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Descriptive analysis of bacon smoked with Brazilian woods from reforestation: methodological aspects, statistical analysis, and study of sensory characteristics

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ABSTRACT

The aim of this study was to perform a descriptive analysis (DA) of bacons smoked with woods from reforestation and liquid smokes in order to investigate their sensory profile. Six samples of bacon were selected: three smoked bacons with different wood species (*Eucalyptus citriodora*, *Acacia mearnsii*, and *Bambusa vulgaris*), two artificially smoked bacon samples (liquid smoke) and one negative control (unsmoked bacon). Additionally, a commercial bacon sample was also evaluated. DA was developed successfully, presenting a good performance in terms of discrimination, consensus and repeatability. The study revealed that the smoking process modified the sensory profile by intensifying the "saltiness" and differentiating the unsmoked from the smoked samples. The results from the current research represent the first methodological development of descriptive analysis of bacon and may be used by food companies and other stakeholders to understand the changes in sensory characteristics of bacon due to traditional smoking process.

1. Introduction

Bacon is one of the most consumed pork products in the world. Therefore, bacon producers are continuously looking for novel ingredients to develop and launch food products with a recognized high sensory appeal (Knipe & Beld, 2014). Regarding its technological processing, the smoking of bacon is one of the most important stages. In this step, the product develops not only its particular sensory characteristics but also its microbiological safety is ensured (Sikorski & Kołakowski, 2010).

Given the importance of the smoking process, the Brazilian regulation states that "*Products treated with liquid smoke and those that have not been subjected to the smoking process should contain the following expression on the label: smoked flavor*" (Brasil, 2012). Thus, the claim *"smoked flavor"* stated on the label of bacon will impact on a high rejection by consumers as they may perceive the product as "artificial" (Bearth, Cousin, & Siegrist, 2014). In this context, the smoking process performed in traditional conditions is presented as the logical strategy to overcome this challenge. Thus, it is very important to assess and compare the sensory characteristics of bacon produced by the traditional smoking process and bacon manufactured with the addition of liquid smoke.

In Brazil, due to availability and cost, Brazilian woods are the most used in the process of food smoking, and among then, Eucalyptus (*Eucalyptus* spp.) is one of the main woods (Luz, 2013). To be environmentally friendly, the traditional smoking requires the use of woods from reforestation, thus preserving the native flora (IBA, 2015). Besides Eucalyptus, other reforestation trees can also be used in the smoking process, such as Bamboo (*Bambusa vulgaris*), Acacia (*A. mearnsii* and *A. Mangium*), Bracatinga (*Mimosa scabrella*) and Teak (*Tectona grandis*).

Sensory characteristics of meat products are important in the selection and acceptance by consumers. Therefore, it is extremely demanding to characterize these products in terms of their sensory profile

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(Saldaña et al., 2018). The most commonly used methodology for sensory characterization of food is DA, which is based on the Quantitative Descriptive Analysis and the Spectrum method (Lawless & Heymann, 2010). DA is suitable for sensory profiling because it provides detailed, consistent and reliable results. Many authors have used this methodology to describe the sensory characteristics of meat products (Braghieri et al., 2016; Selani et al., 2016). However, the main methodological aspects of DA have not been adequately reported in most studies, especially when it comes to highly heterogenic products, such as bacon.

According to this scenario, the aim of this research was three-fold:

a) to develop and describe a detailed protocol for bacon sensory profiling using the DA;
b) to describe extensively the statistical analyses (univariate and multivariate) used to evaluate the performance of the sensory panel, and to understand the interconnections among sensory attributes and;
c) to study the impact of the traditional smoking process using woods from reforestation and liquid smokes on the sensory characteristics of bacon.

2. Materials and methods

2.1. Samples

Seven types of bacon were evaluated in this study (Table 1).

