster Analysis of the consumers and (B) Representation of consumers in the sensory map of the samples.

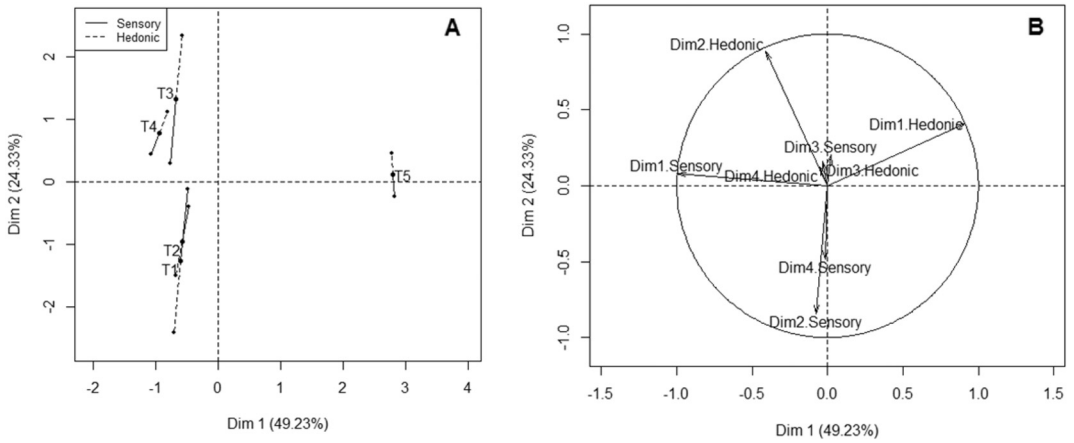

Fig. 6. Multiple factor analysis using both hedonic and sensory data: (A) Individual factor map of the samples using the first two dimensions of the MFA, and (B) Representation of the partial axes resulting of the MFA. In MFA was considered Sensory (Descriptive analysis) and Hedonic (Overall liking) data.

3.2. Descriptive analysis

3.2.1. Panel performance

The panel presented high discrimination between mortadella samples ("sample" effect) since only the term "seasoning particles" showed no significant difference (Table 3). The "Assessor", "Session" and "Assessor ∗ Session" effects were not considered in the study since they are minor effects (Lê & Worch, 2015a).

The effect of "Sample ∗ Assessor", with the exception of the "strange aftertaste" attribute, was considered significant for the terms,

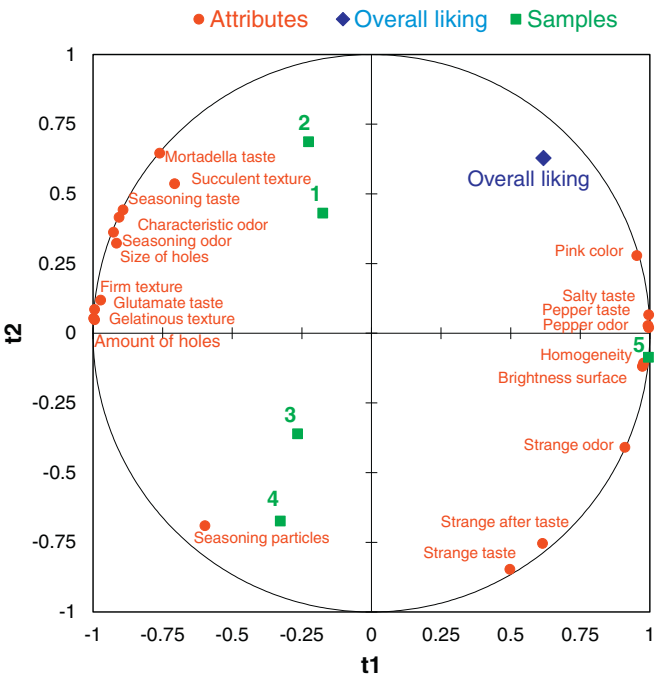

Fig. 7. Correlation between samples, sensory attributes and overall liking in the first two components of the PLSR. (A) Representation of the samples and (B) Representation of the attributes. PC: Pink color; SP: Seasoning particles; H: Homogeneity, AH: Amount of holes, SH: Size of holes, SB: Brightness surface, CO: Characteristic odor, SO: Seasoning odor, PO: Pepper odor, STO: Strange odor, FT: Firm texture, GT: Gelatinous texture, ST: Succulent texture, MT: Mortadella taste, SET: Seasoning taste, PET: Pepper taste, SAT: Salty taste, GLT: Glutamate taste, STT: Strange taste, SATA: Strange after taste.

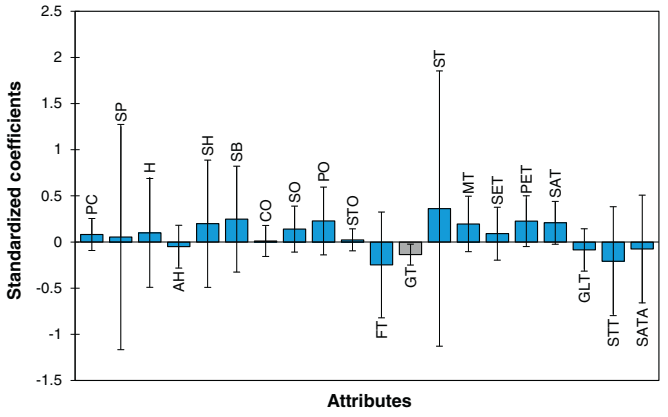

Fig. 8. Standardized Coefficients of the PLSR model for the mortadella samples. PC: Pink color; SP: Seasoning particles; H: Homogeneity, AH: Amount of holes, SH: Size of holes, SB: Brightness surface, CO: Characteristic odor, SO: Seasoning odor, PO: Pepper odor, STO: Strange odor, FT: Firm texture, GT: Gelatinous texture, ST: Succulent texture, MT: Mortadella taste, SET: Seasoning taste, PET: Pepper taste, SAT: Salty taste, GLT: Umami taste, STT: Strange taste, SATA: Strange after taste.

indicating that there was no panel consensus. Due to this result, three additional training and sensory evaluation sessions, with three markedly different samples (samples 2, 4 and 5), were performed and the results showed that there was no improvement in the panel consensus (Fig. S1, Supplementary material). From this, to better understand this significant interaction, the scores of the assessors were plotted for each attribute and in Fig. 1 two of them are presented (due to the large number of attributes), indicating that the apparent lack of consensus was due to the heterogeneity of sample 5 (commercial sample), a trend observed in all terms evaluated. In order to have an overview of all the sensory terms, the attributes and scores were plotted (Fig. S2,

