**University of São Paulo
“Luiz de Queiroz” College of Agriculture**

**Use of sensory analysis and social media for product development
driven by consumers: a case-study for smoked bacon**

Erick Manuel Saldaña Villa

Thesis presented to obtain the degree of Doctor
in Science. Area: Food Science and Technology

**Piracicaba
2019**

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Agroindustrial Engineering

**Use of sensory analysis and social media for product development driven by
consumers: a case-study for smoked bacon**

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RESUMO

Uso da análise sensorial e redes sociais no desenvolvimento de produtos direcionados pelos consumidores: um estudo de caso para o bacon defumado

A seleção diária dos alimentos é feita sem muito esforço e é determinada por processos vivenciados, afetivos e intuitivos, comumente demonstrados através das redes sociais. No entanto, a maioria dos estudos atuais em ciência sensorial e do consumidor usa métodos clássicos, sem considerar as redes sociais, que atualmente são usadas para expressar a “voz do consumidor”. Este fato poderia prejudicar a validade ecológica e a confiabilidade dos métodos atuais de análise sensorial. Nesse sentido, estudos baseados em métodos sensoriais clássicos e novos em conjunto com as redes sociais, poderiam fornecer resultados mais realistas, uma vez que respostas socialmente desejáveis e racionalizadas em relação a um “estímulo” seriam evitadas. Nesse contexto, o objetivo deste trabalho foi estudar a transição da análise sensorial clássica para as redes sociais como uma alternativa no desenvolvimento de bacon defumado, considerando a resposta do consumidor. Esta tese está dividida em oito estudos, com os quatro primeiros estudos baseados nas propriedades intrínsecas do produto. Nos dois estudos seguintes a percepção sensorial dinâmica, usando a Dominância Temporal de Sensações, foi estudada. Os dois estudos finais abordaram as propriedades não sensoriais associadas ao bacon defumado. Os resultados do presente estudo indicaram que as propriedades sensoriais estáticas e o perfil de compostos voláteis do bacon foram dependentes do processo de defumação. Já as propriedades sensoriais dinâmicas mostraram-se dependentes da defumação, conteúdo de gordura e a mastigação. Os fatores não sensoriais afetaram a representação do bacon defumado, sendo a saudabilidade o fator mais importante, seguido do contexto de consumo e da conveniência. A análise lexicométrica dos *tweets* revelou que as principais associações da palavra bacon no Twitter foram: preparações culinárias, ocasiões de consumo e sentimentos positivos. Finalmente, pode-se concluir que o processo de transição dos métodos clássicos para as redes sociais é um fenômeno crescente, que busca complementar as medidas sensoriais intrínsecas estáticas e dinâmicas na busca por uma melhor compreensão do comportamento do consumidor.

Palavras-chave: Bacon; Análise sensorial clássica; Redes sociais; Resposta do consumidor

ABSTRACT

Use of sensory analysis and social media for product development driven by consumers: A case-study for smoked bacon

Daily food selection is made without much effort and is determined by experienced, affective, and intuitive processes, commonly expressed through social media. However, the majority of the current studies in sensory and consumer science use classical methods without considering social media, which are currently used to express the “consumer-voice”. This fact could jeopardize the ecological validity and reliability of the current sensory methods. In this sense, studies based on classical and new sensory methods, along with social media, could provide more realistic results, since social desirable and rationalized responses to a “stimulus” would be prevented. In this context, the objective of the current work was to study the transition from classical sensory analysis to social media as an alternative in the development of smoked bacon considering the consumer’s response. This thesis is divided into eight studies, with the first four studies based on the intrinsic properties of the product. In the following two studies the dynamic sensory perception, using the Temporal Dominance of Sensations, was studied. The two final studies addressed the non-sensory properties associated with smoked bacon. The results of the present study indicated that the static sensory properties and the volatile profile of bacon were dependent on the smoking process. The dynamic sensory properties were dependent on the smoking, fat content and mastication. Non-sensory factors affected the representation of smoked bacon, with healthiness being the most important factor, followed by context of consumption and convenience. The lexicometric analysis of the tweets revealed that the main associations of the word bacon in twitter were: culinary preparations, occasions of consumption and positive feelings. Finally, it can be concluded that the transition process from classical methods to social networks is a growing phenomenon, which seeks to complement the static and dynamic intrinsic sensory measurements in the search for a better understanding of consumer’s behavior.

Keywords: Bacon; Classical sensory analysis; Social media; Consumer response

1. INTRODUCTION, OBJECTIVES AND THESIS STRUCTURE

Sensory characterization is fundamental for the development of food and beverages (Lawless & Heymann, 2010). The sensory science, responsible for providing the descriptive and hedonic measures of foods, has changed in the last decades (Valentin et al., 2012). The main change was “to incorporate the response of consumers” into description of the sensory properties of a product, supported with sophisticated statistical methods (Qannari, 2017). Due to this transition, different consumer-based sensory methods have emerged, which provide results close to the sensory profile given by a trained panel. Despite the improvements of the sensory methods, there is still a little explored factor, the "social media", in which consumers interact daily. In this context, the following question arises: Will the inclusion of the underlying information of social media improve the understanding of the consumer's behavior regarding a product? The present thesis that studied in depth the smoked bacon, was held to answer this question.

Smoked bacon is a meat product consumed throughout the world due to its pleasant sensory characteristics, coming from the smoking process. Despite this, few works have focused on the sensory properties of bacon. The available studies revealed that sensory measurements were only complementary to instrumental measurements. For this reason, this thesis addresses the four main dimensions of the sensory perception, i.e., the quantitative, qualitative, temporal and hedonic dimensions (Issanchou & Niklaus, 2006). To explore these four dimensions, different sensory methods were used. For instance, the descriptive analysis explores the qualitative and quantitative dimension of the sensory perception, while the projective mapping addresses the quantitative (distances between samples) and qualitative (description of samples) dimensions.

The starting point of this thesis came from a new Brazilian regulation that restricts the use of the term "smoked bacon" to products that are not smoked by the pyrolysis of wood (Brasil, 2012). This regulation, which would require modifications in the bacon processing, could also modify the sensory profile and, consequently, the preference of the consumers. In addition, to our knowledge, there are no preliminary reports that studied the sensory profile of smoked bacon with different Brazilian woods. Even in the world, there are few studies where bacon has been analyzed from a sensory perspective. Figure 1 presents a word cloud made with the most cited

Figure 1.1 indicated that the most cited word was flavor, followed by smoking, smoke, liquid, traditional, and cured, among others. This simple representation of the most cited words indicates a clear pattern: the flavor of smoked bacon is directly related to the smoking process.

In this context, the present thesis is organized in three parts, composed of seven original researches, as described in the Figure 1.2. In the first part, the changes in the static sensory characteristics (descriptive analysis, CATA, Napping) and the acceptance of smoked bacons due to smoking with different woods from reforestation were studied. In addition, the potential of these three methodologies in the identification of the ideal product based on the drivers of liking was compared. In the second part of this thesis the dynamic sensory properties during tasting due to smoking and fat content in the bacon were studied. In the third and final part of this

thesis, it is presented how to analyze tweets associated with the word bacon from a lexicometric perspective.

The general objective of this thesis was to study the transition of classical sensory analysis to social media as an alternative to develop smoked bacon considering the consumer's response. For that, some specific objectives were intended:

- To evaluate the impact of smoking on the sensory profile of bacon using descriptive analysis (Chapter 2);
- To correlate the consumer-based sensory properties (Napping) and volatile profile of smoked bacon using multi-block analysis (Chapter 3);
- To evaluate the descriptive and hedonic sensory perception to obtain the drivers of liking of smoked bacons using CATA questions coupled with Ideal Profile, considering the interindividual differences of the consumers (Chapter 4);
- To evaluate the influence of the product space provided by DA, PM, and CATA questions to identify and describe the ideal smoked bacon through the application of PrefMFA and PrefMap (Chapter 5).
- To evaluate the impact of the type of smoking and fat content on the dynamic sensory perception of bacon by Brazilian consumers using Temporal Dominance of Sensations (TDS) (Chapter 6);
- To evaluate the sensory aspects of bacon smoked with reforestation woods and liquid smoke using the TDS (Chapter 7);
- To evaluate the impact of non-sensory factors on the relative importance and utility values of expected liking and purchase intention of bacons, as well as the representation of their labels (Chapter 8);
- To describe a lexicometric approach for analysis and interpretation of Twitter data, considering Brazil as the geographical area and bacon as the inductor word (Chapter 9).

Figure 1.2. Schematic diagram explaining the thesis organization.

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2. DESCRIPTIVE ANALYSIS OF BACON SMOKED WITH BRAZILIAN WOODS FROM REFORESTATION: METHODOLOGICAL ASPECTS, STATISTICAL ANALYSIS, AND STUDY OF SENSORY CHARACTERISTICS¹

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.

Keywords: Descriptive analysis; Bacon; Sensory profiling; Principal component analysis

2.1. 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

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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. To be environmentally friendly, the traditional smoking requires the use of woods from reforestation, thus preserving the native flora (IBA, 2015). In the current work, reforested woods (Eucalyptus, Acacia, and Bamboo) were used in the traditional smoking process.

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. 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.

2.2. Materials and methods

2.2.1. Samples

Seven types of bacon were evaluated in this study (Table 2.1):

Table 2.1. Description of treatments

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

2.2.2. 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 were removed and sprayed with liquid smoke at a proportion of 1% of the weight of the bacon (selected based on pilot testing).

2.2.3. 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 flowchart shown in Figure 2.1 was followed.

Figure 2.1. Flowchart of the steps of the generic descriptive analysis.

2.2.3.1. Candidates' recruitment

Thirty-five candidates (aged between 18 and 62 years, 72% females and 28% males) 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.

2.2.3.2. 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 $\geq 75\%$ 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 $\geq 65\%$ 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 ($\pm 150\text{ }^{\circ}\text{C}$) until a core temperature of $75\text{ }^{\circ}\text{C}$ was achieved. Burgers were cut into cubes ($2 \times 2 \times 2\text{ cm}$), 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 Figure 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 Figure 2.2, 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 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.

Figure 2.2. Test chart for sequential analysis of Wald. P = candidate.

2.2.3.3. 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).

2.2.3.4. Training and panel performance

The panel performance was checked regarding the discrimination, consensus and repeatability. According to Table 2.3, 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 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 et al. (2004), products with heterogeneous characteristics require more training sessions. In this study, each assessor was trained for 6 h (total of 6 sessions). 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 et al. (2015) trained a sensory panel to evaluate low-sodium fish burgers using 6 sessions (1 h/each), but did not detail clearly the behavior of the panel according to the consensus.

2.2.3.5. 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 et al. (2014).

2.2.4. 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 (Team 2017) using SensoMineR (Lê & Husson, 2008) and FactoMineR (Lê, Josse, & Husson, 2008) packages. The PCA was performed using XLSTAT 2015 (Addinsoft, New York, USA).

2.3. Results and discussion

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

2.3.1. 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 2.2). This reduction is completely normal and aims to standardize the attributes and references (before training). Barcenas et al. (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).

2.3.2. Training and performance of the panel

The panel performance was checked regarding the discrimination, consensus and repeatability. According to Table 2.3, 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).

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Table 2.2. 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)

In a study conducted by Chambers et al. (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 et al. (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.

Table 2.3. 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.

2.3.3. Final evaluation of bacon

The mean scores and standard deviations for the attribute and sample are shown in Table 2.4. 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 et al. (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.

Table 2.4. 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	4.7 ± 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.

This behavior was already reported in smoked ham (Pham et al., 2008). According to Font-i-Furnols & Guerrero (2014), the “fat content” influences the perception of moisture, which would explain the difference between these samples.