2.2. Bacon manufacture

The bacons were manufactured following a randomized block design with 3 blocks (replicates), in which each block corresponded to an independent bacon processing. Initially, pork bellies were washed and then weighed. Brine (2.5% salt, 0.5% sucrose and 0.02% sodium nitrite [w/v]) was injected (Super Inject Max Power Flavor, Stander model) in each belly (30 randomly selected points) at a proportion of 20% of the weight of the meat. Samples were stabilized at 1.5 °C/24 h. The traditional smoking (Verinox, Italy) process was performed using the following steps: (1) heat-drying at 65 °C/30 min, (2) smoking at 70 °C/60 min, (3) moist-heating at 70 °C/30 min and (4) steam-heating until the internal temperature of the sample reached 75 °C. Then, the samples were removed and cooled. Finally, they were vacuum-packaged and stored at 1.5 °C for 12 h until sensory evaluation. For the liquid smoking process, the same time-temperature program was used (step 2 was ruled out). In this stage, bellies (~70 °C) were removed and sprayed with liquid smoke (~25 °C). Both liquid smokes consist of natural condensates of smoke obtained by the pyrolysis of wood. The concentration of each type of liquid smoke followed the recommendations of their manufacturers (LS1 was diluted in water to a concentration of 10% and LS2 was applied without dilution). The liquid smokes were applied at a proportion of 1% of the weight of the bacon (selected based on pilot testing).

Table 1
Description of the bacon samples.

Sample	Description
Control	Sample not subjected to either the smoking process or to the addition of liquid smoke
LS1	Sample with addition of commercial liquid smoke - brand 1
LS2	Sample with addition of commercial liquid smoke - brand 2
Eucalyptus	Sample smoked with Eucalyptus wood from reforestation
Commercial	Commercial sample of Brazilian bacon
Acacia	Sample smoked with Acacia wood from reforestation
Bamboo	Sample smoked with Bamboo wood from reforestation

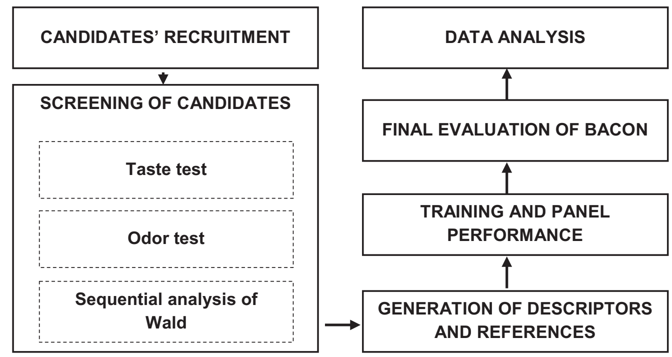

Fig. 1. Flowchart of the steps of the generic descriptive analysis.

2.3. Descriptive analysis

The study was conducted in 16 sessions from 20 to 60 min. The samples coded with random three-digit numbers were presented in a monadic way, following a balanced order of presentation to avoid bias. Evaluations were made in a sensory analysis laboratory, equipped with individual sensory booths. Mineral water was used in order to cleanse the assessors' palate. This study was supported by the Ethics Committee for Human Research of the Escola Superior de Agricultura "Luiz de Queiroz" - ESALQ-USP (protocol No. 1.550.783). In the current study, the DA followed the flowchart shown in Fig. 1.

2.3.1. Candidates' recruitment

Thirty-five candidates (aged between 18 and 62 years, 72% women and 28% men) were recruited among students and employees of the university with experience in DA. They were asked to fill out a questionnaire in which they detailed personal information, eating habits, affinity for the product, availability and interest in the study.

2.3.2. Screening of candidates

The screening was carried out in three sub-stages: recognition of basic tastes (RBT), recognition of basic odors (RBO) and sequential analysis of Wald (SAW).

For the RBT, different solutions were prepared for the recognition of sweet, salty, umami, sour and bitter tastes (ISO, 2012). The solutions were presented in disposable cups of 50 mL in two series of the same solutions. Candidates with ≥75% of correct answers were selected to move to the next stage (Elortondo et al., 2007). For the RBO, Oregano, cinnamon, sausage seasoning, vanilla, banana essence and liquid smoke were used to generate different odors and were presented in black containers of 50 mL. Candidates received the samples into two series, and were asked to identify and relate them. Candidates with ≥65% correct identification moved to the next stage (Elortondo et al., 2007). For the SAW, four commercial burgers with different sensory characteristics were cooked on a hot plate (± 150 °C) until a core temperature of 75 °C was achieved. Burgers were cut into cubes (2 × 2 × 2 cm), wrapped in wax paper and heated in microwave for 5 s prior to the evaluation (Selani et al., 2016). Parameters of the analysis of Wald showed on Fig. 2 were: $\alpha = 0.05$ (probability of selecting an unacceptable candidate); $\beta = 0.05$ (probability of rejecting an acceptable candidate); $p_0 = 0.45$ (maximum unacceptable ability) and $p_1 = 0.70$ (minimum acceptable ability). Lines of acceptance and rejection were $d_0 = 2.809 + 0.578n$ and $d_1 = -2.809 + 0.578n$, respectively. In Fig. 2, 4 of the 21 candidates are presented. Candidates who succeeded in crossing the acceptance line were automatically accepted without completing all the tests. Nine participants presented similar behavior to that of P1. One participant needed to complete all tests to be accepted as the P2. Four candidates were rejected, two of them for failing to overcome the line of acceptance after completing all tests, being in the training area (similar to P3 behavior), and two more