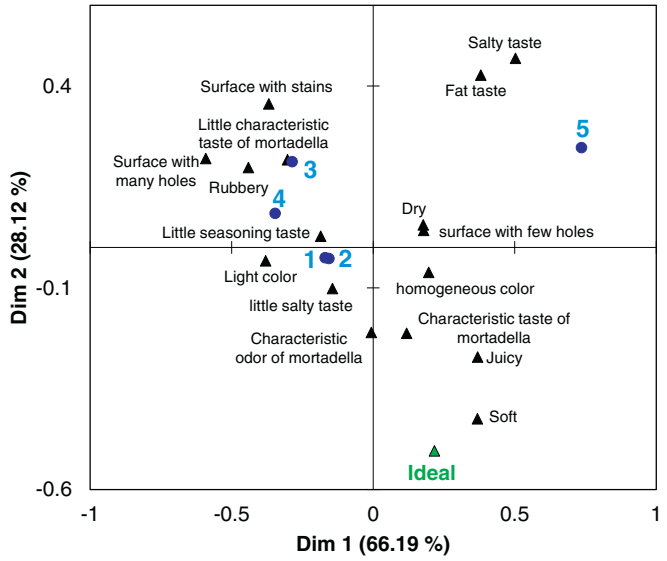

Fig. 9. Representation of the samples and attributes in the first two dimensions of the correspondence analysis of the mortadella samples using CATA questions.

Supplementary material), considering all the trained assessors and the panel means. The graphs showed that the sensory attribute intensities of samples 1, 2, 3 and 4 followed the same tendency around the mean, while sample 5 showed high amplitude in the attributes intensities. Therefore, panel had consensus and the generated data were reliable for this effect. For the effect "Sample ∗ Session", most of the attributes were not significant, indicating that the panel showed good reproducibility.

3.2.2. Final evaluation

The sample effect was significant for all the attributes (Table 4). Regarding the terms related to appearance, samples 1, 2, 3 and 4 had low scores for "pink color". For these samples, low scores for "seasoning particles" were also observed due to their lower amount of seasonings in the formulation when compared with the commercial sample. Samples formulated in this study showed little homogeneity on the surface of the slice when compared with sample 5 (commercial). When animal fat of mortadella is reduced or replaced, a meat emulsion with many holes is created. Thus, when a slice is evaluated on its surface, these holes interfere in the assessment of homogeneity, leading the sample to be evaluated as heterogeneous.

Mortadella samples developed in this study showed high "amount of holes", however the "size of the holes" was small. This result agrees with the study of Saldaña, et al. (2015a), which stated that changes in the texture of samples, when animal fat is replaced by non-meat lipids, occur due to the generation of small spaces in the microstructure of the product. Mortadella samples developed in this study had lower scores ($P < 0.05$) than commercial sample for "brightness surface", which, despite being light, showed high values for this attribute.

Regarding odor attributes, samples 1 and 2 (16% and 8% animal fat, respectively) showed high scores ($P < 0.05$) for "characteristic odor" and "seasoning odor" when compared with samples 3 and 4 (with pre-emulsion), which in turn had higher scores than sample 5. Interestingly, samples 1, 2, 3, and 4 had the same amount of seasonings and the only difference among them was the type of lipid used. Thus, it can be stated that the presence of pre-emulsion in the mortadella resulted in a reduction of the perception of "characteristic odor" and "seasoning odor". For "pepper odor" and "strange odor", samples developed in this study showed lower scores compared with the commercial sample, which certainly occurred due to the lower concentration of seasonings in the formulation and the addition of unconventional ingredients to mortadella.