2.3.4. 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 2.5, 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 original variables with their respective standardized coefficients (eigenvectors): $PC_1 = 0.375S + 0.354QF + 0.140R + 0.372Y + 0.334S + 0.386SA + 0.389F + 0.405SU$. 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: $PC_2 = -0.220S - 0.454QF + 0.492R - 0.041Y + 0.426S + 0.371SA - 0.401F + 0.147SU$. 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 (Figure 2.3)

Table 2.5. Eigenvalues and eigenvectors associated with each principal component.

Component	Eigenvalue	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.

The sensory attributes are correlated with the principal components through the variable loadings (Table 2.6). 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 2.6. 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.

Table 2.6 shows that the variable loadings have high values. According to Chapman et al. (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 Figure 2.3 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 2.4 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.

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.

Figure 2.3 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).

Figure 2.3. Principal component analysis on correlation matrix the means of attributes: representation of samples and attributes.

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 no scientific study that assessed its sensory profile using conventional descriptive analysis. In this sense, this research fills this scientific gap.

2.4. 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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3. RELATIONSHIP BETWEEN VOLATILE COMPOUNDS AND CONSUMER-BASED SENSORY CHARACTERISTICS OF BACON SMOKED WITH DIFFERENT BRAZILIAN WOODS²

Abstract

Bacon is a product made from pork meat that is subjected to curing, drying, and smoking. Researchers aim to associate the worldwide high-acceptance of such a product with the sensory and chemical properties of bacon. In this context, the objective of the present study was to characterize bacon samples smoked with different woods from reforestation using chemical and sensory methodologies, which were subsequently correlated by means of statistical multi-block analysis. Volatile compounds (VCs) of the smoked bacons were studied using solid-phase microextraction (SPME) coupled with gas chromatography-mass spectrometry (GC–MS), and the consumer sensory perception was explored by the Napping technique. VCs were identified in smoked samples, which triggered sensory attributes related to odor, flavor, and texture, such as “smoky flavor”, “salty taste”, “pleasant taste”, “woody flavor”, and “hard texture”. Multi-block analysis showed that the sensory attributes were associated with a group of VCs and not by a single compound.

Keywords: Wood; Smoking process; Sensory analysis; Napping; SPME GC-MS

3.1. Introduction

The sensory attributes related to the flavor of meat products can influence their acceptance and purchase intent (Calkins & Hodgen, 2007; Font-i-Furnols & Guerrero, 2014; Resano et al., 2011; Yu & Sun, 2005). The peculiar sensory characteristics of meat products are mainly related to the presence of volatile and non-volatile compounds that interact to generate the flavor of meat-based products (Khan, Jo, & Tariq, 2015). In this sense, in smoked products, such as bacon, lipid oxidation and Maillard reaction give rise to volatile compounds (Yu, Sun, Tian, Qu, 2008), but smoking is the process that most influences the generation of volatile compounds (VCs), and consequently, the bacon flavor (Font-i-Furnols & Guerrero, 2014).

According to the Brazilian Regulation, smoking is a mandatory step in the manufacturing of bacon (Brasil, 2000). In this process, the meat is exposed to the smoke of wood chips that are pyrolysed until temperatures higher than 500 °C are achieved

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(Ledesma, Rendueles, & Díaz, 2017; Ledesma, Laca, Rendueles, & Díaz, 2016), leading to the generation of a series of volatile compounds (Aaslyng & Meinert, 2017). According to Flores (2010), aldehydes, pyridines, pyrazines, furans, alcohols, and ketones are the main aroma compounds found in bacon. An alternative to the generation of these compounds from the traditional smoking is the use of wood smoke condensates, commonly known as liquid smoke. The use of liquid smoke allows higher process control, eliminates carcinogenic compounds, such as polycyclic aromatic hydrocarbons, giving much of the desired flavor and aroma of conventional smoking (Lingbeck et al., 2014).

Sensory characteristics and volatile compounds of smoked bacon mainly depend on the chemical composition of the wood used in smoking process (Montazeri et al., 2013). Since native flora must be preserved, the use of woods from reforestation seems to be suitable to smoke meat-based products. In Brazil, Eucalyptus (*Eucalyptus spp.*) is one of the most used woods in the smoking process (Luz, 2013), since this species is the most representative among the woods from reforestation (about 75%) (IBGE, 2016). 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*).

In order to get a better understanding of the bacon flavor it is necessary to find correlations between the sensory data and instrumental measurements. From an instrumental perspective, the volatile compounds are usually identified and quantified by gas chromatography (Azarnia, Boye, Warkentin, & Malcolmson, 2012). From a sensory standpoint, the descriptive analysis conducted by a trained panel is the most used method by the food industry to develop and control the sensory quality of products (Lawless & Heymann, 2010; Selani et al., 2016)

However, some authors have pointed out that the perception of a trained panel do not reflect the sensory perception of consumers (Saldaña, de Oliveira, et al., 2018; ten Kleij & Musters, 2003). Considering the high competitiveness of the current market, companies need to base their decisions on the consumer preferences in order to manufacture products with increased odds of success (Delarue, 2015). In this context, several alternative methods using potential consumers have been implemented to study

the sensory characteristics of foods (Valentin, Chollet, & Lelie, 2012). Among these techniques, the Projective Mapping (PM) (Risvik, McEwan, Colwill, Rogers, & Lyon, 1994), later adapted and called Napping (Pagès, 2005), is a method of data collection, in which consumers project the products in a two-dimensional graph according to their similarities and differences (Pagès, 2005; Risvik et al., 1994; Risvik, McEwan, & Rødbotten, 1997; Nestrud & Lawless, 2008; Perrin & Pagès, 2009)

In spite of the relevance of flavor as an important quality factor of meat-based foods (Ulla, Antti, Oskar, & Mari, 2016), it is of pivotal importance to assess the relationship between consumer-based sensory properties and the volatile compounds of smoked bacon. Although Jeremiah, Ball, Uttaro, & Gibson (1996) have studied the relationship of chemical components with the flavor attributes of bacon, this work considered only trained assessors responses. Afterwards, Ai-Nong & Bao-Guo (2005) reported the bacon flavor considering only chemical properties. Recently, Saldaña et al. (2019) studied the descriptive and hedonic sensory perception of Brazilian consumers for smoked bacon, but these authors did not make any association between consumer perception and volatile composition. In this context, the study of the consumer-based sensory properties and volatile profile of smoked bacon will help to understand the relationship between volatile compounds generated during the smoking process and the sensory attributes. According to the panorama presented, the aim of this work was to study the sensory characteristics of bacon smoked with different Brazilian woods from reforestation using a consumer-based perspective and the volatile profile measured by gas chromatography. In addition, a statistical multi-block analysis was used to explore the associations between VCs and sensory attributes.

3.2. Materials and methods

3.2.1. Samples

In the present work, seven treatments were studied: smoked bacon with reforestation wood from (1) Eucalyptus, (2) Acacia, and (3) Bamboo; two bacon samples smoked with commercial liquid smoke (4) LS1 (pH=2.50-4.50, density=0.90-1.15 g·mL⁻¹, Acidity=10.00-11.00%, Salmonella in 25 mL: absence, Sodium=2.40 mg·g⁻¹) and (5) LS2 ((pH=2.20-2.20, density= 1.09-1.19 g·mL⁻¹, Acidity=9.50-11.00%, Salmonella in 25

mL=absence, Sodium=1.50 mg·g⁻¹); (6) one commercial sample (CS) (manufacturer information: carbohydrates=0g, saturated fat=1.7g, sodium=77 mg, protein=1g, trans fat=0g, total fat=4.7g) purchased in the local market; and (7) one unsmoked sample (negative control). The bacon manufacturing process was carried out as described by Saldaña et al. (2018), following a randomized block design with 3 blocks (replicates), and each block corresponded to an independent bacon processing. 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 pork belly at a proportion of 20% of the meat weight. After stabilization at 4 °C/24 h, the traditional smoking (Verinox, Italy) 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 75 °C was reached. For the liquid smoking process, steps 1 and 3 followed the same time-temperature program of the conventional smoking, but in stage 2, instead of receiving thermal treatment and smoke from the wood burning, the bellies were removed from the smoker and sprayed with liquid smoke in the proportion of 1% of the weight of the meat (selected based on pilot testing). Then, the samples were cooled, vacuum-packaged, and stored at 1.5 °C for 12 hours until sensory evaluation. For the liquid smoking process, the same time-temperature program was used (step 2 was ruled out). In this stage, bellies were removed and sprayed with liquid smoke at a proportion of 1% of the meat weight (Saldaña et al., 2019).

3.2.2. Volatile compounds profile

The extraction of the volatile compounds was carried out by headspace-solid phase microextraction (SPME) using Divinylbenzene / Carboxen / Polydimethylsiloxane (DVB / CAR / PDMS) fibers of 1cm of length with 50/30 µm of coating (Supelco, Bellefonte, PA). Before the analysis, fibers were conditioned in the GC injector, as indicated by the manufacturer. Three grams of the sample were homogenized in 40 mL of double-distilled water. Then, an aliquot (~ 1 mL) of the homogenized sample was added in vials sealed with silicone caps (Supelco, Bellefonte, PA). Vials were placed in a water bath at 60 °C for 30 min to equilibrate the headspace. Then, the fiber was exposed to the headspace for 30 min at 60 °C. The compounds absorbed by the fiber were desorbed in

the injector of the GC-MS (Shimadzu, 2010, Japan) for 5 min at 260 °C in a splitless mode. The compounds were separated on a DB-5 MS capillary column (30 m long, 0.25 mm diameter and 0.25 µm thickness, Agilent, USA). Helium was used as carrier gas at a linear velocity of 36 cm·s⁻¹. The chromatograph oven temperature was maintained at 40 °C for 5 min, then the temperature was raised from 40 to 240 °C in 15 min. Mass spectra were obtained by the electron impact at 70 eV in the range of 40 to 400 amu. The compounds were identified by comparison with the Kovats retention index (Kováts, 1958) and confirmed by mass spectra databases (Wiley, NIST, and Flavornet libraries), considering the mean of the relative peak area. This analysis was carried out in duplicate.

3.2.3. Consumer sensory evaluation

3.2.3.1. Consumers

Ninety-three healthy individuals (55% women and 45% men, ages ranging from 18 to 62 years) were recruited in the campus of the *Escola Superior de Agricultura “Luiz de Queiroz” (ESALQ) - Universidade de São Paulo (USP)*. The inclusion criteria were the regular bacon consumption and the interest and availability of time to participate in the study.

The study was conducted in a single session of approximately 15 – 30 min. Samples were presented in 50 mL disposable cups coded with three-digit random numbers, at room temperature, and under artificial white light in individual booths. Water and bread were offered to consumers to cleanse the palate between samples. The Ethics Committee of Human Research of the ESALQ - USP (protocol No. 1.550.783) approved the present protocol.

3.2.3.2. Napping procedure

Consumers were asked to evaluate seven bacon samples and to place them on a white paper sheet (A3 – 420 x 297 mm) according to their global similarities and differences. Consumers were instructed to use the entire surface of the sheet according to their own criteria (Varela & Ares, 2012). In addition, they were informed that two samples located nearby indicate high similarity, whereas if they were distant from each

other, the samples would be different. After positioning the samples, consumers grouped them if necessary. Finally, ultra-flash profiling task was performed by adding sensory attributes directly on the sheet to describe the bacon samples in order to obtain their sensory characteristics (Perrin et al., 2008; Santos et al., 2013).

3.2.4. Data analysis

3.2.4.1. Volatile compounds profile

For each sample, the number of compounds belonging to a specific chemical family was identified. Independently, a principal component analysis (PCA) was performed using the correlation matrix based on the mean values of the relative peak area of each volatile compound for each sample, in a way that bacon samples were placed in the rows (individuals) and volatile compounds were placed in the columns (variables).