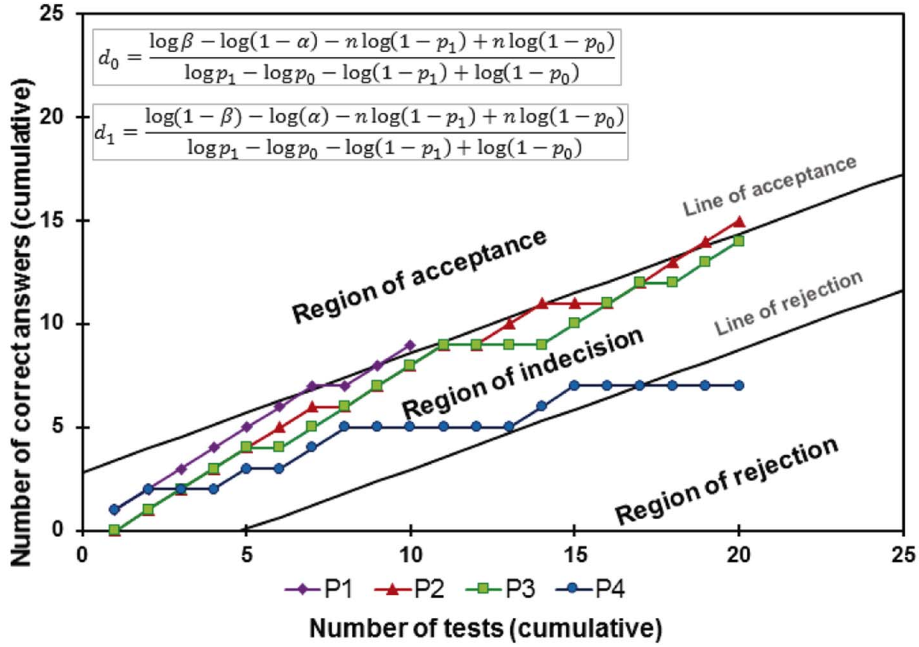

Fig. 2. Test chart for sequential analysis of Wald. P = candidate.

had a high number of errors, such as P4. In addition, seven candidates gave up for lack of time and failed to complete all sessions (see Fig. 3).

2.3.3. Generation of descriptors and references

The lexicon of sensory descriptors was generated by the Kelly's repertory grid method using the seven samples of bacon presented in triads. Participants received 6 triads in two sessions of about 30 min (3 triads per session). The sessions were performed on different days. Assessors were asked to describe the similarities among the first two samples and the differences from the third samples based on appearance, aroma, taste and texture. Once the list of attributes was generated, the sensory panel participated in several sessions to establish uniform concepts and the technique to be used in the evaluation of samples and references. Synonyms and antonyms were grouped until orthogonal descriptors were obtained (Lawless & Heymann, 2010).

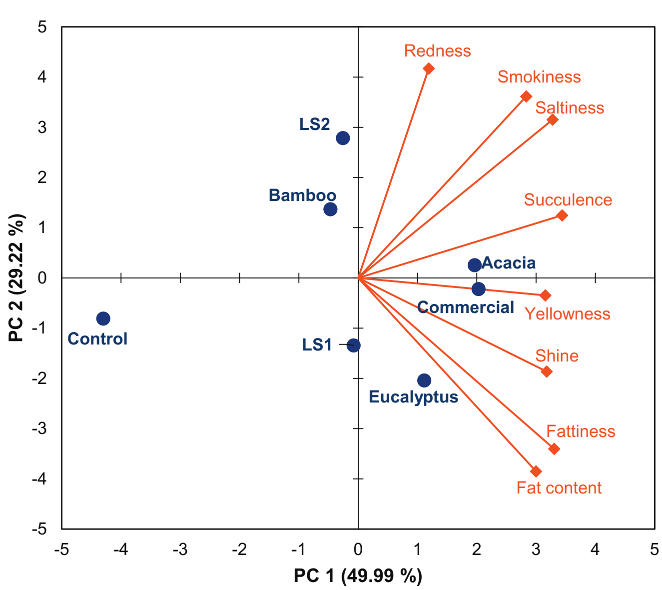

Fig. 3. Principal Component Analysis on correlation matrix the means of attributes: representation of samples and attributes.