For texture attributes, mortadella samples developed in this study

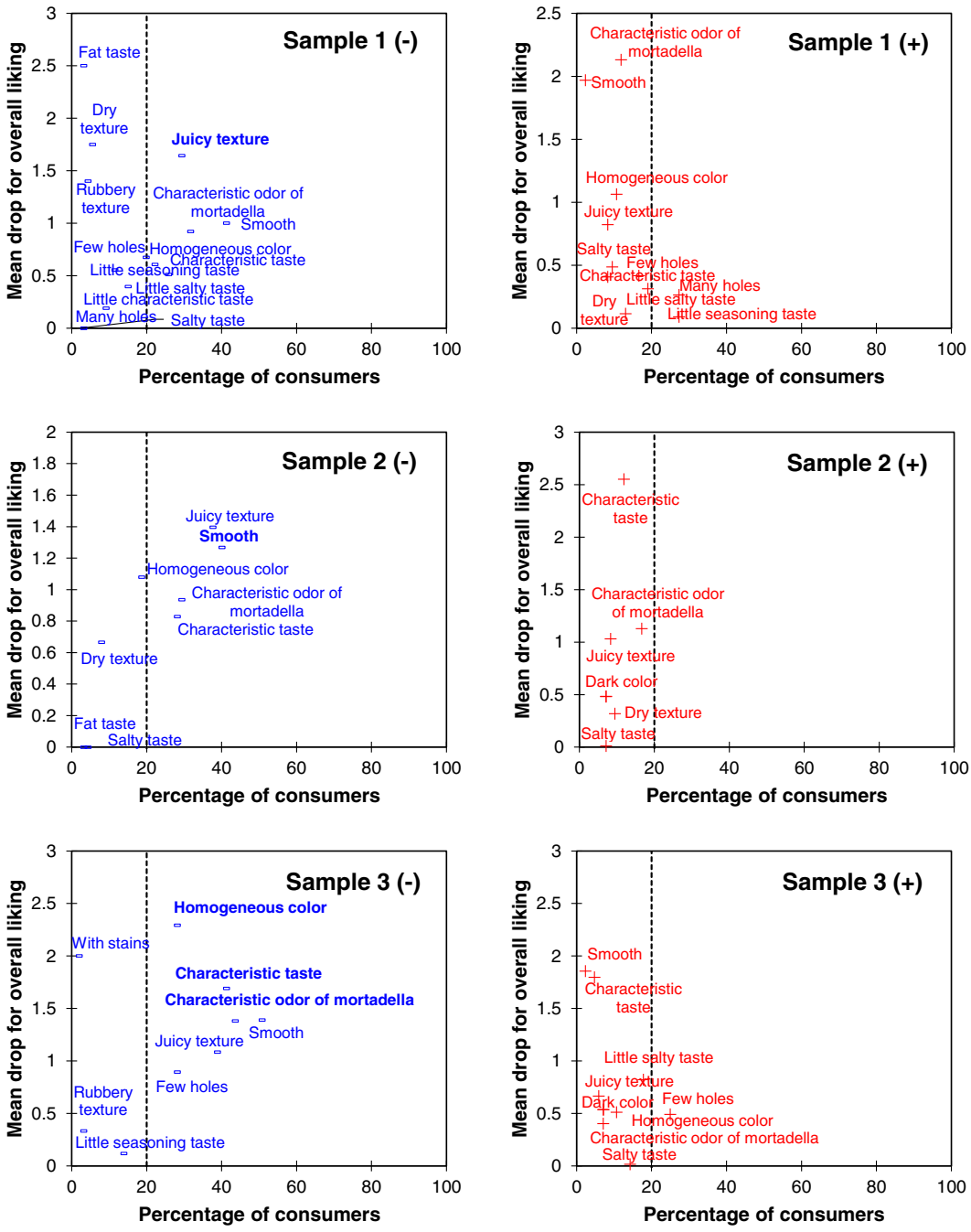

Fig. 10. Mean drop for overall liking in function of the percentage of consumers that described samples differently from the ideal. Negative sign (−) indicates attributes that were not present in the real sample but that it was present in the ideal (0,1) and positive sign (+) indicates attributes that were present in the real sample but not in the ideal (1,0). Attributes in bold correspond to those selected by > 20% of consumers who considered a deviation from the ideal, leading to a significance drop in overall liking, according to the Kruskal-Wallis test at 95% of confidence.

were firmer and more gelatinous, as well as slightly more succulent than the commercial sample, showing that the major changes of the product occur in these attributes. This fact corroborates with the reported by Saldaña et al. (2015a) and Saldaña et al. (2015b), who stated that the replacement or reduction of fat in mortadella results in hardness issues. Thus, it is believed that these attributes could subsequently influence the consumers' liking.

The results of the taste attributes showed that samples 1 and 2 had higher intensity of "characteristic taste" and "seasoning taste" than samples 3 and 4, which in turn showed higher intensity than sample 5. These differences are explained not so much by the quantity but rather by the characteristics of the lipids. Thus, samples with pre-emulsion addition showed a decrease in the "characteristic taste" and "seasoning taste", probably due to the generation of other tastes, since they showed significantly higher scores for the attributes "strange taste" and "strange aftertaste" in relation to samples 1 and 2. It was expected that "pepper taste" and "salty taste" were more pronounced in the commercial sample, as pepper and salt are commonly added in higher quantities in commercial products with reduced fat, in order to reduce the perception of the strange taste. Umami taste was more intense in the formulated samples when compared to the commercial sample.

3.2.3. Principal component analysis

DA results were analyzed in a multidimensional way through PCA

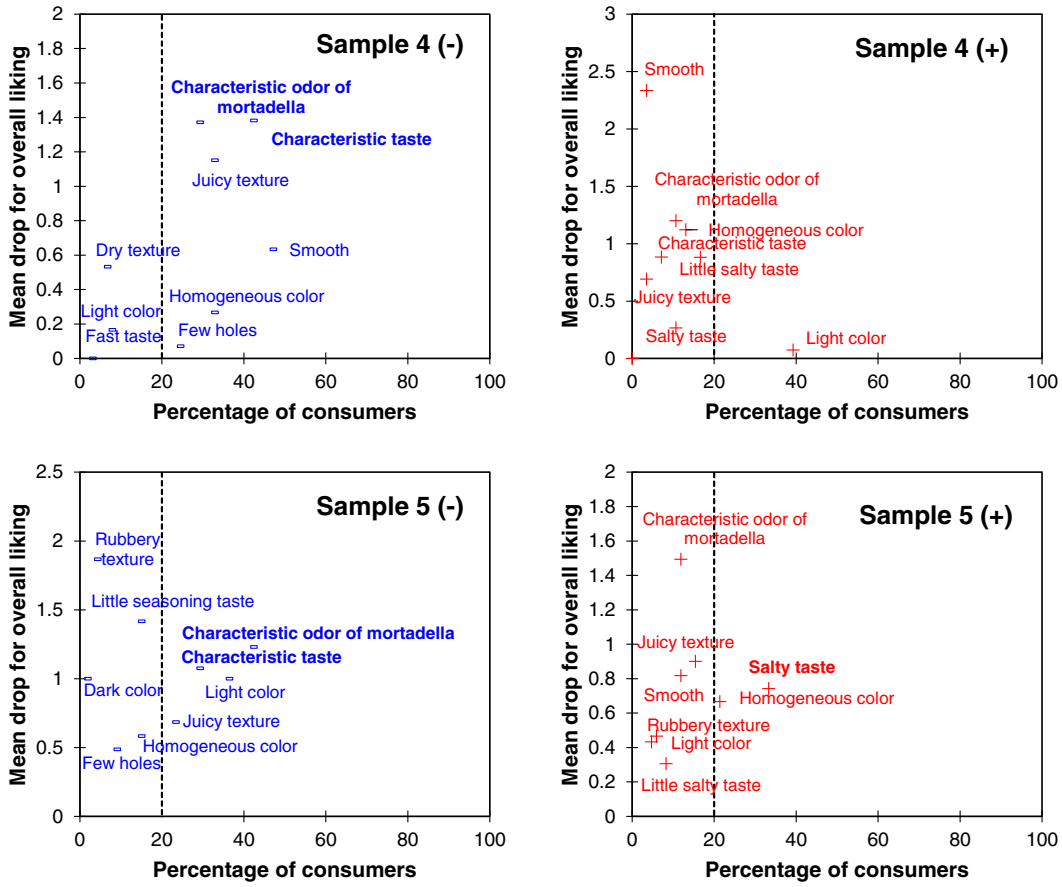

Fig. 10. (*continued*)

(Fig. 2), which showed that the first and the second principal components accounted for 83.64% and 13.55% of the experimental variability of the data, respectively, representing 97.19%.