3.2.4.2. Napping

Napping data were analyzed by Multiple Factor Analysis (MFA) (Escofier & Pagès, 1994; Pagès, 2005). Firstly, the coordinates of each sample were obtained based on the sensory map of each consumer considering the bottom left of each sheet as the origin of the coordinates. The coordinates of each consumer were used as active variables. Confidence ellipses were plotted from MFA by parametric bootstrapping to assess the stability of the sample configurations (Dehlholm, Brockhoff, & Bredie, 2012; Dehlholm, Brockhoff, Meinert, Aaslyng, & Bredie, 2012) using the script provided by Dehlholm, Brockhoff, & Bredie (2012). In addition, the words generated by consumers to characterize the samples were analyzed by lemmatization and categorization; then, the frequency of each sensory attribute was quantified obtaining a contingency table. The attributes were included in the contingency table when at least 10% of consumers used for, at least, one sample (Ares, Giménez, Barreiro, & Gámbaro, 2010). This step was carried out by triangulation, considering the analysis of three independent researchers, with previous experience in consumer sensory evaluation (Modell, 2005). The contingency table was considered as a supplementary variable in the MFA because it was not used for plotting the coordinates. To evaluate the significant difference between rows (bacon samples) and columns (sensory attributes), a global χ^2 test was performed on the contingency table and when the difference was significant ($P < 0.05$), a χ^2 test per

cell was performed to identify if each cell observed was significantly different from the theoretical value (Symoneaux, Galmarini, & Mehinagic, 2012).

As consumers used their own criteria to group similar bacon samples and then define the descriptive attributes, a clustering analysis was performed to evaluate what does “consensus” mean, since assessors use different criteria (Næs, Varela, & Berget, 2018). The consumers segmentation was analyzed by means of HCA based on similar individual maps using the coordinates of the first four dimensions of the MFA (Vidal et al., 2016). For the HCA, the Euclidean distances and Ward’s agglomeration method were used, where the optimal number of clusters was determined by the Calinski and Harabasz index (Milligan & Cooper, 1985).

3.2.4.3. Relationship between volatile compounds and sensory attributes

A multiblock approach was used to associate the consumer-based sensory attributes with the volatile compounds. The MFA was chosen because it can be used for samples characterized by categorical and quantitative data. In this study, a contingency table containing the sensory attributes was considered as a categorical table, while the volatile compounds were considered as a quantitative table. The superimposed representation of the samples was performed through a partial individual plot (Pagès & Husson, 2014). Sample configurations defined by the sensory descriptors and volatile compounds were compared with the RV coefficient to verify the degree of relationship between two sets of variables (Josse, Pagès, & Husson, 2008).

3.2.4.4. Software

PCA, HCA, global χ^2 test and χ^2 test per cell were performed using XLSTAT 2015 (Addinsoft, New York, EEUU). The MFA and the optimal number of clusters were performed in the R environment, with the FactoMineR (Lê, Josse, & Husson, 2008) and NbClust (Charrad, Ghazzali, Boiteau, & Niknafs, 2014) packages, respectively.

3.3. Results and discussion

The smoking process is crucial for the development of particular sensory characteristics of bacon (Saldaña et al., 2018), which can modify the consumer

perception (Saldaña et al., 2019). These sensory characteristics are associated with the volatile compounds generated during curing and smoking. Thus, it becomes increasingly important to relate the sensory characterization performed by consumers with the VCs profile.

3.3.1. Volatile compounds profile

Thirty-nine VCs were identified, their relative peak areas were determined (Supplementary Table 3.1) and they were subsequently grouped into six chemical families: phenols, furans, aldehydes, ketones, alcohols, and others. Figure 1 shows the relative peak area of each chemical family found in bacon samples. The VCs profile found in bacon samples manufactured in the current study is in agreement with the bacon volatile profile of a previous study (Flores, 2010). Yu, Sun, Tian, & Qu (2008) identified 48 volatile compounds in Chinese traditional smoke-cured bacon. The high content of VCs found by these authors may be related to the prolonged smoking time (1 month) compared to the time adopted in the present study (2 h). Other factors may also have influenced the obtained data, such as the wood type, the ventilator velocity, and the smoke density (Hitzel, Pöhlmann, Schwägele, Speer, & Jira, 2013), as well as the cooking process prior to the quantification (Flores, 2010).

In the current study, the unsmoked bacon had the lowest variety and number of identified volatile compounds ($n=9$). Jin et al. (2015) found 14 volatile compounds in unsmoked bacon cured for 12 h and Yang et al. (2017) verified 15 volatiles in bacon (unsmoked) after 24 h of curing, quantities that are slightly higher than that found in this study. Variations in the amounts of VCs can be attributed to differences in raw materials (especially in the amount of fat and its oxidative state) and process conditions. The low number of compounds was expected because the majority of the VCs are derived from the smoking process. This fact may be an indication of possible sensory differentiation between bacon samples. Except for LS1 ($n=20$), the other smoked samples presented 31-34 VCs, which were probably generated from the smoking process, the seasonings used in the formulation, and from different reactions between meat constituents (lipids, proteins, carbohydrates) (Lawrie & Ledward, 2006).

Figure 3.1. Relative peak area of the major categories of volatile compounds of bacon. CS: Commercial sample, LS: Liquid smoke.

From the 39 volatile compounds, 13 (33.3%) belonged to phenols. From the smoked samples, CS had the high relative area of this family group (Figure 1), accounting for 45.5% of the total peak area, while bacons with liquid smokes showed the lowest relative areas. According to Ho, Lee, & Jin, (1983), the majority of phenols in wood smoke flavor are generated by the pyrolysis of lignin. The presence of these compounds are strongly related to the wood smoke flavor (Maga, 1992).

Among the phenolic compounds, 2-methoxyphenol had the highest relative peak area in CS (10.50×10^6), Acacia (1.94×10^6), and Bamboo (1.76×10^6), followed by phenol and 2-methoxy-4-methylphenol. Methoxyphenols and phenols are powerful aromatic compounds with pungent, cresolic, heavy, burnt, and smoky notes (Guillén & Manzanos, 2002). In agreement with the present study, 2-methoxyphenol (guaiacol) was also the predominant smoke component in smoke-cured bacon manufactured with different fiber coatings (Yu, Sun, Tian, Qu, 2008). Guaiacol is essential for the sensory characteristics of smoked meat products (Sheard, 2010), once it is primarily related with smoke flavor (Ellis, 2001).

Olivares, Navarro, & Flores (2009) reported that the presence of aldehydes in meat products comes from lipid oxidation, Strecker degradation of amino acids, and Maillard reactions in the product (Mottram, Croft, & Patterson, 1984). This chemical family was identified in all samples, but the Eucalyptus stood out due to its high relative peak area (Figure 1). Some of the aldehydes found in the bacon samples were hexanal, heptanal, octanal, nonanal, and decanal, all of them linear saturated aldehydes with more than five C-atoms, which indicates a lipid oxidation origin (Belitz, Grosch, & Schieberle, 2009). These aldehydes were also found by Yu, Sun, Tian & Qu (2008) in traditional smoke-cured bacon. In general, hexanal was the most abundant aldehyde in the samples, which can confer rancid aroma when present in high concentrations, as well as grass aroma when low concentrations are found (Lorenzo, Carballo, & Franco, 2013). On the other hand, the two benzene-derived aldehydes (benzaldehyde and benzeneacetaldehyde) are probably related to amino acid degradation (Forss, 1973). Benzaldehyde is related to bitter almond sensory note, while benzeneacetaldehyde contribute to acorn, rancid and pungent sensations (Lorenzo, Carballo, & Franco, 2013). Five ketones were found in bacon samples and, among them, 2-hydroxy-3-methyl-2-cyclopenten-1-one was one of the most abundant, with CS and LS2 showing the highest relative peaks areas. This compound comes from the Maillard reaction (Nursten, 2005) and, according to Lustre & Issenberg (1970), it acts as a flavor enhancer and has an important influence on bacon flavor, even at low concentrations. Another ketone found in the bacon samples was the 2,3-dimethyl-2-cyclopenten-1-one, which is reported as a typical VC of wood smoke (Maga, 1987). According to Forss (1973) methyl ketones come from lipid degradation and the cyclopentenones may come from wood smoke (Xie, Sun, & Wang, 2008).

The total peak area of furans ranged from 0 (control) to 9.24×10^6 (Eucalyptus) (Figure 1) and five compounds of this category were found. Furans can be formed by biochemical reactions (thermal degradation of lipids and Maillard reactions) from different biomolecules naturally present in food, such as carbohydrates, amino acids, fatty acids, carotenoids (Elmore, Mottram, Enser, & Wood, 1999). Additionally, Yu et al. (2008) reported that furans are generated by the interaction between Maillard reaction compounds and smoking compounds in smoked bacon. This fact explains the absence

of furans in the control sample. According to the results, 2-furanmethanol showed the highest peak area in CS and the second highest peak area in Acacia, Eucalyptus, LS2 and Bamboo. The relevance of this compound was confirmed by the study of Xie et al. (2008), who found this furan in large amounts in Chinese smoke-cured bacons. According to Viani & Horman (1974), furan derivatives can provide aroma of caramel, sweet, butterscotch, brandy, burnt, and sugar.

Four alcohols were found in bacon samples and the sum of their relative areas ranged from 0 to $14,45 \times 10^6$ (Figure 3.1). In meat products, volatile alcohols come from the lipid oxidation reactions (Estévez, 2017). Furthermore, according to Donald (1998), dicarbonyls formed by Maillard reaction are converted into aminoketones or aminoalcohols, which can also react with themselves or with other compounds providing a wide variety of aromatic compounds.

In order to establish the multidimensional relationships between the bacon samples and VCs, a PCA was performed. The first two PCs accounted for up to 68% of the total variance, which is a high value considering the 39 VCs. According to Figure 3.2, the first PC separates the samples as a function of the number of volatile compounds. The right side of the first PC showed a high content of volatile compounds correlated with Eucalyptus and CS samples. According to PCA data, these samples were mainly related with aldehydes, ketones, and phenols. It is important to note that the bacon smoked with Eucalyptus showed a high number of aldehydes, while CS presented more phenolic compounds. On the other hand, there were few VCs correlated with Acacia, Bamboo, LS2, Control, and LS1 samples.

Figure 3.2. Biplot of the first two dimensions of the PCA performed on volatile compounds data. **Phenols:** F1: phenol; F2: 2-Methylphenol; F3: 3-Methylphenol; F4: 2-Methoxyphenol; F5: 4-Ethylphenol; F6: 4-Methoxy-3-methylphenol; F7: 2-Methoxy-4-methylphenol; F8: 2-methoxy-4-Ethylphenol; F9: 4-Ethenyl-2-methoxyphenol; F10: 2,6-Dimethylphenol; F11: 2-Methoxy-4-(2-propenyl)-phenol; F12: 2-Methoxy-4-propylphenol; F13: 2,6-Dimethoxy-4-methylphenol. **Furans:** FU1: 2-Furaldehyde; FU2: 2-Furanmethanol; FU3: 2-Acetylfuran; FU4: 5-Methyl-2-furfuraldehyde; FU5: 3-methyl-2(5H)-Furanone. **Aldehydes:** AL1: Hexanal; AL2: Heptanal; AL3: Benzaldehyde; AL4: Octanal; AL5: Benzeneacetaldehyde; AL6: Nonanal; AL7: Decanal. **Ketones:** C1: 2-Cyclopenten-1-one, 2 methyl; C2: 2-Cyclopenten-1-one, 3 methyl; C3: 2-Hydroxy-3-methyl-2-cyclopenten-1-one; C4: 2,3-Dimethyl-2-cyclopenten-1-one; C5: 3-Ethyl-2-hydroxy-2-Cyclopenten-1-one. **Alcohols:** A1: 1-Butanol; A2: Benzylalcohol; A3: Octanol; A4: 2-Phenoxyethanol. **Others:** O1: Carbon disulphide; O2: Unknown; O3: Diethyl phthalate; O4: 2-Methylhexane; O5: 1,4 Dichlorobenzene.