2.3.4. Training and panel performance

The selected assessors were trained for 6 sessions of approximately 60 min. In the first session, the candidates were instructed to use a 10 cm unstructured scale anchored in the ends with "low"/"none" and "high". In the second session, the candidates used ballots to assess the nine sensory attributes. The samples were presented in slices of 0.3×4 cm, served immediately after being heated in a microwave oven (Electrolux, 1300 W) for 60 s.

The performance of the panel was evaluated as described by Saldaña et al. (2015), according to discrimination (significant sample effect [$P < 0.05$]: Panel was able to discriminate the samples with respect to a sensory attribute given), consensus (Non-significant interaction between Sample and Assessor [$P > 0.05$]: Assessors present a similar perception of the samples with respect to a sensory attribute given), and repeatability (Non-significant interaction between Sample and Session [$P > 0.05$]): Assessors use an attribute similarly from one session to another).

2.3.5. Final evaluation of bacon

The panel was composed of 10 trained assessors, who evaluated all samples considering nine sensory attributes in three repetitions (each repetition was conducted in a session) using a 10 cm unstructured scale, using the same anchors of the training stage. The number of assessors used in the current study is in-line with the recommendations proposed by Silva, Minim, Silva, and Minim (2014).

2.4. Data analysis

Panel performance was evaluated using a mixed-model analysis of variance (ANOVA) considering samples, sessions, assessors and their double interactions as sources of variation, in which the sample was taken as a fixed effect and assessors, sessions, and interactions as random effects. Least significant differences were calculated by Tukey's test ($P < 0.05$). To summarize the relationship between samples and sensory attributes, Principal Component Analysis (PCA) was performed on the correlation matrix of the average scores of the sensory attributes that showed significant differences ($P < 0.05$) between the samples (Næs, Brockhoff, & Tomic, 2010a). ANOVA and panel performance was performed in R environment (R Core Team, 2017) using SensoMineR (Lê & Husson, 2008) and FactoMineR (Lê, Josse, & Husson, 2008)

Table 2
Sensory descriptors and references used in DA of bacon.

Parameter	Attribute name	Definition	Technique	References
Appearance	Shine	Perception of brightness (surface).	Place samples in the center of vision of the booth and tilt the head approximately 30° prior to the evaluation.	Low: Raw pork bacon dried with absorbent paper. High: Bacon (Sadia®, Brazil) coated with 2.5 mL of soy oil.
	Fat content	Perception of fat in the sample.	Place samples in the center of vision of the booth and tilt the head approximately 30° prior to the evaluation.	Low: Bacon with 5% of visible fat. High: Bacon with 90% of visible fat.
	Redness	Color of the fleshy part of bacon.	Place samples in the center of vision of the booth at the edge and tilt the head approximately 90° prior to the evaluation of the meat color.	Low: The fleshy part of bacon with 90% of visible fat. High: The fleshy part of bacon with 5% of visible fat previously microwaved (60 s)
	Yellowness	Yellow characteristic of the fat.	Place samples in the center of vision of the booth at the edge and tilt the head approximately 90° prior to the evaluation of the fat color.	Low: Pork fat. High: Chicken fat.
Flavor	Saltiness	High perception of saltiness.	Chew the sample (twice) and leave it on the tongue for 5 s.	Low: Bacon soaked in water for 30 s. High: Bacon added with 1% salt.
	Smokiness	Perception of smoky flavor.	Chew the sample (twice) and leave it on the tongue for 5 s.	Low: Unsmoked bacon. High: Traditional smoked bacon added with 0.2 mL of liquid smoke (Ibrac®, Brazil).
	Fattiness	Perception of fat after chewing.	Chew the sample (twice) and leave it on the tongue for 5 s.	Low: Bacon with 10% of visible fat and of 90% visible meat. High: Bacon with 90% visible fat and 10% visible meat.
Texture	Succulence	Perception of liquid released at the first bite.	Place the sample between the incisors and chew it just once.	Low: 5 mm thick portion with low fat (stored 1 h at room temperature). High: 5 mm thick portion with high-fat content (freshly cooked in the microwave).
	Chewiness	Time necessary until the sample is ready for swallowing.	Count the number of chews before swallowing	Low: Hot dog (Sadia®, Brazil). High: Skin bacon (Sadia®, Brazil)

Table 3
P-values used to evaluate the panel performance of the descriptive panel.