In Fig. 2B, on the one hand the first principal component was positively correlated with the attributes: amount of holes, gelatinous texture, umami taste, firm texture, size of holes, seasoning odor, seasoning taste, characteristic odor, succulent texture and characteristic taste, and negatively correlated with the attributes: strange taste, strange aftertaste, strange odor, brightness surface, homogeneity, pepper taste, pepper odor, salty taste, pink color. On the other hand, the second principal component was positively correlated with the attributes: seasoning particles, strange taste, and strange aftertaste. It may be noted that the attributes represented as vectors had a modulus of approximately 1, which suggests a clear explanation of all attributes in the first two principal components. The sample 1 is close to sample 2 and sample 3 is close to sample 4 and all of them are markedly separate from sample 5, which was expected since sample 5 is the commercial sample. Sample 5 showed the highest variability in the analyzed attributes, which can be seen through the highest amplitude of the confidence ellipse (Fig. 2A), the high standard deviation of the sensory attributes (Table 4) and the significant effect of the "Sample ∗ Assessor" interaction (Fig. 1).

Sample 5 was located on the left side of the first principal component, indicating a higher intensity of the attributes negatively correlated with that component. Samples 3 and 4 were very close to each other and their confidence ellipses were overlapped, which also occurred with samples 1 and 2. All these treatments (samples 1, 2, 3, and 4) were located on the right side of the first principal component. The second principal component differentiated the samples developed in this study, showing samples 3 and 4 (with pre-emulsions) located in the positive area and samples 1 and 2 (16% animal fat and 8% animal fat in formulation, respectively) in the negative area.

Through PCA it was possible to differentiate samples based on the lipid material used in the formulation. This behavior had already been observed by Albert, Varela, Salvador, Hough, & Fiszman (2011), who differentiated the method of cooking of fish nuggets through sensory attributes related to the texture, using the DA data analyzed by PCA.

3.2.4. Overall liking

The OL scores ranged from 5.7 to 6.5 (Fig. 3), on a hedonic scale of 9 points, indicating that the changes were not very large, but they were enough to be significantly different. Sample 5 showed a mean ranging from "like slightly" and "like moderately" and it was significantly most liked than sample 3, which was the least liked, with a mean corresponding to "like slightly". Samples 1, 2, and 4 were neither significantly different from each other nor from the other two samples.

Furthermore, a deeper analysis (MDPREF and Cluster Analysis) was performed, since Varela (2014) recommends not just looking at the OL means, which can be segmented, being necessary in such cases to identify these consumer segments, classifying them according to similarities or differences in their preferences.

3.2.5. Internal preference mapping

The MDPREF (Fig. 4) based on the OL of the samples evaluated here showed that the first two principal components explained 65.55% of the experimental data variability, with 35.79% and 29.76% corresponding to the first and second principal components, respectively. In Fig. 4A, consumers are represented as vectors indicating the direction of the OL in relation to the mortadella samples. According to Fig. 4B the first principal component separated samples formulated in this study (left side) from the commercial sample (right side) and the second principal component separated the samples with pre-emulsion from the

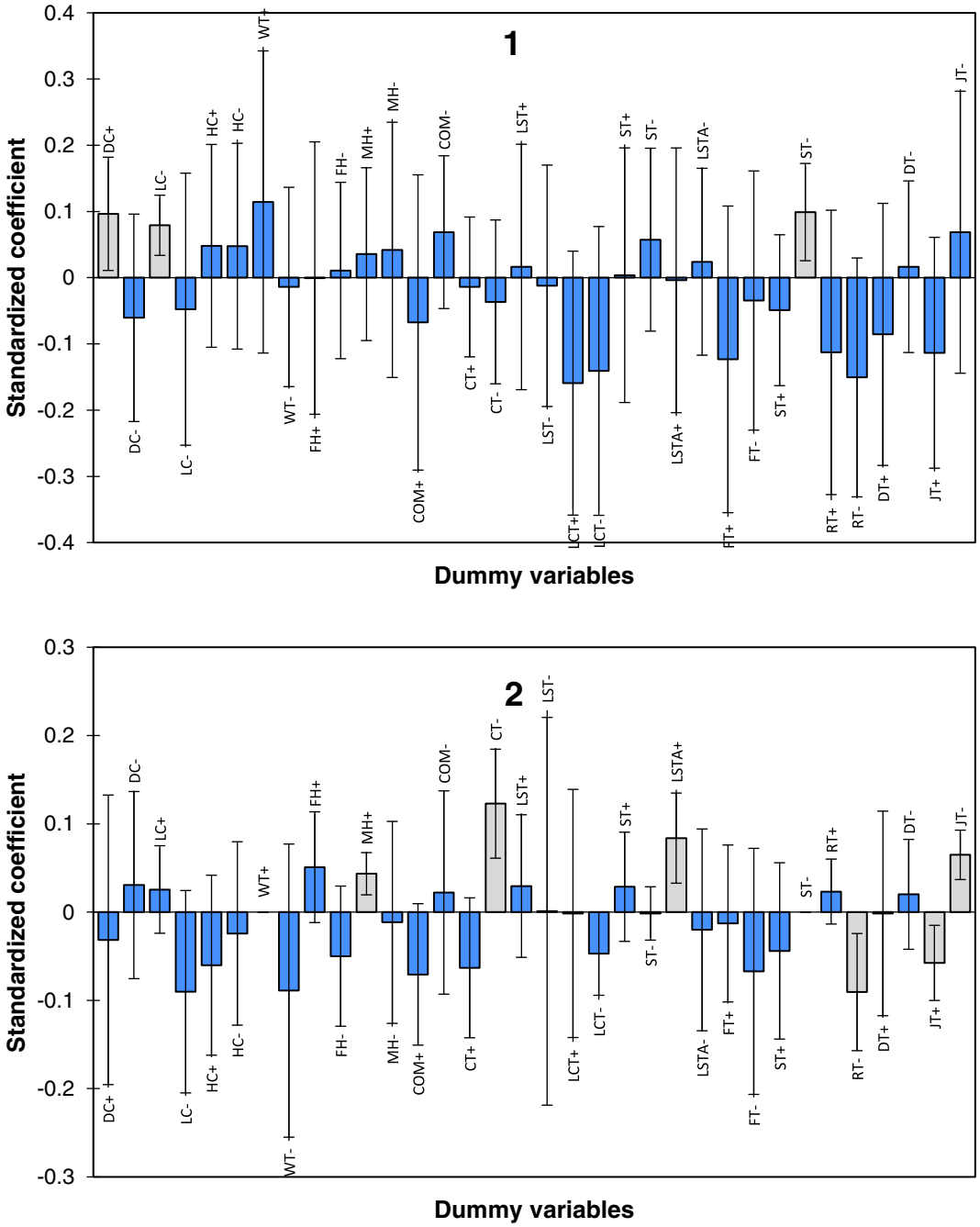

Fig. 11. Standardized Coefficients of the PLSR calculated using OL and dummy variables for the all mortadella samples. DC: Dark color, LC: Light color, HC: Homogeneous color, WT: With stains, FH: Few holes, MH: Many holes, COM: Characteristic odor of mortadella, CT: Characteristic taste, LST: Little seasoning taste, LCT: Little characteristic taste, ST: Salty taste, LSTA: Little salty taste, FT: Fat taste, ST: Soft texture, RT: Rubbery texture, DT: Dry texture, JT: Sandy texture.

ones without pre-emulsion.