3.3.2. Consumer sensory evaluation

Consumers placed all samples on a paper sheet and each consumer used between 4 and 12 attributes to describe the samples. Table 3.1 shows the attributes used by consumers to characterize each sample. From a total of the 66 attributes, only 17 were considered as supplementary variables in the MFA, since they were mentioned by more than 10% of the consumers. The most frequently mentioned attributes were: salty, smoky, little hard, hard, and pleasant. These sensory attributes obtained directly from

consumers are consistent with those reported by Saldaña et al. (2018) who studied the sensory profile of bacon using conventional descriptive analysis.

The attributes and samples were highly significant by global χ^2 test ($\chi^2 = 161.43$, $p < 0.001$), indicating that the attributes were significantly different between bacon samples. The χ^2 test per cell performed on the contingency table showed that the control bacon was characterized by being “little hard”, “tasteless” and by presenting a low frequency of “smoky”, “hard”, “crunchy”, and “woody” attributes. A low frequency of the attribute “tasteless” was verified in the commercial sample (CS), whereas “strange taste” and “little smoky” were the least mentioned attributes for LS1. For LS2, the attribute “hard” was frequently mentioned and the terms “little hard”, “pleasant”, and “succulent” showed a low frequency. On the other hand, “smoky” had a high frequency in bacon smoked with Acacia and “little pleasant” and “little smoky” were the least cited attributes. In samples smoked with Bamboo wood, the attribute “little salty” showed a high frequency, whereas the least frequently mentioned terms were “bright” and “woody”. Finally, bacon smoked with Eucalyptus wood had a high frequency of “salty” and “woody” and a low frequency of “little salty”. The multisensory association between the attributes “salty” and “woody” may be a promising result for the development of sodium-reduced meat products (Fig. 3.3B and 3.3D), since the salt content could be reduced, maintaining the perception of the salty taste. The bacon samples perceived as the most and least smoked were Acacia and the control, respectively. Conversely, the attribute “woody” was perceived only in the bacon smoked with Eucalyptus wood, suggesting that the “smoky” and “woody” attributes do not represent the same sensation for the consumers.

Table 3.1. Frequency of the attributes used by consumers to describe the samples.

Attributes	Samples						
	LS1	LS2	Acacia	Bamboo	Eucalyptus	CS	Control
Salty	15	18	26	15	28(+)	20	10
Little salty	8	3	4	12(+)	0(-)	4	8
Smoky	12	22	29(+)	21	21	18	3(-)
Little smoky	0(-)	1	0(-)	1	1	1	2
Hard	7	19(+)	10	14	11	10	2(-)
Little hard	15	6(-)	14	13	12	13	25(+)
Pleasant	15	5(-)	10	8	9	15	5
Little pleasant	1	1	0(-)	2	2	0(-)	2
Gelatinous	9	11	11	9	6	9	7
Tasteless	11	9	5	6	6	3(-)	11(+)
Dry	5	9	6	7	3	3	6
Crunchy	3	9	6	3	7	6	0(-)
Sweet	4	3	4	3	3	2	5
Bright	4	3	5	0(-)	2	5	2
Strange taste	0(-)	3	1	5	3	1	5
Woody	2	2	2	0(-)	6(+)	4	0(-)
Succulent	3	0(-)	1	2	2	2	2

Values in bold are significantly higher (+) or lower (-) than the expected theoretical value according to chi-square per cell ($p < 0.05$).

MFA explained 73.18% of the original variance and shows the samples and attributes considering the first four dimensions (Figure 3.3). Several authors have used the first four dimensions to represent various products, such as wine (Fariña et al., 2015), soymilk (Grygorczyk, Lesschaeve, Corredig, & Duizer, 2013), and yogurt (Cadena et al., 2014).

Figure 3.3. Representation of the samples and attributes in the first four dimensions of MFA performed on the Napping data. A: Samples in the first and second dimensions; B: Attributes in the first and second dimensions; C: Samples in the third and fourth dimensions; D: Attributes in the third and fourth dimensions.

In the sample representations (Figure 3.3), the confidence ellipses around the samples indicate their variability considering 500 virtual consumers. The overlapped confidence ellipses showed that there is no significant difference between samples (Abdi & Valentin, 2007). In the first two dimensions, Acacia and LS2 were overlapped, indicating that these samples were very similar. The confidence ellipses and spatial representation revealed four groups or clusters: the first cluster consisted of Acacia and LS2 for presenting similar texture, while the second group consisted of Eucalyptus and LS1 because of “woody”, “bright”, and “pleasant” characteristics. The third group

consisted of CS and Bamboo, which were mainly described as “dry”, and the fourth group consisted of the control, which was perceived as “little hard”, “little pleasant”, “sweet”, “little salty”, and “little smoky”. Analyzing the four sensory dimensions to represent the samples and their sensory descriptions, the first dimension was related to “texture attributes”, and for this reason, we named it “texture dimension”. The second dimension was related to “taste-hedonic attributes” and, for this reason, it was named “taste-hedonic dimension”. Analogously, the third and fourth dimensions were named “sensory-hedonic dimension” and “sensory dimension”, respectively. Considering the third and fourth dimensions, the control sample was placed in the center of the map, with a slight tendency to the attribute “little pleasant”, coinciding with the information presented in the first two dimensions. In general, the Napping technique revealed that the control was perceived as “little pleasant” and that this sample is likely to be rejected by consumers.

In the Napping method, consumers create a global representation of similarities and differences between samples based on the information synthesis related to their perception (Jaeger, Wakeling, & MacFie, 2000). Individual differences in the information processing patterns and consumer preferences could significantly affect the global representation of the samples and the sensory attributes, since consumers may give different relevance to similarities and differences between samples. Therefore, the consensus configurations have low dimensionality (considering the first two dimension of MFA), since they do not represent the perception of all consumers.

The analysis of global representations alone can lead to inaccurate conclusions regarding the consumers' sensory perception about the products or the loss of valuable information about the perception of some consumer groups. In this sense, to identify groups of consumer or segments with similar dimensions of the final configurations, HCA on the first four dimensions of the MFA was performed. In Figure 3.4, the four segments are shown (Calinski and Harabasz index = 25.98). These four segments were probably generated because of the heterogeneity of the consumers to evaluate the similarities and differences between the smoked bacon samples. This heterogeneity in the responses is mainly associated with different ways of processing the stimuli given to the consumers. According to Peterson & Deary (2006), consumers can evaluate the

samples “holistically” as they tend to organize and process the information globally, or “analytically” if they organize and process the information individually. In complement to the different ways of processing the information, Torri et al. (2013) reported that familiarity, knowledge, and prior experience with the product may affect consumer responses when executing the Napping task. Another possible cause for segmentation in the consumer responses may be the fact that meat products are considered a complex food matrix and, therefore, are difficult to be evaluated.

Figure 3.4. HCA performed on first four dimensions of the MFA.

In order to deeply analyze the consumer segmentation, a MFA for each segment was performed. Figure 3.5 shows the consensus configurations and the four segments. It is important to note that the confidence ellipses of the segments were greater than the confidence ellipses of the consensus configuration of the samples. This fact was previously reported by Cadoret & Husson (2013), who showed that as the number of consumers decreases, the size of the ellipses increases, decreasing the stability of the samples on the map. Analyzing Figure 5, the sample configuration of the segment 4

presented 4 groups of samples, just like the consensus configuration, being clear that one of the segments presented a configuration similar to the consensus. The remaining segments had a heterogeneous behavior with no apparent relation to the consensus configuration of the samples. This behavior was previously reported by Vidal et al. (2016), where the representation of the samples in the first two MFA dimensions of at least one segment was related to the consensus configuration.

In Figure 3.5, each segment is described in detail. The first segment based its differences on the first MFA dimension, differentiating samples smoked with reforestation woods from samples manufactured with liquid smoke and commercial samples. It is noteworthy that the commercial sample was placed in the center of the first dimension. The second segment did not show a clear clustering criterion, since the commercial sample and the control were considered similar. Segment 3, consisting of 16 consumers, considered the control sample as different from the others. However, the large size of the ellipses due to the low number of consumers does not allow us to draw any sound conclusions at the multidimensional level since the stability of the samples in the perceptual space is low. Segment 4 showed a behavior pattern similar to the consensus configuration, where the control was clearly perceived as totally different from the other samples. It is possible to attest that the segments 1, 3, and 4 evaluated the samples analytically, valuing the sensory characteristics. On the other hand, the second segment seemed to be more intuitive, valuing the samples as a whole, denoting a holistic cognitive process. In the present study, only the final configurations of the consumers were analyzed (see supplementary Figure 1). However, a recent study performed by Lê, Husson, & Lê (2016) showed that the sensory dimensions used by consumers when performing the Napping technique varied in the course of the whole task until the final configuration was reached. Thus, a study of the evolution of the sensory dimensions of the samples over time may result in a more efficient segmentation criterion and in obtaining segments that are more consistent. At the end of this section, we would like to highlight the importance of the segmentation in Napping studies since this procedure allows the identification of consumer groups (Berget, Varela, & Næs, 2019) that give different relative importance to the sensory characteristics of bacon samples.

Figure 3.5. Representation of the samples (consensus and segments) in the first two dimensions of the MFA.

3.3.3. Relationship between volatile compounds and sensory attributes

The sensory attributes developed by consumers during the Napping task were correlated with the VCs by means of Multiple Factor Analysis, considering the sensory attributes of 93 consumers and 39 volatile compounds. Figure 6 shows the chemo-sensory map (55.33% of the explained variance), where the majority of the volatile

compounds are placed on the positive side of the first dimension, which is associated with “pleasant”, “bright”, and “woody” attributes. It is important to point out that the “smoky” and “woody” attributes are far from each other, showing that consumers do not perceive them as the same sensory sensation.

According to Figure 3.6, the “woody” attribute was associated with ketones and phenols. From the 39 volatile compounds, 18 were found between ketones and phenols (46.2%) and most of them was found in smoked samples, such as CS, Acacia, and Eucalyptus (see supplementary Table 3.1). According to Jerković et al. (2010), ketones derived from the 2-cyclopenten-1-one are most likely originated from Maillard reactions of the pyrolysis of complex carbohydrates (cellulose) during smoking. This is in accordance with Figure 6, where the attribute woody is close to almost all of the cyclopentenones (C1, C2, C4), and really close to the C5 (3-ethyl-2-hydroxy-2-cyclopenten-1-one), which could be considered as the ketone with the greatest influence on the generation of this attribute. On the other hand, the pyrolysis of lignin mainly produces phenols (Rozum, 1998), and the presence of these compounds are desirable because they represent the major contributors to the wood smoke flavor (Maga, 1992). According to Sheard (2010), the wood smoke flavor is responsible for the well-accepted flavor of these types of products. Similarly, Ellis (2001) reported that the smoking step enhances the meat taste and odor and brings out the color of the product. These facts explain the association between the attributes “pleasant” and “woody” and the phenolic compounds in the chemo-sensory map.

The “bright” term was mainly associated with aldehydes and phenols (Figure 3.6). These two groups are related to the smoking process, since high relative peak area of these compounds, mainly phenols, were found in smoked samples (Figure 3.1), besides the fact that this attribute was strongly correlated with Eucalyptus (Figure 3.3B) and CS (Figure 3.3D). According to Rozum (1998), after the smoking process, proper resins, phenols, and aldehydes are deposited onto the meat surface, giving a glossy appearance to the products.