Attribute	Sample (Sa)	Assessor (A)	Session (Se)	Sa * A	A * Se	Sa * Se
Shine	< **0.001**	**0.031**	**0.001**	0.460	0.344	**0.004**
Fat content	< **0.001**	< **0.001**	**0.036**	0.268	0.482	0.433
Redness	**0.010**	0.088	**0.028**	0.374	0.682	0.160
Yellowness	**0.001**	< **0.001**	**0.024**	0.332	0.854	**0.006**
Saltiness	< **0.001**	< **0.001**	0.105	**0.001**	0.670	**0.006**
Smokiness	< **0.001**	< **0.001**	**0.014**	**0.001**	0.580	0.054
Fattiness	< **0.001**	**0.009**	0.092	**0.012**	0.812	0.500
Succulence	**0.002**	0.117	0.951	**0.004**	0.098	0.088
Chewiness	0.059	< **0.001**	0.464	**0.021**	0.507	< **0.001**

Bold values indicate significant difference ($p < 0.05$) between samples 5% significance.

packages. The PCA was performed using XLSTAT 2015 (Addinsoft, New York, USA).

3. Results and discussion

After the recognition of basic tastes and odors and the sequential analysis of Wald, only 10 candidates were selected for DA.

3.1. Descriptors and references

The assessors generated between 10 and 38 terms to describe the samples, with a total of 218 terms. Once the sensory terms were consensually defined, nine attributes remained: shine, fat content, redness, yellowness, saltiness, smokiness, fattiness, succulence and chewiness (Table 2). This reduction is completely normal and aims to standardize the attributes and references (before training). Barcenas, Elortondo, Salmeron, and Albisu (1999) in their study of sheep's milk cheese generated a total of 269 attributes but the trained panel was able to reduce this number to 29. Attributes such as “saltiness” and “smokiness” have been reported in dry-cured bacon (Li, Zhuang, Qiao, Zhang, & Wang, 2016).

3.2. Training and performance of the panel

The panel performance was checked regarding the discrimination, consensus and repeatability. According to Table 3, the panel showed a high discrimination as the “sample” effect was significant for most attributes. This suggested that candidates were able to detect differences between the attributes of the bacon samples. However, no significant difference was observed for "chewiness", indicating that the smoking process did not influence the perception of this attribute. Some authors argue that the smoking process has significant influence on flavor (Soladoye, Shand, Aalhus, Gariépy, & Juárez, 2015). However, there is no single report that describes any influence on texture characteristics. In the current study, the discrimination capacity of the panel was very high, representing 88.9% (8 of 9 attributes were significant).

Consensus among assessors, estimated from the interaction "sample * assessor” effect, represents an important aspect of evaluation. This interaction indicates whether the products are perceived similarly by the different assessors (Lê & Worch, 2014). Therefore, a significant interaction indicates a lack of consensus among the assessors for a certain attribute (Carbonell, Izquierdo, & Carbonell, 2007). Table 3 shows that 4 of the 9 sensory attributes showed significant interactions; in this sense the sensory panel presented 44.4% of consensus. The lack of consensus was observed with respect to flavor and texture and this behavior was probably due to the fact that texture attributes are associated with kinesthetic sensations that are usually difficult to quantify in consensus (Albert, Varela, Salvador, Hough, & Fiszman, 2011). It should be also considered that training assessors cannot make up for

Table 4
Means and standard error for sensory attributes based on DA.