According to Fig. 4A, it can be noted that consumers do not have a clear preference for any treatment, even with sample 5 showing higher OL scores than sample 3. The vectors are distributed throughout the MDPREF. Thus, it is clear that consumers' preference is segmented. In this regard, Lê & Worch (2015b) indicate that if consumers are distributed throughout the correlation circle of the MDPREF, then it is necessary to segment consumers' responses by the fact that they present different patterns of preference. Hence, a Hierarchical Cluster Analysis (HCA) was performed using the Euclidean distance and the Ward's method as clustering criteria in order to segment groups of consumers. The results showed that there was a clear preference segmentation, but the consumers of each group and the preferred samples for each group were not clearly defined (Figs. 4 and 5). This may have occurred because the number of consumers per group was low. So, it would be recommended to perform AAH with a higher number of people. Within this context, the following steps of this study considered the means of the OL scores.

3.2.6. Correlation between overall liking and sensory attributes

3.2.6.1. Sensory space of the samples. The PREFMAP relates, through a regression analysis, the OL data of each consumer with the descriptive sample space, built from the DA data. This methodology is useful since it provides a map with information about the sensory and hedonic characteristics of the samples, thus facilitating their optimization (van Kleef, van Trijp, & Luning, 2006). However, one of the main criticisms

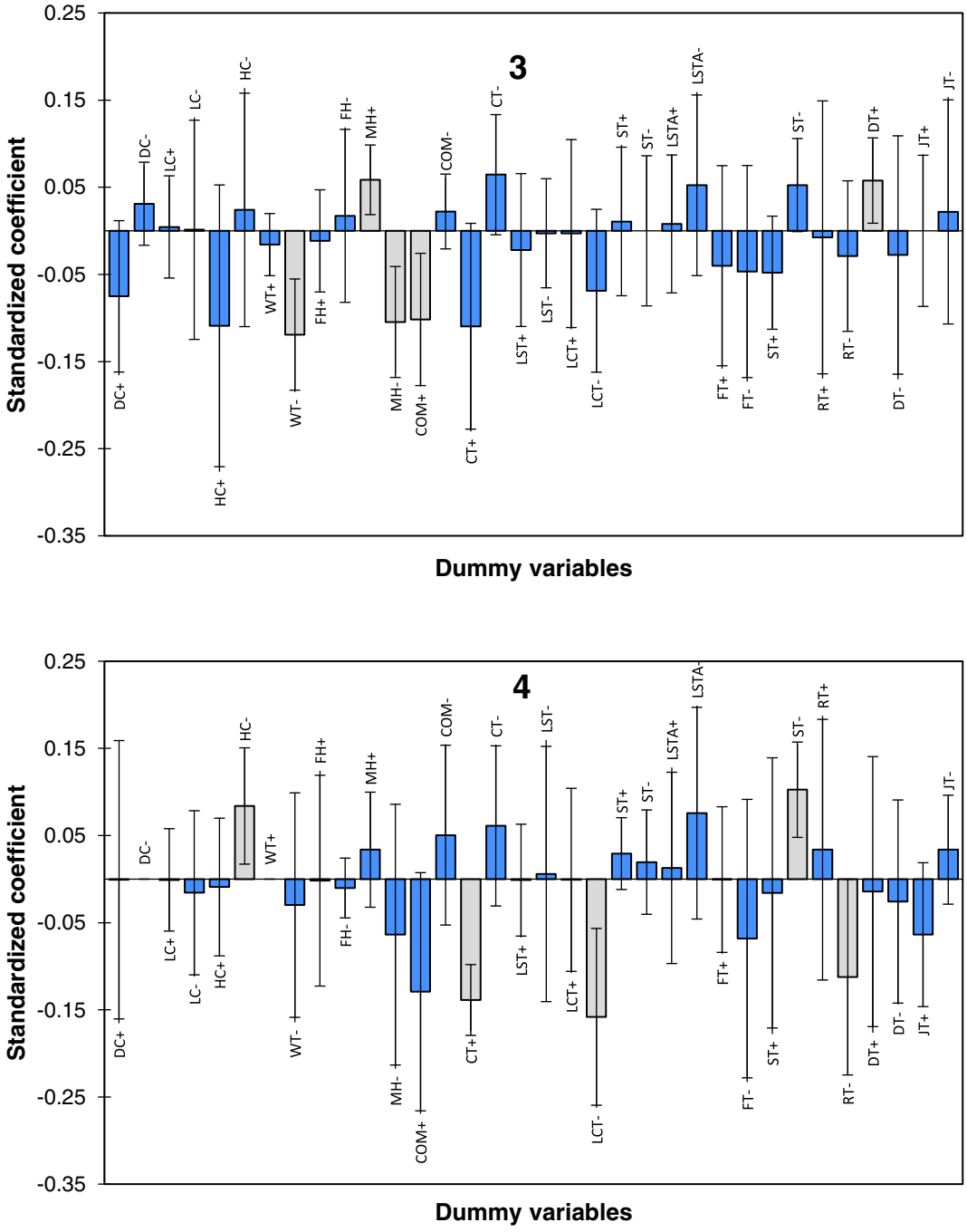

Fig. 11. (*continued*)

of PREFMAP is that it considers that the sensory space of the samples is equal to sensory (DA) and hedonic data (OL), when it is not always the case (Lê & Worch, 2015b). Thus, in this study, before performing the PREFMAP, a Multiple Factor Analysis (MFA) on the hedonic and sensory data was performed, in order to see if the sensory space of the samples of both data groups was common. In Fig. 6B it can be seen that the first and the second dimensions of the MFA were correlated with the first and second dimensions of the hedonic and sensory data.