Figure 3.6. Representation of the sensory attributes and volatile compounds based on the MFA. **Phenols:** F1: phenol; F2: 2-Methylphenol; F3: 3-Methylphenol; F4: 2-Methoxyphenol; F5: 4-Ethylphenol; F6: 4-Methoxy-3-methylphenol; F7: 2-Methoxy-4-methylphenol; F8: 2-methoxy-4-Ethylphenol; F9: 4-Ethenyl-2-methoxyphenol; F10: 2,6-Dimethylphenol; F11: 2-Methoxy-4-(2-propenyl)-phenol; F12: 2-Methoxy-4-propylphenol; F13: 2,6-Dimethoxy-4-methylphenol. **Furans:** FU1: 2-Furaldehyde; FU2: 2-Furanmethanol; FU3: 2-Acetylfuran; FU4: 5-Methyl-2-furfuraldehyde; FU5: 3-methyl-2(5H)-Furanone. **Aldehydes:** AL1: Hexanal; AL2: Heptanal; AL3: Benzaldehyde; AL4: Octanal; AL5: Benzeneacetaldehyde; AL6: Nonanal; AL7: Decanal. **Ketones:** C1: 2-Cyclopenten-1-one, 2 methyl; C2: 2-Cyclopenten-1-one, 3 methyl; C3: 2-Hydroxy-3-methyl-2-cyclopenten-1-one; C4: 2,3-Dimethyl-2-cyclopenten-1-one; C5: 3-Ethyl-2-hydroxy-2-Cyclopenten-1-one. **Alcohols:** A1: 1-Butanol; A2: Benzylalcohol; A3: Octanol; A4: 2-Phenoxyethanol. **Others:** O1: Carbon disulphide; O2: Unknown; O3: Diethyl phthalate; O4: 2-Methylhexane; O5: 1,4 Dichlorobenzene.

Corroborating with the PCA result of "volatile compounds and bacon samples" (Figure 3.2), where the VCs were correlated with smoked bacons, the graph of "volatile compounds and sensory attributes" also showed the same trend. Figure 3.6 shows that most of the VCs were located close to the characteristic attributes of smoked products, such as "woody", "salty", "smoky", "pleasant", and "bright", indicating that almost all of the VCs were generated during the smoking process and that they were responsible for the characteristic flavor of the product. This becomes even clearer when attributes, such as "tasteless", "strange taste", "little pleasant", "little salty", "sweet", and "little smoky",

which are not characteristic of smoked meat products, did not present VCs related to them.

Besides, Figure 3.6 clearly shows that a sensory attribute is associated with more than one volatile compound. Overall, the sensory attributes related to the smoking process are associated with aldehydes, phenols and ketones families. According to Ellis (2001), there are some specific compounds that play a prominent role in the sensory aspects of smoked products. Nonetheless, along with the main compounds, there are many minor components (which may be hundreds) that contribute to the characterization of smoke flavor and odor.

In Figure 3.7A and 3.7B each group of data (chemical and sensory) is projected. The position of a group is defined from the inter-individual distances brought about by the target group. The proximity between chemical and sensory groups (Figure 3.7A) corresponds to a similarity of shape between the corresponding clouds of partial individuals (Figure 3.7B) (Saldaña et al., 2015). Figure 3.7A shows that the RV coefficient between the sensory and physicochemical data is intermediate (0.64). This result is mainly due to variations in the second dimension of MFA. Figure 3.7B indicates that sensory and instrumental differences were found in some bacon samples. For example, control, LS1, LS2, and CS were considerably different. However, the samples obtained by means of conventional smoking with Brazilian woods showed little difference between the volatile compounds and the sensory attributes, which indicates that the smoking process with Eucalyptus, Acacia, and Bamboo woods was the main responsible for the generation of sensory attributes of the products.

Figure 3.7. Representation of the bacon samples in the MFA: (a) Representation of the sensory and chemical group variables, (b) Superimposed partial representation considering sensory and chemical perspectives. N: Napping. VCs: Volatile compounds.

3.4. Conclusions

According to the SPME-GS/MS analysis, 39 VCs were identified in bacon samples, which were distributed in: phenols (13), aldehydes (7), ketones (5), furans (5), alcohols (4) and other components (5). The smoking process increased the number of VCs and consequently the number of sensory attributes perceived by consumers. Additionally, both VCs and sensory profile were dependent on the wood type used in the smoking process. The multi-block analysis showed that the “woody” and “pleasant” attributes were very similar, and they had a high number of related volatile compounds, mainly "aldehydes, phenols and ketones". The high association between sensory analysis and instrumental measurements in samples obtained by traditional smoking with Brazilian woods from reforestation indicate that this process is the main responsible for the generation of sensory attributes to the products. Therefore, changes in the volatile profile of smoked bacon modify the consumer sensory profile.

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Author contributions

ES and CCC conceived and designed the study. ES and JHB analysed the data. LS, ES, CCC, MMS wrote the paper. LS, ES, JCS, LDS, MAA, JSSP and contributed to data collection. All the authors discussed and approved the paper.

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4. DESCRIPTIVE AND HEDONIC SENSORY PERCEPTION OF BRAZILIAN CONSUMERS FOR SMOKED BACON³

Abstract

The descriptive and hedonic sensory perception of bacon manufactured using different smoking processes was studied. Six bacon samples were evaluated: three manufactured with woods, two with liquid smokes, and a commercial bacon. Consumers rated their overall liking (OL) and responded the check-all-that-apply (CATA) questions coupled with ideal profile method (IPM). The preliminary result showed that LS2 and Bamboo were the best-rated bacons. However, data analysis indicated two segments of consumers (both $n=50$), with significant differences in the OL. The first segment liked fatty and smoked bacons, while the second valued the texture and appearance. The drivers of liking in both segments were the attributes related to texture, juiciness and the smoky aroma. The use of different woods in the bacon smoking process modified the descriptive and hedonic sensory perception of consumers.

Keywords: Bacon; Sensory characterization; Check-all-that-apply (CATA) questions.

4.1. Introduction

Smoked bacon is consumed worldwide for its sensory characteristics, mainly developed during the processes of curing and smoking, which are highly appreciated by consumers (Saldaña et al., 2018). Smoking is one of the oldest preservation techniques for meat and meat-based products (Toth, 1982). Initially, this technique was used to increase the shelf life of products from the pyrolysis of wood (Bortolomeazzi, Sebastianutto, Toniolo, & Pizzariello, 2007) and dehydration of the product (Fellows, 2009). Today, it is mainly applied to confer sensory properties, since it imparts desirable flavor and color to smoked foods (Suñen & Aristimuño, 2001).

The wood used in the smoking process can influence the type and amount of compounds generated in the pyrolysis. It is known that hardwood varieties produce better smoke than softwoods, since the latter tend to produce higher concentrations of polycyclic aromatic hydrocarbons, in addition to having a greater amount of resins, which negatively affect the flavor of the product (Stumpe-Viksna, Bartkevičs, Kukare, & Morozovs, 2008). Despite these facts, there are few studies in the literature relating the

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type of wood or the use of liquid smokes with the sensory characteristics of smoked products (Malarut & Vangnai, 2018). Due to availability, cost, and because they are reforestation trees in Brazil, the Eucalyptus, Bambu, Acacia and Bracatinga woods are interesting options for use in traditional smoking and were chosen to be evaluated in this study (Saldaña et al., 2018).

As it is widely known, the sensory properties of foods drive the consumer's liking (De Almeida, Villanueva, Pinto, Saldaña, & Contreras-Castillo, 2016; Selani et al., 2016), and consequently its success or failure in the competitive market (Giacalone, 2018). Descriptive analysis (DA) is one of the most flexible, powerful, sophisticated and widely used tools in sensory science (Murray, Delahunty, & Baxter, 2001), since it plays an important role to assist the meat scientist in describing the sensory profile of a product. However, DA has some limitations related to the high cost and time demanded to perform all the steps, from the panel screening to the final data analysis (Varela & Ares, 2012). Moreover, it is argued that the sensory profile obtained from DA does not necessarily represent the consumers' perceptions, and consumers are ultimately responsible for the success or failure of a product (Qannari, 2017). To overcome these limitations, in the last decade different sensory methods have been developed, tested, and optimized (Valentin, Chollet, Lelièvre, & Abdi, 2012). According to Delarue (2015), alternative sensory methods are fast and provide the sensory profile directly from consumers. Among these methods, free sorting task, projective mapping, and check-all-that-apply (CATA) questions have attracted the attention of the scientific community (Qannari, 2017).

The use of CATA questions has shown a fast growth because of its quick design and execution, and its simplicity to be performed (Ares, 2015). This method provides the sensory profile directly from consumers, and when coupled with overall liking (OL) and the description of the ideal product measures, it represents one of the most powerful tools for the development of foods (Saldaña, Rios-Mera, et al., 2018). Obtaining liking and sensory profile directly from consumers allows the segmentation of consumers based on their preferences (Varela, 2014). The internal preference mapping (MDPREF) and cluster analysis are appropriate techniques to explore the consumers segmentation,

which have been widely used to relate the sensory profile and the OL of the different segments of consumers (Berget, 2018; Næs, Varela, & Berget, 2018).

The present study first explores the perception of all consumers through the CATA questions coupled with ideal profile method (IPM) and the OL. Then, the different OL patterns are studied, i.e., groups of consumers with similar preference within each group and different between groups. For this purpose, the members of each segment are identified by cluster analysis on the OL. Thus, in each cluster, the sensory attributes that modify the preference, also known as drivers of liking (DL), are determined by multivariate techniques.

In this context, the aim of this paper was twofold:

- (a) to study the descriptive and hedonic sensory perception, as well as the DL of different smoked bacons using CATA questions coupled with IPM and OL of consumers.
- (b) To study the different OL patterns of consumer segments identified by cluster analysis.

4.2. Materials and methods

4.2.1. Samples

Bacons were manufactured using a complete block design, considering three different blocks (each block representing one independent processing). Pork bellies (70 kg, pH = 5.8, similar proportion fat/meat) were provided by the "Suinco" slaughterhouse (São Paulo, Brazil). Eucalyptus (*Eucalyptus citriodora*), Bamboo (*Bambusa vulgaris*) and Acacia (*Acacia mearnsii*) woods were used in the smoking process, in small pieces of 1 x 1 x 3 cm³ and dehydrated at 240 °C for 30 min. Two commercial liquid smokes, consisting of natural condensates of smoke obtained by the pyrolysis of wood, was used: LS1 (pH=2.50-4.50, density=0.90-1.15 g·mL⁻¹, Acidity=10.00-11.00%, Salmonella in 25 mL: absence, Sodium=2.40 mg·g⁻¹), LS2 (pH=2.20-2.20, density= 1.09-1.19 g·mL⁻¹, Acidity=9.50-11.00%, Salmonella in 25 mL=absence, Sodium=1.50 mg·g⁻¹). A commercial smoked bacon (composition in a portion of 10 g, according to the manufacturer: energy value=46 kcal, dietary fiber=0g, carbohydrates=0g, saturated

fat=1.7g, sodium=77 mg, protein=1g, trans fat=0g, total fat=4.7g) was also included in the study.

The bacon processing was performed at the *Qualidade e Processamento de Carnes* Laboratory at the Department of *Agroindústria, Alimentos e Nutrição (LAN)* of the *Escola Superior de Agricultura “Luiz de Queiroz” (ESALQ) - Universidade de São Paulo (USP)*, following the recommendations of Saldaña et al. (2018). Six types of bacon were evaluated in this study: three bacon samples were manufactured through conventional smoking, each one using a different wood from reforestation (Eucalyptus, Bamboo and Acacia); two bacon samples had the conventional smoking replaced by the use of two different brands of liquid smoke (called LS1 and LS2); and a commercial bacon sample that was added to the study for comparison purposes (Saldaña, de Oliveira Garcia, et al., 2018).