Attribute	Samples						
	Acacia	Commercial	Eucalyptus	Bamboo	LS2	LS1	Control
Redness[1]	5.9 ± 0.3[ab]	5.0 ± 0.4[ab]	4.7 ± 0.5[a]	5.5 ± 0.4[ab]	6.5 ± 0.3[b]	5.7 ± 0.4[ab]	4.6 ± 0.5[a]
Yellowness[1]	5.5 ± 0.5[b]	5.1 ± 0.7[ab]	5.5 ± 0.5[b]	4.1 ± 0.6[ab]	4.6 ± 0.7[ab]	3.7 ± 0.5[a]	3.8 ± 0.7[a]
Shine[1]	3.7 ± 0.4[c]	2.7 ± 0.4[abc]	2.8 ± 0.3[abc]	2.3 ± 0.5[abc]	2.0 ± 0.4[ab]	3.4 ± 0.5[bc]	1.6 ± 0.3[a]
Fat content[1]	4.0 ± 0.3[bc]	4.3 ± 0.4[c]	5.0 ± 0.4[c]	2.8 ± 0.5[ab]	2.5 ± 0.5[a]	4.3 ± 0.5[c]	2.4 ± 0.4[a]
Fattiness[2]	3.5 ± 0.4[cd]	4.0 ± 0.5[cd]	4.2 ± 0.4[d]	2.6 ± 0.5[bc]	1.9 ± 0.3[ab]	3.6 ± 0.6[cd]	1.8 ± 0.4[a]
Saltiness[2]	4.0 ± 0.6[c]	4.1 ± 0.7[c]	3.7 ± 0.4[bc]	3.9 ± 0.5[bc]	4.3 ± 0.7[c]	2.9 ± 0.4[ab]	2.4 ± 0.4[a]
Smokiness[2]	4. ± 0.6[c]	4.6 ± 0.6[c]	2.5 ± 0.6[b]	4.6 ± 0.6[c]	4.2 ± 0.7[c]	1.6 ± 0.4[ab]	0.9 ± 0.3[a]
Succulence[3]	4.5 ± 0.3[ab]	5.4 ± 0.3[b]	4.3 ± 0.6[ab]	4.6 ± 0.4[ab]	4.7 ± 0.5[b]	4.9 ± 0.6[b]	3.1 ± 0.6[a]
Chewiness[3]	5.2 ± 0.5[a]	5.0 ± 0.6[a]	4.6 ± 0.6[a]	4.9 ± 0.3[a]	4.9 ± 0.4[a]	4.0 ± 0.4[a]	3.9 ± 0.7[a]

Different letters in the same row indicate statistically different averages by the Tukey test ($p < 0.05$). 1: Attributes related to appearance, 2: attributes related to flavor, 3: attributes related to texture.

fundamental biological differences between assessors (Running & Hayes, 2016).

Usually texture attributes, such as “succulence” and “chewiness”, are more associated with intrinsic characteristics of each assessor (previous experience, learning, gender, age, and genetic differences), and even if there is a prolonged training, a consensus may not be always reached on these attributes since uncontrollable factors are involved in their measurement, such as the difference in body temperature and the rate of salivation. On the other hand, the lack of consensus of some attributes may also be due to lack of training. According to Labbe, Rytz, and Hugi (2004), products with heterogeneous characteristics require more training sections. In this study, each assessor was trained for 6 h (total of 6 sections). It is important to note that most international scientific papers do not indicate the number of sessions and the total time spent at this step. For instance, Laboissiere et al. (2007) only indicates that they conducted training sessions in the Quantitative Descriptive Analysis developed to assess the juice of passion fruit subjected to high hydrostatic pressures, but the number of sections is not described whatsoever. Quadros, Rocha, Ferreira, and Bolini (2015) trained a sensory panel to evaluate low-sodium fish burgers using 6 sections (1 h/each), but did not detail clearly the behavior of the panel according to the consensus.

In a study conducted by Chambers, Allison, and Chambers Iv (2004), the authors recommended an extensive training of the panel to obtain consistent results. However, the lack of consensus does not ensure an improvement due to the heterogeneity of the meat samples that are beyond the control of the researchers, such as differences originated from their diet, age, gender, among others. A study of Bayarri, Carbonell, Barrios, and Costell (2011) used 4 sessions to develop all steps of the descriptive analysis of yogurt, showing that the training time does not guarantee the consensus of the panel. Other factors should be taken into consideration: sample type, physiological characteristics of the assessors, among others.

Finally, the panel showed 100% of repeatability and this effect was measured based on the interaction between the “sample ∗ session” that was not significant. This indicated that the scores were stable from one session to another (Saldaña et al., 2015) and that the training of the 10 assessors was adequate.

3.3. Final evaluation of bacon

The mean scores and standard deviations for the attribute and sample are shown in Table 4. Significant effects ($P < 0.05$) were observed in four appearance attributes (“shine”, “fat content”, “redness” and “yellowness”), three flavor attributes (“saltiness”, “fattiness” and “smokiness”) and one texture attribute (“succulence”). The texture attribute "chewiness" did not show significant differences among the bacon samples, indicating that a variation in the smoking process had no significant effect on this attribute.