The strong relationship between sensory and hedonic data confirmed that the use of the first two dimensions of the sensory data was adequate to model the OL. To evaluate the common sample space between both data groups, Fig. 6A shows the representation of the MFA partial points, where it can be observed that samples 2, 4, and 5 were the closest among the two data groups. Even so, the sensory space of the samples for both data groups was very close, then it can be considered common.

3.2.6.2. Partial least squares regression. Fig. 7 was designed to facilitate the visualization of the DA and OL results, through the representation of the samples, the sensory attributes and the OL on the same graph, using PREFMAP technique based on the PLSR model. According to Laureati, Giussani, & Pagliarini (2012), attributes that are close to the OL positively contribute to its estimation (positively contributing to product liking), while variables that are far, and even more, on the opposite side of the OL, negatively contribute to the OL estimation (negatively contributing to product liking). In this case, attributes that were close to the OL were: pink color, salty taste, pepper taste, pepper odor, homogeneity, brightness surface, characteristic taste, succulent

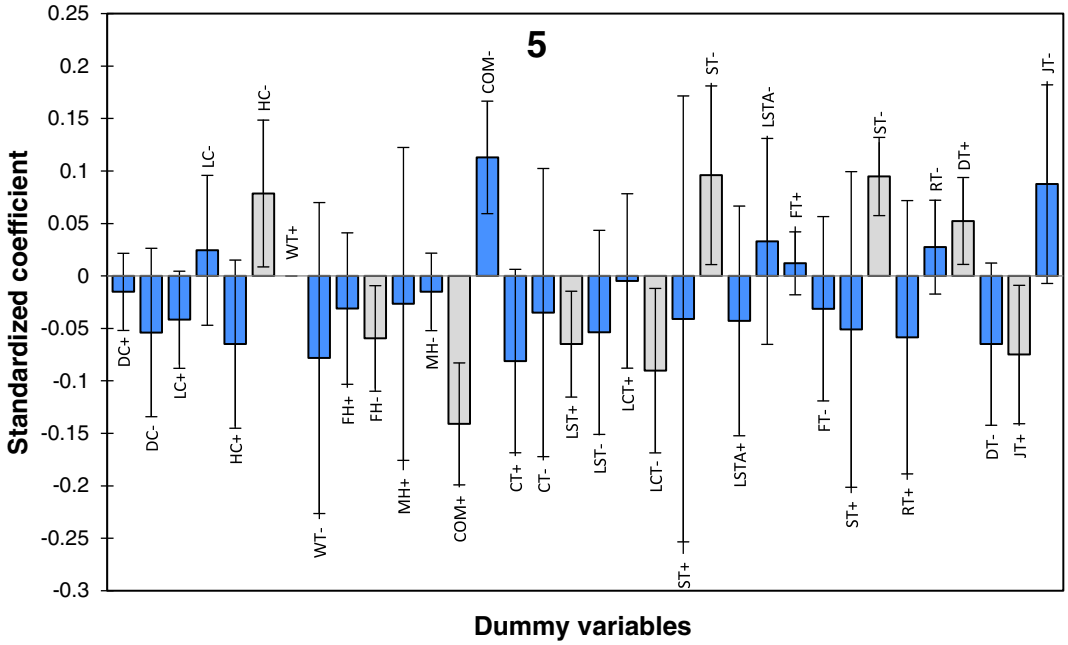

Fig. 11. (*continued*)

texture, seasoning taste, characteristic odor and seasoning odor. OL is located in the upper right quadrant, next to samples 1, 2, and 5, indicating that they are significantly more liked than samples 3 and 4. It can be observed that strange taste and strange aftertaste attributes are close to samples 3, 4 and 5.

The standardized coefficients are represented in Fig. 8. In this graph, the descriptor terms that are in the positive and negative part of the Y-axis are considered positive and negative for mortadella OL, respectively.

The size of the columns indicates the influence of the attribute in the OL of the samples, both positively and negatively. Thus, the higher the column, the higher the influence of the descriptor in the sample OL. Moreover, the standard deviation should be noted, which, if crossing the X-axis indicates that the influence of the attribute cannot be considered with 95% confidence interval (Gomes, Pflanzer, Cruz, de Felício, & Bolini, 2014).

Thus, the only attribute identified as a negative DL with 95% confidence was the gelatinous texture and it was not possible to find a positive DL. It is clear that texture modification resulting from lipid reduction is reflected in the increase of mortadella hardness, which in a previous study was technologically solved with the addition of hydrocolloids (optimization of the instrumental hardness and springiness of mortadella). However, hardness decrease does not guarantee a suitable texture in the sensory point of view and in the present study we observed that the decrease in hardness by adding hydrocolloids generated a new sensory attribute perceived by the trained panel, called “gelatinous texture” and identified as the only DL by the PLSR.

The attribute “gelatinous texture” was located in the negative part of the first dimension of Fig. 7 and was correlated with the samples developed in this study, particularly with samples 1 and 2, which did not have pre-emulsion in the formulation. Sample 4 was the farthest one from this attribute, which suggests that it is the potential treatment for further reformulation, besides having shown the highest OL score for samples with pre-emulsion. These results agree with the study of Santos et al. (2013), which concluded that fat reduction resulted in hard and unsalted mortadellas, besides having unpleasant taste. Cáceres, García, & Selgas (2008) reported changes in the texture of mortadella enriched with fish oil.

3.2.7. CATA questions

The nonparametric Cochran's Q test was performed, and according to it there were significant differences for 18 of the 41 terms used to characterize the samples.

The high number of sensory terms used in this study has already been reported to characterize milkshakes with hydrocolloids (47 descriptors terms) (Morell, Fiszman, Varela, & Hernando, 2014). In the present study, CATA questions, containing 41 sensory terms, were carried out by category (appearance, odor, taste, and texture). Each category had no > 14 terms, since an excess of them could influence the visual attention (Jaeger et al., 2015). After Cochran's Q test, it was verified that 18 terms were significant. The sandy term was removed as recommended by Tarancón et al. (2015) since the frequency of mention was < 10%. CA using chi-squared distance was applied to represent samples and sensory terms (Fig. 9). The first two dimensions of the CA explained 94.31% of the experimental data variance.