For each independent processing, ten pork bellies were used, two for each of the five treatments prepared in the laboratory (Eucalyptus, Bamboo, Acacia, LS1 and LS2). The bacon manufacturing started with the injection of 20% w/w of brine (3.0g/100mL NaCl, 0.6g/100mL sucrose, and 0.024g/100mL sodium nitrite) over the whole belly. Subsequently, the belly was vacuum-packaged and stored at 4 °C for 24 h. Then, the belly was rinsed to remove excess salt from the surface and immediately placed in the smoker (Verinox, Italy), where an electrode was introduced into the product to monitor the temperature during the entire cooking process. The cooking process was carried out using a three-stage approach: first drying (65 °C for 30 min), then smoking (75 °C for 60 min) and, finally, steam cooking (at 75 °C for 30 min and then at 80°C until the core temperature reached 75 °C). For the liquid smoking process, stage one (drying) and three (steam cooking) followed the same time-temperature program of the conventional smoking. However, in stage two (smoking), instead of receiving thermal treatment and smoke from the wood burning, the bellies were removed from the smoker and sprayed with liquid smoke in the proportion of 1% of the weight of the meat (selected based on pilot testing). After steam cooking, the samples of all treatments were cooled to room temperature, vacuum packaged, and subsequently stored at 2 °C for 24 h until sensory analysis.

4.2.2. Consumer sensory evaluation

The sensory evaluation was conducted in a single session of about 30 min, in the sensory analysis laboratory of the LAN/ESALQ/USP, equipped with individual booths and designed according to ISO 8589 (ISO, 2007). Bacon samples were sliced (0.3 × 4 cm) and cooked in a hot plate at 300 °C until the temperature of 75 °C was achieved. Sensory analysis was performed from the participants' prior scheduling. Due to this, the six samples of smoked bacon were cooked on time for each consumer. Once the samples were presented monadically, to maintain and standardize the temperature between the first and last sample, they were kept in an oven until they were offered to consumers. Bacon slices (50 g) were presented at 45 ± 2 °C in white plastic plates coded with three-digit random numbers, served monadically following a Williams Latin Square design (Wakeling & MacFie, 1995). Consumers evaluated the six samples, in a single session, with a stop of 10 min after the third sample, to avoid sensory fatigue. Mineral water was available for consumers to rinse the palate after each evaluation. Data collection was carried out entirely on A4 white paper.

4.2.2.1. Consumers

One hundred habitual consumers of bacon (60 women and 40 men, between 18 and 56 years old) were recruited among students and employees of the LAN/ESALQ/USP. The frequency of consumption of the consumer panel was: 28% declared to consume smoked bacon once a week, 27% three times a month, 22% once a month, 8% twice a week, 8% from time to time, 3% twice a month, and 4% presented a lower frequency of consumption. Before performing the sensory task, each consumer signed an informed consent form of voluntary participation.

4.2.2.2. Procedure

Consumers were accommodated in individual sensory booths, then the samples were presented, and they were asked to indicate their OL using a 9-point hedonic scale structured from "dislike extremely" to "like extremely". Subsequently, they answered the CATA questions composed of 32 descriptors randomly presented. Consumers were

asked to check all the descriptors that they considered appropriate to describe each sample. After evaluating all the samples, they were also asked to imagine an ideal bacon and describe it using the same descriptors list (Saldaña, de Oliveira Garcia, et al., 2018; Worch, Lê, Punter, & Pagès, 2013).

The 32 descriptors (see Table 4.1) used in the questionnaire were the descriptive sensory attributes previously reported by Saldaña et al. (2018). Non-sensory terms were provided by an internal sensory evaluation team, composed by 10 experts in sensory evaluation of meat-based products, by means of the free description of the attributes that characterize the samples. Subsequently, the most cited attributes were maintained in the CATA questions.

4.2.3. Data analysis

First, the data analysis of the responses of the CATA questions and the OL of all consumers was carried out. Subsequently, consumers were segmented using Hierarchical Clustering on Principal Components (HCPC) on the OL scores. For each segment identified, the sensory profile and the OL were analyzed. Finally, the DL through Penalty Analysis (PA) and Partial Least Squares Regression (PLSR) models in each segment were obtained. Data analysis was performed in the R environment (R Core Team, 2017) using the *SensoMineR* (Le & Husson, 2008) and *FactoMineR* (Lê, Josse, & Husson, 2008) packages.

4.2.3.1. Overall liking

The OL of the six bacon samples was analyzed by the mixed ANOVA model, considering samples (fixed), consumers (random) and presentation order of the samples (fixed) as sources of variation at the level of 5% of significance. Tukey's means comparison test was performed to check for differences between the means.

4.2.3.2. Hierarchical Clustering on Principal Components (HCPC)

A Principal Component Analysis (PCA) was carried out on the OL data considering the Pearson's correlation matrix. Samples and consumers were represented in the first two principal components to show the consumer's liking heterogeneity. This representation is also known as MDPREF (Macfie, 2007). The identification of the consumer members of each segment was proceeded using the first 5 eigenvectors of the MDPREF previously obtained (Argüelles, Benavides, & Fernández, 2014). These eigenvectors maintained 100% of the total inertia of the original data; therefore, the noise of the one hundred consumers was efficiently eliminated, making the segmentation process more robust. The hierarchical clustering was carried out on these 5 eigenvectors considering the Euclidian distance and the Ward's agglomeration method was employed to construct the dendrogram.

4.2.3.3. CATA questions

A contingency table was generated counting frequency of mention of each descriptor that characterized each target sample (Meyners, Castura, & Carr, 2013). Then, the non-parametric Cochran's Q test (Manoukian, 1986) was applied to identify significant differences between samples for each of the terms included in the CATA questions. The Cochran's Q statistic is shown for a target attribute in Eq.1.

$$Q = \frac{n_k(n_k - 1) \sum_{k=1}^{n_k} (T_k - \bar{T})^2}{n_k \sum_{j=1}^{n_j} R_j - \sum_{j=1}^{n_j} R_j^2} \quad (1)$$

Where k represents the samples, j represents the consumers, n_k represents the number of samples, n_j denotes the number of consumers, T_k expresses the total number of checks (1) of the attribute "a" for the sample "k", R_j expresses the total number of checks (1) of the attribute "a" for the consumer "j" in all the "k" samples, $\bar{T}$ expresses the total average of checks (1) of the attribute "a" for all the samples and is calculated by dividing the total number of checks by the number of samples. The Cochran's Q statistic was compared to a theoretical chi-square value with $n(k-1)$ degrees of freedom.

The Correspondence Analysis (CA) was based on a contingency table composed of descriptors that showed significant differences between samples using the Cochran's Q test. The CA was also performed in each of the segments identified in the HCPC. It was constructed using the ϕ^2 index equivalent to the chi-squared statistics (Cariou & Qannari, 2018). The aim of this analysis is to obtain a perceptual map of samples, descriptors and the ideal bacon (supplementary individual). Around each bacon sample, confidence ellipses obtained by bootstrapping resampling were constructed with 500 virtual consumer panels (Cadoret & Husson, 2013). The confidence ellipses represented the multidimensional stability of each sample within the perceptual map, where two overlapped ellipses indicate similarity.

Finally, in each segment, a PA was applied in order to determine the mean drop of OL associated with the deviation of the ideal product for each descriptor included in the CATA question (Ares, Dauber, Fernández, Giménez, & Varela, 2014; Saldaña, de Oliveira Garcia, et al., 2018). For each sample, the percentage of consumers who described the samples differently from the ideal bacon was calculated, as well as the change in the OL associated with the differences from the ideal characteristic. With the aim to analyze which attributes had the greatest impact on the OL, the mean drop of OL was plotted according to the percentage of consumers who described the sample evaluated as 'different from the ideal'. A threshold of 20% of consumers who found differences between the real and the ideal description was used (Popper, 2014). In addition, an arbitrary "mean drop of OL" threshold of 0.5 on a 9-point hedonic scale was used, aiming to pinpoint the attributes with a high mean drop of OL.

Furthermore, an analysis of dummy variables was carried out following the recommendations of Ares et al. (2014) and Saldaña et al. (2018). Two dummy variables, coded as Z+ and Z-, were constructed, where Z is the target descriptor. A value of 1 was assigned to Z+ (presence of the attribute) and 0 to Z- (absence of the attribute). When the descriptor was present in both the ideal and the target bacon, a value of 0 was assigned for Z+ and Z-. On these dummy variables, a Partial Least Squares Regression (PLSR) was performed to obtain the weight of deviation from the ideal product. For each sample and segment, an individual PLSR model was constructed considering the OL as

a response variable and the dummy variables as independent variables. Finally, a summary table was elaborated with the dummy variables in the rows and the frequency of mention and the regression coefficient (RC) of each sample and segment in the columns. The intersection value of the PLSR model was considered as the maximum possible OL that a sample could obtain. The significant attributes for each PLSR model were identified as the most influential parameters in the mean drop of OL.

4.3. Results and discussion

4.3.1. Consumers segmentation

According to the results, LS2 (6.44) and Bamboo (6.42) were the most liked samples (ANOVA not shown for brevity). However, as it is widely known, the consumers' OL is segmented, therefore, the conclusions obtained from the average OL could hide the liking of some consumers who prefer other samples (Varela, 2014). In order to segment the consumers' preference into homogeneous groups, different multivariate analyzes were performed and are shown in Figure 4.1A that represents the OL of each consumer in the first two dimensions of the MDPREF, which maintained 56.57% of the total inertia of the original data. The consumer's OL was distributed, in its majority, in the second and third quadrant, while in the fourth and first quadrant the remaining consumers were positioned. The distribution of the samples in the MDPREF (Fig. 4.1B) followed the same behavior as the distribution of the consumers; Acacia and Eucalyptus were positioned in the second quadrant, while LS1 was located in the third quadrant. The remaining samples were distributed between the first and fourth quadrant.

After confirming that the consumer's OL is segmented, the allocation of the consumers in each segment was carried out. For this purpose, a HCPC was performed using a dendrogram height of 0.78 as the cut-off point (which is conservative, since the maximum value is 1), where two segments of 50 consumers were identified (Fig. 4.1C, D). To confirm significant differences ($p < 0.05$) between the segments and samples, a one-way ANOVA was performed, showing that the OL of segments was statistically different for Eucalyptus, Acacia, and Bamboo (Fig. 4.2). Therefore, the differences

between the segments occurred in samples smoked with woods from reforestation, which have a particular and complex sensory profile originated from its volatile composition (Saldaña et al., 2018). For segment 1, the best-rated samples were eucalyptus, Acacia, LS2, and Commercial; for segment 2, the best-rated samples were bamboo, LS2, and Commercial. To understand the reasons for the OL, the sensory characteristics of all consumers and of each segment were analyzed below.

Figure 4.1. Segmentation of consumers' panel. A: representation of the consumers in the MDPREF; B: Representation of the samples in the MDPREF, C: Factor map of consumers based on the two segments found; D: Representation of the consumers according to the cluster they belong to resulting from the HCPC. The overall liking was based on a 9-point hedonic scale.

Figure 4.2. Representation of the OL scores. LS1: Liquid smoked 1; LS2: Liquid smoked 2. Different letters indicate statistically significant difference between samples for each cluster according to the Tukey test at 5% of significance. The overall liking was rated on a 9-point hedonic scale.

4.3.2. Sensory characterization of the samples

Table 4.1 shows the frequency of mention of the all consumers for the 32 descriptors that characterized the target samples and the ideal bacon. The Cochran's Q test identified 21 significant descriptors between samples ($p < 0.05$), which showed independence with the samples according to the Pearson's Chi-squared test (X^2 : 812.78, df : 120, p -value: < 0.001), a necessary requirement for subsequent use of the CA. The CA is shown in Fig. 4.3 as a two-dimensional map (also called a perceptual map) that preserves 80.41% of the original inertia of data. In this perceptual map, bacon samples and the descriptors are represented. The ideal bacon was also projected as a supplementary individual. The distance between samples and attributes in the perceptual map is a measure of the association between them. In addition, the ellipses around samples represent their stability in the perceptual map; consequently, the overlapping of two confidence ellipses indicates multidimensional similarity between them.