Appearance attributes of the unsmoked sample, such as “redness” (muscle part) and “yellowness” (fat layer), had the lowest ratings for both attributes, showing that the smoking process increased their intensity. Several authors reported that the application of liquid smoke could reproduce similar sensory characteristics that those from traditional smoking (Gonulalan, Kose, & Yetim, 2004). However, in the results shown in Table 4, the attributes “redness” and “yellowness” showed statistically significant differences between samples. This is mainly caused by the liquid smoke that, unlike traditional smoking, allows the standardization of the appearance of the final product (Emmerson, 2011).

For the “shine” and “fat content” attributes, significant differences were observed between samples, suggesting that the smoking process caused this effect. The “fattiness” is a typical attribute caused by the high fat level (at least 25%) in these products (Gibis, Kruwinnus, & Weiss, 2015). According to Jeremiah, Ball, Uttarob, and Gibson (1996), the “fat content” is positively correlated with “fattiness”. The “fat content” is extremely important in bacon since lipids retain several compounds that enhance the flavor developed in the smoking process (Font-i-Furnols & Guerrero, 2014). “Saltiness” was significantly higher in smoky samples than in the unsmoked sample. According to Jeremiah et al. (1996), the perception of “saltiness” is positively correlated with the “smokiness”, “fattiness”. “Smokiness” in the Acacia, Bamboo, Commercial and LS2 samples showed the highest mean scores, while the mean score of the unsmoked sample was significantly lower. This result demonstrates that the smoking process is important for the perception of this sensory attribute. This behavior was already reported in smoked ham (Pham et al., 2008). According to Font-i-Furnols and Guerrero (2014), the “fat content” influences the perception of moisture, which would explain the difference between these samples.

3.4. Principal Component Analysis

According to the ANOVA, there were significant differences between samples for most of the sensory attributes, indicating a high discrimination. However, differentiation between bacon samples can be driven by the perception of two or more attributes simultaneously. In this regard, PCA was used to study the correlations between sensory attributes. The data analysis of DA performed by PCA converted a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables, called principal components (linear combinations of original sensory attributes) (Næs, Brockhoff, & Tomic, 2010b).

In Table 5, eigenvalues and eigenvectors for the first 6 components are presented. The first and second principal components explained 49.99% and 29.21% of the total variance, respectively, indicating they contain the greatest amount of information of the original variables (about 79%).

The first component presented the following combination of the

Table 5
Eigenvalues and eigenvectors associated with each principal component.

Component	Eigen value	Variance (%)	Cumulative variance (%)	Eigenvectors							
				S	QF	R	Y	S	SA	F	SU
1	3.99	49.99	49.99	0.375	0.354	0.140	0.372	0.334	0.386	0.389	0.405
2	2.33	29.21	79.21	−0.220	−0.454	0.492	−0.041	0.426	0.371	−0.401	0.147
3	0.98	12.31	91.52	−0.447	−0.070	−0.508	0.578	0.219	0.253	−0.001	−0.301
4	0.48	6.00	97.53	−0.443	0.018	−0.410	0.444	0.121	0.055	0.174	0.625
5	0.17	2.12	99.66	0.449	−0.254	−0.355	−0.256	0.665	−0.230	0.049	−0.211
6	0.02	0.33	100.00	−0.129	0.298	0.100	−0.503	0.057	0.531	0.268	−0.524

S: Shine, QF: Fat content, RC: Redness, YC: Yellowness, S: Smokiness, SF: Saltiness, F: Fattiness, SU: Succulence.

original variables with their respective standardized coefficients (eigenvectors): $\mathbf{PC_1} = 0.375\mathbf{S} + 0.354\mathbf{QF} + 0.140\mathbf{R} + 0.372\mathbf{Y} + 0.334\mathbf{S} + 0.386\mathbf{SA} + 0.389\mathbf{F} + 0.405\mathbf{SU}$. It is interesting to highlight that the coefficients presented similar values (except for R). The second component is orthogonal to the first principal component and, therefore, the variance related to other attributes is explained. PC2 has the following structure: $\mathbf{PC_2} = -0.220\mathbf{S} - 0.454\mathbf{QF} + 0.492\mathbf{R} - 0.041\mathbf{Y} + 0.426\mathbf{S} + 0.371\mathbf{SA} - 0.401\mathbf{F} + 0.147\mathbf{SU}$. In this principal component, the coefficient related to eigenvector **R** (redness) is high, unlike what is observed in PC1. This result indicates that redness is better explained by the second principal component (PC2). To obtain the coordinates of the two principal components, the mean scores of the attributes for each bacon sample were plotted in a two-dimensional graph (Fig. 2).