Three groups of samples with different sensory characteristics have been identified. Samples 1, 2, 3 and 4 were located in the negative part of the first dimension and were correlated with the following terms: with stains, little characteristic taste, many holes, rubbery texture, little seasoning taste, light color, little salty taste, and characteristic odor, which were generated by the reduction or replacement of the animal fat. Sample 5 was located in the positive part of the first dimension and was correlated with the terms: salty taste, fat taste, dry texture, few holes, and homogeneous color. The fat taste term generated by the consumers was not noticed by the trained panel during the development of the descriptive terminology or was included in another attribute, such as strange taste. The ideal sample was located in the negative part of the second dimension and was characterized by the following terms: soft texture, succulent, characteristic taste, characteristic odor and homogeneous color.

In the PLSR, gelatinous texture was identified as the main negative DL. This DL was also generated by the consumers as rubbery texture. Thus, the importance of attributes related to texture was evidenced by both consumers and assessors. It was also verified that rubbery texture was related to the attribute “many holes” on the sample surface, which was expected, since when animal fat is reduced or replaced, holes begin to be formed.

3.2.7.1. Penalty analysis. PL is based on the deviation of the proportion

Table 5
Frequency of mention of terms of CATA question used by consumers to describe the all mortadella samples.

Terms	*p*-Value	Samples					
		1	2	3	4	5	Ideal
Dark color[a,***]	< 0.0001	3	6	6	0	53	4
Light color[a,***]	< 0.0001	45	41	50	63	10	36
Smooth[a,ns]	0.079	31	32	28	32	42	47
Few pieces of fat[a,ns]	0.347	33	38	29	28	29	34
Homogeneous color[a,***]	< 0.0001	31	40	26	24	46	40
Presence of seasonings[a,ns]	0.687	25	23	22	24	29	27
With stains[a,***]	0.001	22	17	30	28	12	2
Brightness surface[a,ns]	0.843	14	15	11	12	15	5
Few holes[a,**]	0.006	32	32	32	27	48	34
Many holes[a,***]	< 0.0001	24	25	29	27	1	3
Little brightness surface[a,ns]	0.054	29	25	39	34	30	36
Characteristic odor of mortadella[b,**]	0.002	45	51	31	46	36	61
Strange odor[b,ns]	0.067	9	12	14	11	21	1
Seasoning odor[b,ns]	0.963	26	26	27	24	24	30
Pepper odor[b,ns]	0.183	16	7	15	12	13	11
Fat odor[b,ns]	0.457	10	6	10	7	12	3
Little characteristic odor[b,ns]	0.089	28	20	35	30	29	7
Smoked odor[b,ns]	0.807	14	18	17	19	16	37
Rancid odor[b,ns]	0.539	5	7	10	7	5	1
Characteristic taste[c,**]	0.001	44	45	28	29	42	58
Strange aftertaste[c,ns]	0.150	12	12	19	17	9	2
Little seasoning taste[c,*]	0.037	32	32	25	27	17	18
Little pepper taste[c,ns]	0.327	17	19	17	23	13	21
Little characteristic taste[c,***]	< 0.0001	21	20	32	33	14	10
Strange taste[c,ns]	0.174	9	11	14	19	14	3
Salty taste[c,***]	< 0.0001	10	7	12	9	30	4
Little salty taste[c,**]	0.008	32	26	30	21	15	28
Seasoning taste[c,ns]	0.136	19	16	23	24	28	26
Pepper taste[c,ns]	0.247	9	5	13	9	11	6
Glutamate taste[c,ns]	0.467	7	6	4	8	10	6
Fat taste[c,**]	0.006	4	3	8	6	14	3
Smoke taste[c,ns]	0.388	21	19	19	13	18	34
Rancid taste[c,ns]	0.352	3	5	8	3	5	1
Firm texture[d,ns]	0.505	44	43	51	47	43	33
Soft texture[d,***]	< 0.0001	19	18	11	15	32	51
Rubbery texture[d,***]	< 0.0001	37	40	41	41	10	8
Gelatinous texture[d,ns]	0.068	11	12	11	17	6	7
Dry texture[d,*]	0.043	15	10	5	9	15	8
Succulent texture[d,***]	< 0.0001	21	14	11	14	32	38
Little succulent texture[d,ns]	0.058	23	21	31	23	15	11
Sandy texture[d,**]	0.002	1	3	3	0	9	1

ns: no significant difference ($p > 0.05$) according to Cochran's Q test. The ideal sample was not included in the Cochran's Q test.
*** Significant difference at $p < 0.001$.
** Significant difference at $p < 0.01$.
* Significant difference at $p < 0.05$.
[a] Surface.
[b] Odor.
[c] Taste.
[d] Texture.

Table 6
Summary of the recommendations for the reformulation of the mortadella samples based on the results of the PA, PLSR, and CATA questions.

Sample	Main recommendations for a reformulation	
	Increase	Decrease
1	Succulence	Hardness
2	Softness and Succulence	Hardness
3	Color homogeneity, characteristic odor and taste, succulence and softness	Amount of holes, amount of stains, strange odor
4	Characteristic odor and taste, succulence	Strange taste and rubbery texture.
5	Characteristic odor and taste, salty taste and color homogeneity	Salty taste, amount of holes, strange and seasoning odor, and rubbery texture

of selection of each term for the real samples compared to the ideal sample, as well as the impact of this deviation in the OL (Ares et al., 2014). When CATA question attributes are selected for both real and ideal sample (1,1) or for neither real nor ideal sample (0,0), this is considered a congruent behavior, i.e., this result does not provide any information about the possible differences between real and ideal samples and their consequences in the OL. However, if the consumer selects an attribute in the real sample, but not in the ideal (1,0) or vice versa (0,1), this is considered an incongruent behavior that provides important information to better understand what could "be missing" or "too much" in an attribute, as well as its effect on the OL (Agudelo, Varela, & Fiszman, 2015; Meyners et al., 2013).

Fig. 10 shows the mean drop of the OL as a function of the percentage of consumers that described the samples differently from the ideal. The graphs where the incongruences were represented by negative signs (−) indicated drop of OL because the attribute was not present in the real sample but it was present in the ideal sample (0.1), suggesting a "must-have" attribute. Positive signs (+) indicate a drop in the OL because the attribute was present in the real sample but not in the ideal (1.0), suggesting a "to be avoided" attribute (Agudelo et al., 2015). It is important to highlight that terms where the decrease of OL was negative, were not considered in the PA for being terms where the deviation from the ideal was not penalized. For PA, only attributes in which at least 20% of the consumers perceived difference between the sample and the ideal were considered (Xiong & Meullenet, 2006).