Table 4.1. Contingency table of the 6 bacon samples and the ideal bacon for the 32 CATA descriptors.

Descriptor	Samples						
	Ideal	Acacia	Bamboo	Eucal	LS1	LS2	Com
Bright ^{ns}	42	43	44	38	38	36	54
Opaque ^{ns}	20	28	27	29	28	29	12
Little fatty ^{***}	59	12	27	19	11	41	24
Very fatty ^{***}	5	53	36	41	49	14	45
Appearance of red meat ^{***}	72	19	48	41	11	70	46
Homemade appearance ^{ns}	45	11	10	11	8	12	16
Appearance of white fat ^{***}	40	63	47	58	60	25	40
Appearance of yellow fat ^{ns}	20	24	29	23	28	30	36
Aroma that resembles a diner ^{***}	39	18	23	15	8	20	38
Rancid aroma ^{**}	0	8	2	11	13	7	2
Homemade food aroma ^{ns}	54	24	12	25	14	28	23
Little artificial aroma ^{ns}	27	26	21	23	24	29	25
Artificial aroma [*]	2	9	23	18	26	14	16
Woody aroma [*]	41	19	30	20	9	16	21
Light smoky aroma ^{***}	48	58	28	53	50	58	34
Intense smoky aroma ^{***}	34	12	40	9	1	10	36
Little salty ^{***}	7	35	31	41	25	22	10
Very salty ^{**}	19	6	7	5	19	7	18
Light smoked taste ^{**}	27	50	35	49	56	44	30
Very smoked taste ^{***}	50	7	33	9	6	22	29
Little fatty taste ^{***}	61	14	34	18	12	39	26
Very fatty taste ^{***}	8	53	27	38	49	23	32
Little spicy [*]	32	37	31	45	46	37	26
Very spicy [*]	37	12	8	11	8	11	23
Soft ^{ns}	68	55	51	47	38	53	63
Hard [*]	0	11	11	21	16	7	8
Dry ^{ns}	19	6	14	13	8	9	7
Juicy ^{***}	74	44	34	25	23	54	48
Rubbery [*]	0	30	25	36	44	23	25
Fibrous ^{ns}	7	18	28	30	29	28	17
Little crispy ^{ns}	17	39	37	31	41	30	40
Very crispy ^{ns}	56	3	5	4	3	7	5

***indicates significant differences with $p < 0.001$, **indicates significant differences with $p < 0.01$, *indicates significant differences with $p < 0.05$, while ns indicates that there were no significant differences ($p > 0.05$) according to the Cochran's Q test. The ideal product was not used in the Cochran's Q test.

Fig. 4.3 showed three groups of samples. The first group was located in the negative side of the first dimension and contained the following bacon samples: LS1, Acacia, and Eucalyptus (the confidence ellipses of the last two samples are overlapped). These bacon samples were characterized by their appearance of white fat, very fatty taste, artificial aroma, rubbery, hard, little salty, little spicy, light smoked taste, and light smoked aroma. The second dimension separated the two remaining groups: on the positive side the Commercial and Bamboo samples are overlapped, being perceived by consumers as very spicy, with aroma that resembles a dinner, a woody aroma, and a very smoked taste. LS2 sample is located on the negative side of this dimension, which is characterized by little fatty, appearance of red meat and little fatty taste.

Figure 4.3. Representation of samples and descriptors in the first two dimensions of CA of the CATA questions.

The ideal bacon is associated with bamboo and commercial samples characterized by “very smoked taste” descriptor. However, because the OL of consumers is segmented, each segment was analyzed individually, to identify the different descriptors that characterize the ideal bacon in each segment. In this context, the following question arises: Is there an ideal product for each segment of consumers? The answer is “yes” (Worch & Ennis, 2013). To identify the ideal product of each consumer segment, as well as the position of the samples in the perceptual map, a contingency table was constructed for each segment and the samples associated with the statistically significant descriptors tested by the Cochran’s Q test were subsequently plotted, with more than 10% of frequency of mention.

Figure 4.4 shows the perceptual map of segment 1 considering the first two dimensions of the CA based on the 20 significant attributes with a frequency of mention greater than 10%. In this segment, three groups of samples were found based on the overlapping of the confidence ellipses. The first of them was positioned on the negative side of the first dimension (Acacia, LS1 and Eucalyptus) characterized by the attributes very fatty, very fatty taste, artificial aroma, appearance of white fat, rubbery, little spicy, little smoked taste, light smoky aroma and little salty, which were perceived as unpleasant. The second group included the Commercial sample that, unlike the perceptual map of all consumers, was not similar to the Bamboo smoked sample, being characterized by very salty, very spicy, intense smoky aroma, and homemade appearance.

Figure 4.4. Representation of the samples and descriptors characterized by the first segment (n = 50).

The third group was positioned in the fourth quadrant of the perceptual map, composed of bacon smoked with Bamboo and LS2, which were perceived as very smoked taste, juicy, soft, woody aroma, appearance of red meat, little fatty taste and little fatty. These sensory attributes reveal that this segment valorizes few greasy products with smoked flavor. It is important to note that the position of the ideal sample in the first segment is similar to the data found when all consumers were considered (Fig. 4.3).

The perceptual map of the second segment of consumers in terms of samples, descriptors and ideal bacon is shown in Fig. 4.5. The ideal bacon was positioned on the negative side of the first dimension and was close to the LS2 sample, being perceived as juicy, appearance of red meat, and little fatty. These descriptors indicate that the attributes related to the texture and appearance of bacon were the most valued by these consumers. Based on the results, the main difference between the two segments is that the first one appreciates the attributes associated with the smoking process, whereas the second segment shows the opposite behavior. Therefore, the first segment

would be more susceptible to detect changes related to the smoking process. However, this information must be taken with care since the perception of sensory attributes is a multisensory phenomenon, i.e., the change of an attribute can modify the entire sensory profile.

Figure 4.5. Representation of the samples and descriptors characterized by the second cluster ($n = 50$).

4.3.3. Penalty analysis

In Fig. 4.6, the mean drop of OL (comparison between real and ideal sample) is displayed in both segments. The number of penalized attributes in the second segment was greater than in the first segment for most samples. Therefore, in the second segment, the ideal bacon was different from the samples studied. As mentioned above, the main difference between segments was the position of the ideal product and consequently the descriptors that the consumers expected to have in the ideal product. This variation in the sensory profile explains the differences in the number of penalized descriptors between segments. The segment 2 did not value sensory attributes related to the smoked taste. For this reason, the presence of sensory attributes related to the smoking process was penalized. For the Acacia sample, the first segment did not penalize any descriptor, while the second segment penalized 7 descriptors ("Intense smoky aroma", "Rubbery", etc.). For this reason, the first segment presented a higher

OL score for Acacia bacon compared to the second segment. For the sample smoked with Bamboo, the first segment penalized 5 descriptors, while the second segment penalized 6. In the Commercial sample, the first segment penalized 3 descriptors related to appearance and texture while the second penalized 9 descriptors related to aroma, texture, and appearance. For bacon smoked with Eucalyptus, the first segment penalized 8 attributes and the second penalized 11 attributes, of which 5 attributes were penalized in common by both segments (Rubbery, Very smoked taste, Intense smoky aroma, Juicy, Very fatty). Therefore, the remaining attributes caused the statistical difference in the overall liking between segments (Figure 4.2A). The LS1 sample penalized 8 sensory attributes for the first segment and 11 sensory attributes for the second segment. However, this divergence in the number of attributes was not enough to impact on a significant difference in the OL score between the two segments. Finally, the LS2 sample presented 4 penalized attributes for the first segment, while the second segment penalized 9 attributes. It is important to note that, for both segments, LS2 sample was close to the ideal, but the segment 2 was more critical showing a more analytical behavior.

Figure 4.6. Penalty analysis of each cluster considering the ideal bacon. The overall liking was rated on a 9-point hedonic scale.

From the previous analysis, it is known that the penalization of descriptors varied from no penalized attribute to eleven penalized attributes, and these findings provide valuable information for consumers' perception and possible changes to be made in future reformulations to obtain an ideal product dedicated to specific consumer segments. To complement this analysis and, at the same time, to better select the descriptors that really drive the liking, the OL was modeled according to two dummy variables per sensory attribute for each segment and for each sample. For this purpose, each of the dummy variables was analyzed according to the significance of the RC and the percentage of citation. In this way, a significant positive (Z+) dummy variable indicates that consumers perceived it as absent in the target bacon but desirable in the ideal bacon. Conversely, a significant negative (Z-) variable would indicate that consumers perceived in the target bacon a characteristic that they would not want in their ideal bacon.

According to Table 4.2, the mean “drop of overall liking” was affected by a reduced group of sensory attributes even lower than the number of attributes detected in the penalty analysis (Figure 4.6). The dummy variable "Rubbery-" was significant for most samples and segments. Therefore, this attribute is not regarded as a desirable characteristic of smoked bacon. "Juicy+" was the second most cited dummy variable and it presented significant regression coefficients. Thus, it is clear that the texture attributes can still be optimized. The texture of meat-based products depends mainly on the "meat-fat" ratio, which modifies the product's sensory profile, mainly in the Commercial sample. When analyzing the attributes related to the smoking process, the dummy variable "Intense smoky aroma+" stands out, i.e., consumers did not perceive this attribute in bacon smoked with Acacia in both segments, and in the LS2 bacon in the second segment.

Table 4.2. Regression coefficients and intercepts of the PLSR models used to study OL based on dummy variables. Significant coefficients are in bold with a gray background for easy reading.