The sensory attributes are correlated with the principal components through the variable loadings (Table 6). The variable loadings are useful in the interpretation of the principal components because they indicate the association between attributes with each principal component (Husson, Lê, & Pagès, 2017).

Table 6 shows that the variable loadings have high values. According to Chapman, Lawless, and Boor (2001), an absolute value greater than 0.56 represents a strong influence of sensory attributes on their respective component. The first component is strongly correlated with all attributes, except for "redness". The second component stands out because it is positively correlated with "redness", "smokiness", and "saltiness", where a negative correlation was observed with "fattiness". It is known that each component represents different explained variances. This fact can be clearly observed for redness – an attribute that was not correlated with PC1 but was highly associated with PC2.

In Fig. 2 it is possible to observe that the panel was able to differentiate the bacon samples as they were homogeneously distributed throughout the sensory map. The Acacia and Commercial samples were positively correlated with the PC1 and both samples presented similar characteristics. This behavior can also be seen in Table 4 as these bacon samples garnered similar mean scores for most sensory attributes. On the other hand, the unsmoked sample was negatively correlated with PC1, inferring that this sample presented completely different characteristics as compared to the bacon manufactured with Acacia wood or the Commercial bacon. Indeed, the unsmoked bacon garnered low mean scores for "smokiness" and "saltiness", among others.

Table 6
Variables loading of PCA conducted on DA.

Variable (attribute)	Principal component					
	1	2	3	4	5	6
Shine	**0.7490**	−0.3357	−0.4439	−0.3073	0.1851	−0.0212
Fat content	**0.7070**	**−0.6941**	−0.0694	0.0125	−0.1048	0.0490
Redness	0.2802	**0.7517**	−0.5041	−0.2840	−0.1463	0.0164
Yellowness	**0.7440**	−0.0625	**0.5742**	−0.3080	−0.1057	−0.0828
Smokiness	**0.6678**	**0.6516**	0.2173	0.0839	0.2742	0.0094
Saltiness	**0.7723**	**0.5678**	0.2512	0.0379	−0.0948	0.0876
Fattiness	**0.7789**	**−0.6136**	−0.0011	0.1203	0.0203	0.0441
Succulence	**0.8108**	0.2249	−0.2992	0.4330	−0.0872	−0.0864

The variable loadings with an absolute value greater than 0.56 are shown in bold.

The second component is related to the samples LS1, LS2, bamboo and eucalyptus. The LS1 and Eucalyptus samples are at the bottom of the sensory map because they garnered higher mean scores for "fattiness". Bamboo and LS2 samples are positively correlated and are on top of this component because they had high scores for the positive attributes related to this component.

Fig. 2 shows that "fat content" and "fattiness" are projected close together, suggesting there is a directly proportional correlation between these attributes. This behavior was already reported by Jeremiah et al. (1996), who indicated the existence of a direct relationship between the "fat content" and "fattiness". In addition, the attributes related to fat are in the same quadrant and close to "shine". The fat content influences the water retention properties of the sample (Troy & Kerry, 2010). On the other hand, "smokiness" and "saltiness" becomes more intense with the smoking process (Jeremiah et al., 1996).

In general, the sensory panel detected the sensory attributes in the smoked products, which are mainly due to the volatile compounds generated during the smoking process and lipid oxidation (aldehydes and ketones). According to Flores (2010), the presence of these chemical groups is associated with the following sensory attributes: grassy, rancid, fatty, sweet, and meaty. On the other hand, the sensory panel did not show significant differences between the samples naturally smoked and those added with liquid smoke.

As a final remark, the descriptive sensory profile associated with consumers studies will generate products with great potential for success in the current evolving and competitive market, in addition to identifying attributes that influence consumer's choices. Although bacon is a highly consumed product worldwide, there are is scientific study that assessed its sensory profile using conventional descriptive analysis. In this sense, this research fills this scientific gap.

4. Conclusions

The present paper is the first report to show the methodological aspects of DA of smoked bacon. Therefore, the generated data are extremely valuable for sensory scientists, companies and other stakeholders.

This study showed that the sensory profile of the traditional bacon is significantly affected by the smoking process. The smoking process caused an increase in the intensity of smokiness and saltiness but did not affect chewiness. Principal Component Analysis revealed that the unsmoked sample was different from the other samples. Overall, no differences on the sensory profile were observed between the natural process and the bacon added with liquid smoke. Smoked bacon manufactured with Acacia wood presented similar sensory characteristics to the commercial bacon. Therefore, Acacia wood showed promising results and should be the target of future studies to better understand the changes during the smoking process.

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