For sample 1, the incongruence was represented by the negative sign (−) and by the attributes succulent and soft texture. From these two terms, the attribute succulent caused a significant drop in the OL, indicating that it is the main attribute that should be present in the sample. For sample 2, the incongruence was also represented by the negative sign (−) and by the attributes succulent and soft texture. In this case, soft texture showed a significant decrease in the OL, indicating that, for this sample, this attribute must be present. This result also suggests that, according to consumer's perception, sample 2 was harder than the ideal. Regarding sample 3, the penalty was represented by the negative sign (−), with the presence of the following attributes to increase OL being required: homogenous color, characteristic taste, characteristic odor, soft texture and succulent texture, which were not detected, probably due to the incorporation of the pre-emulsion. The incongruence of sample 4 was represented by the negative sign (−) and by the attributes characteristic taste, characteristic odor and succulent texture, causing a drop in the OL that was perceived by > 20% of the consumers. Thus, these attributes must be present in this formulation to increase the OL. Finally, for sample 5, the incongruence was represented by the negative sign (−) with the attributes characteristic odor and characteristic taste, and by the positive sign (+) with the attribute salty taste, indicating that terms with (−) must be present whereas attributes with (+) must be less intense in the sample. It is interesting to note that, for this sample, consumers indicated that the intensity of salty taste should be reduced when compared to the ideal.

Fig. 11 shows the graphic of the standardized coefficients of the PLSR model of the dummy variables (Z), permitting to draw conclusions about the attributes that significantly affected OL. Thus, a significant positive dummy variable (Z +) indicates that consumers did not detect this attribute in the real sample compared with the ideal sample. On the other hand a significant negative dummy variable (Z −) indicates that consumers detected an attribute in the sample that they would not want in the ideal sample (Ares et al., 2014).

According to Fig. 11, the significant dummy variables for sample 1 were: dark color +, light color +, and soft texture-, showing that color and texture attributes caused a strong impact on consumers' OL. The standardized coefficient was positive for both dark + and light color +, indicating that sample 1 was perceived as very dark and very light by the consumers. This contradictory fact may be occurred due to consumers' segmentation, where some of them perceived the sample as very light and others as very dark. Regarding soft texture-, this sign (−)

indicates that the attribute was present and positively affected the OL of the sample.

For sample 2, the dummy variables with positive standardized coefficient were: many holes +, characteristic taste-, little salty taste +, succulent texture-, and the variables with negative standardized coefficients were: rubbery texture- and succulent texture +. According to consumers' perception, the attributes many holes +, and little salty taste + (absent in the sample), as well as characteristic taste-, and succulent texture- (present in the sample) were perceived as positive. On the other hand, attributes such as rubbery texture- (present in the sample) and succulent texture +, (absent in the sample), negatively influenced the OL.

Sample 3 showed two dummy variables, in which the absence of some attributes positively affected the OL. These attributes were: many holes + and dry texture +, indicating that consumers prefer samples without holes and with a succulent texture. The dummy variables that negatively influenced the OL were the presence of the attributes with stains- and many holes- as well as the absence of the attribute characteristic odor +, indicating that consumers prefer samples without stains and many holes and with characteristic odor of mortadella.

Sample 4 also presented two dummy variables (presence of homogeneous color- and absence of soft texture-) that positively influenced the OL, indicating that consumers prefer homogeneous and not very soft samples, which is probably related to the rubbery term caused by the addition of hydrocolloids in the pre-emulsion. The dummy variables that negatively influenced the OL were: the absence of characteristic taste + and the presence of little characteristic taste- and rubbery texture-, indicating that consumers prefer samples with characteristic taste and without rubbery texture.

Regarding sample 5, the dummy variables that positively affected the OL were the presence of homogeneous color-, salty taste-, and soft texture- and the absence of dry texture +, indicating that consumers prefer a mortadella with homogeneous surface, salty taste, soft texture, and without a dry texture. The dummy variables that negatively influenced OL were: the presence of few holes-, the absence of characteristic odor +, the absence of little seasoning taste +, the presence of little characteristic taste- and the absence of a succulent texture +, suggesting that consumers prefer samples with few holes, with characteristic odor, without excessive seasoning and mortadella odor and with a succulent texture. Thus, consumers' preference was clearly segmented, as one group of consumers preferred a characteristic odor and a mortadella odor, while other group preferred their samples without mortadella odor.

By combining the result of penalty analysis with the modeling of the dummy variables by PLSR, it was possible to identify the necessary recommendations for improving each of the mortadella samples (Table 5). In general, texture attributes related to hardness should be improved in all of the samples, even in the commercial one. The advantage of performing DA, CATA questions and OL together in order to understand the sensory attributes of the samples and the possible strategies for reformulation is clear. According to van Kleef et al. (2006), methods based on the identification of attributes of an ideal product provide more realistic information than the regression-based methods.

Both methods of sensory characterization, DA and CATA, indicated similar sample space showing samples 1 and 2 together, as well as samples 3 and 4, with sample 5 located away from the other samples. This similarity in the sample space agrees with the results obtained by Albert et al. (2011) and Worch, Lê, & Punter (2010).

According to the results (Table 6), it can be stated that CATA questions represent a good alternative to study the sensory characteristics of food products, especially when there is no time and resources available to develop DA. However, it should be take into consideration that CATA questions are easier and faster to perform by consumers (Ares & Jaeger, 2013), with the disadvantage of not allowing to obtain information on the intensities of the attributes.

The use of "CATA ideal" helped to identify the sensory characteristics of the ideal mortadella according to the consumers' perceptions. This method, with PA and PLSR using dummy variables, represents a very useful tool to identify key attributes to be modified in order to improve sample acceptance.

4. Conclusion

The DA performed on reformulated mortadella samples showed a differentiated sensory profile for samples developed in this study when compared with the commercial sample. Among the samples developed here, those with pre-emulsion addition were different from the samples without this component. Consumers preferred the commercial mortadella, but the study should be researched further considering a higher number of consumers, since a clear segmentation of the preference was verified.

According to the correlation between DA and OL, the DL attribute was the gelatinous texture, confirming that, even adding a hydrocolloid to decrease mortadella hardness (attribute presented in previous studies), this decrease generated a new negative attribute. CATA questions along with Penalty Analysis and PLSR of dummy variables with OL helped to identify the "strange taste", "characteristic taste", "gelatinous texture" and "firm texture" as the main attributes to be modified at a later product reformulation.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.meatsci.2017.11.027.

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