Terms	Acacia				Bamboo				Eucalyptus				LS1				LS2				Commercial			
	Cluster 1		Cluster 2		Cluster 1		Cluster 2		Cluster 1		Cluster 2		Cluster 1		Cluster 2		Cluster 1		Cluster 2		Cluster 1		Cluster 2	
	%	RC	%	RC	%	RC	%	RC	%	RC	%	RC	%	RC	%	RC	%	RC	%	RC	%	RC	%	RC
Little fatty +	29	0.02	22	0.00	20	-0.24	25	0.06	26	-0.38	24	-0.12	25	0.17	26	-0.09	15	0.00	14	0.01	23	0.00	21	-0.13
Little fatty -	1	-0.61	3	0.31	9	0.37	4	0.37	4	0.37	6	0.06	0	0.00	3	0.77	5	-0.40	6	0.39	6	-0.35	3	0.14
Very fatty +	3	-0.30	2	0.31	3	0.46	1	1.27	1	0.58	2	0.84	1	-0.83	2	1.22	3	-0.63	1	1.12	2	0.25	1	-0.61
Very fatty -	32	0.03	21	-0.36	11	-0.61	24	-0.13	21	-0.33	18	-0.51	25	0.06	22	-0.28	9	-0.52	4	-0.49	24	-0.09	19	-0.33
Appearance of red meat +	31	0.08	27	-0.17	11	-0.40	22	-0.30	20	0.24	19	-0.37	32	-0.19	32	-0.51	8	0.12	9	-0.51	15	-0.05	18	-0.21
Appearance of red meat -	3	-0.47	2	0.31	7	-0.18	2	0.88	4	-0.83	4	0.26	2	0.13	1	0.22	7	0.18	8	0.02	5	-0.35	2	-0.39
Appearance of white fat +	4	0.25	4	0.07	8	0.23	6	-0.12	6	-0.45	5	-0.16	7	-0.09	4	-0.28	14	0.22	11	-0.18	10	0.31	7	-0.11
Appearance of white fat -	16	-0.01	15	-0.28	7	-0.12	14	0.09	12	0.16	17	-0.01	18	0.15	13	-0.65	4	-0.16	6	-0.16	7	-0.73	10	-0.20
Homemade appearance +	15	0.23	13	-0.08	8	0.07	17	-0.38	14	0.22	19	-0.37	16	0.01	19	-0.29	13	0.25	17	-0.18	9	-0.02	8	0.20
Homemade appearance -	3	0.54	4	0.07	4	-0.04	5	0.49	4	-0.35	5	0.34	4	0.13	0	0.00	6	-0.49	5	0.12	9	-0.66	7	-0.11
Artificial aroma +	1	0.36	0	0.00	0	0.00	1	-1.21	1	-1.23	1	-1.72	1	0.60	0	0.00	1	1.24	0	0.00	1	-0.71	0	0.00
Artificial aroma -	5	-0.56	3	0.31	8	-0.37	14	-0.44	14	0.08	4	-0.11	13	-0.13	12	-0.38	5	0.14	8	-0.23	11	0.04	4	-0.77
Woody aroma +	13	-0.22	15	-0.41	7	0.07	14	0.21	14	0.08	16	0.06	17	-0.02	19	0.07	11	0.23	16	-0.13	14	0.01	11	-0.36
Woody aroma -	4	-0.01	2	0.55	4	-0.34	6	0.27	6	-0.95	3	0.30	3	-0.70	1	-0.16	0	0.00	2	0.71	1	-0.23	4	-0.41
Light smoky aroma +	10	-0.33	8	-0.27	10	-0.20	20	-0.01	11	-0.25	13	-0.06	12	-0.20	14	-0.33	10	-0.02	7	-0.09	17	-0.47	14	-0.31
Light smoky aroma -	17	0.45	11	-0.27	6	0.42	4	-0.29	16	0.06	13	-0.25	20	-0.27	8	-0.25	19	0.07	8	-0.35	11	0.42	6	0.15
Intense smoky aroma +	17	0.32	10	-0.49	7	-0.05	5	-0.50	20	-0.35	11	-0.47	22	-0.16	12	-0.29	18	-0.12	10	-0.74	14	0.15	4	-0.88
Intense smoky aroma -	1	-1.58	4	-0.56	4	-0.44	14	0.17	3	-0.18	3	0.30	0	0.00	1	1.39	1	-0.27	3	-0.15	7	-0.18	13	-0.62
Little salty +	2	0.61	-	-	2	0.25	-	-	0	0.00	-	-	2	0.62	-	-	4	0.78	-	-	3	0.76	-	-
Little salty -	22	-0.26	-	-	11	-0.01	-	-	27	-0.12	-	-	11	-0.12	-	-	11	-0.51	-	-	3	0.26	-	-
Very salty +	13	-0.17	-	-	13	-0.04	-	-	14	0.04	-	-	13	0.41	-	-	13	-0.05	-	-	9	0.23	-	-
Very salty -	1	0.36	-	-	3	0.19	-	-	0	0.00	-	-	6	-0.31	-	-	1	0.73	-	-	4	0.27	-	-
Little smoked taste +	6	-0.41	-	-	5	-0.26	-	-	4	-0.23	-	-	2	0.37	-	-	3	0.42	-	-	7	-0.42	-	-
Little smoked taste -	21	0.14	-	-	11	0.03	-	-	22	-0.17	-	-	25	-0.43	-	-	16	-0.16	-	-	12	0.17	-	-
Very smoked taste +	25	-0.06	20	-0.31	12	-0.12	14	-0.24	25	-0.39	19	-0.22	27	-0.15	19	-0.45	20	0.05	17	-0.36	21	0.00	11	-0.10
Very smoked taste -	1	-0.61	1	0.77	3	-0.07	6	-0.27	2	-0.79	1	-0.33	1	-0.35	1	-0.55	2	0.24	7	-0.09	6	0.01	5	0.12
Little fatty taste +	29	0.06	-	-	17	-0.17	-	-	23	-0.02	-	-	26	0.03	-	-	16	-0.12	-	-	20	-0.30	-	-
Little fatty taste -	1	-0.61	-	-	12	0.12	-	-	0	0.00	-	-	1	0.60	-	-	8	0.12	-	-	5	-0.25	-	-
Very fatty taste +	2	0.86	3	-0.01	4	0.57	1	-1.62	3	-0.34	2	-0.58	5	-0.18	3	0.64	3	0.07	1	-0.56	4	0.52	1	-0.61
Very fatty taste -	29	-0.29	21	-0.02	6	-0.56	18	-0.23	20	-0.64	15	-0.38	25	-0.17	24	-0.52	12	-0.40	7	-0.51	17	-0.38	12	-0.40
Little spicy +	8	-0.22	-	-	8	-0.04	-	-	9	-0.03	-	-	8	-0.20	-	-	8	0.05	-	-	9	-0.21	-	-
Little spicy -	12	0.41	-	-	8	-0.26	-	-	17	-0.05	-	-	20	-0.15	-	-	11	0.00	-	-	5	0.27	-	-
Very spicy +	18	0.01	-	-	14	0.01	-	-	16	-0.10	-	-	19	-0.24	-	-	18	-0.03	-	-	12	-0.04	-	-
Very spicy -	3	0.21	-	-	1	-0.32	-	-	2	-0.56	-	-	2	-1.34	-	-	2	-0.53	-	-	7	0.05	-	-
Soft +	18	-0.23	10	-0.32	11	-0.23	19	-0.33	22	-0.32	15	-0.38	19	-0.56	21	0.04	14	-0.86	15	-0.52	11	0.09	7	-0.84
Soft -	5	0.29	10	0.20	9	0.12	4	0.15	8	0.21	8	0.02	4	0.64	6	-0.40	9	0.14	5	0.12	5	-0.35	8	-0.25
Juicy +	27	-0.12	12	-0.17	19	-0.37	28	-0.42	30	-0.28	22	-0.40	26	-0.20	30	-0.62	14	-0.61	15	-0.55	19	-0.24	17	-0.63
Juicy -	5	0.07	4	0.32	6	0.28	1	0.03	2	-0.33	1	-0.33	2	-0.61	3	0.37	6	0.16	3	0.29	6	0.01	4	0.30
Rubbery +	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Rubbery -	20	0.03	10	-0.49	8	-0.20	17	-0.64	23	-0.63	13	-0.53	23	-0.42	21	-0.74	12	-0.62	11	-0.95	14	-0.31	11	-0.46
Aroma that resembles a diner +	-	-	19	-0.23	-	-	25	-0.03	-	-	17	-0.05	-	-	20	-0.27	-	-	20	-0.54	-	-	18	-0.21
Aroma that resembles a diner -	-	-	3	-0.18	-	-	1	0.45	-	-	7	0.07	-	-	2	-0.36	-	-	7	0.39	-	-	3	-0.94
Hard +	-	-	0	0.00	-	-	0	0.00	-	-	0	0.00	-	-	0	0.00	-	-	0	0.00	-	-	0	0.00
Hard -	-	-	4	-0.31	-	-	7	-0.30	-	-	10	-0.69	-	-	10	-0.25	-	-	3	-0.44	-	-	1	-0.61
Intercept	4.35		7.36		7.48		5.98		6.56		7.14		6.02		6.62		7.25		7.69		7.16		7.85	
Mean overall liking	6.36		4.26		4.92		6.84		5.72		4.72		4.42		4.74		6.34		6.54		6.36		6.48	
Mean drop *	2.01		3.10		2.56		0.86		0.84		2.42		1.60		1.88		0.91		1.15		0.8		1.37	

The intercept of the models shows that, for the first segment, Bamboo, LS2, and Commercial bacons have potential to be highly accepted if the negative drivers of liking are optimized. In the second segment, the Commercial and LS2 samples showed the highest values for the intercept, thus it has the potential to obtain the maximum OL values. Both LS2 and the commercial bacon were the most preferred samples in the two consumer segments (Perrot et al., 2018).

4.3.4. Segmentation of consumers

The first segment of consumers preferred bacons smoked with Eucalyptus and Acacia, LS2, and the Commercial one. This segment of consumers liked fatty and smoked bacon (based on penalty analysis) and was composed of Brazilian female consumers (64%), with a high frequency of product consumption. On the other hand, the second segment preferred the Bamboo, LS2, and Commercial samples. This segment valued the attributes related to texture and appearance, which can be explained by the fact that the members had a low frequency of bacon consumption. In addition, this group had fewer women than the first segment (56%) and the nationality of the members was diverse, with a predominance of Brazilians (76%). The results obtained in the current study clearly show that the identification of homogeneous segments is extremely important in sensory analysis and consumer science (Westad, Hersleth, & Lea, 2004). Accordingly, the main reason for the different liking patterns in the segments were gender, frequency of consumption, and nationality. Based on the findings of Ares & Gámbaro (2007), age and gender are underlying factors that induce the food choice. It is important to mention that the reasons for the segmentation may be related to the context of consumption (Onwezen, 2018), genetic variation in taste and aroma (Sandell, Hoppu, & Laaksonen, 2018) and oral processing (Engelen, 2018), which cause differences in the rate of salivation, dental health, number of chewing, among other factors. These factors are beyond the scope of this study, but they should be explored in future studies.

4.4. Conclusion

The preliminary conclusion based on the average liking indicated that the LS2 and Bamboo samples were statistically best rating than the other bacons. However, since the cluster analysis showed that the perception of the consumers was segmented, this hasty conclusion does not represent the reality of the consumer group.

Based on the results of each segment, the OL changed, since the best-rated samples for first segment are Eucalyptus, Acacia, LS2, and Commercial and for the second segment are Bamboo, LS2, and Commercial. According to the descriptors of the

ideal bacon and the penalty analysis, the main differences between the two groups of consumers is related to the fact that, while segment one valorizes attributes related to the smoking, the second segment penalizes samples with these attributes.

LS2 and Commercial samples were the most preferred samples in the two consumer segments. The main drivers of liking in both segments were the attributes related to texture, as well as juiciness and the smoky aroma of bacon. Thus, in a further reformulation, these attributes should be optimized in the LS2 and Commercial samples, in order to produce greatly accepted bacons.

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5. OBTAINING THE IDEAL SMOKED BACON: WHAT IS THE INFLUENCE OF THE PRODUCT SPACE AND MULTIVARIATE PROCEDURE TO CONSTRUCT THE EXTERNAL PREFERENCE MAPPING?⁴

Abstract

Identifying the ideal product is the most important step in new product development and improvement of existing ones. The aim of this study was to identify the ideal smoked bacon using *PrefMFA* and *PrefMap* considering three different sensory spaces obtained via descriptive analysis (DA), projective mapping (PM) and CATA questions. Six smoked bacons were characterized by ten trained assessors using DA, and by two consumers panel using PM (n=93) and CATA questions (n=100). Also, one hundred consumers indicated their overall liking using a nine-point hedonic scale. The results showed that both techniques identified an ideal product. However, the sensory method has a greater effect than the multivariate procedure to obtain the sensory spaces prior to the preference mapping. Subsequent studies with other food matrices are still necessary in order to generalize our results.

Keywords: *PrefMFA*; *Sensory profile*; *Overall liking*; *Ideal bacon*.

5.1. Introduction

The manufacture and consumption of meat products in the Brazilian market has been increasing in recent years. Bacon is one of the most consumed meat products due to its pleasant sensory characteristics, developed during the curing and smoking processes (Saldaña et al., 2018). The sensory properties of bacon are mainly driven by smoking process that provides the smoke flavor, which is highly appreciated by consumers (Kathrine, Ellen, Gunilla, Margrethe, & Bjørg, 2013). For this reason, the sensory profile is considered the best intrinsic predictor of consumers' liking (Saldaña et al., 2018).

Listening to “the voice of the consumer” is a decisive step in the development or improvement of a product (van Kleef, van Trijp, & Luning, 2005). Therefore, characterizing the product through sensory (sensory attributes) and hedonic (overall liking) perspectives is necessary, because together these data will identify the “drivers

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of liking" (Cariou, Verdun, & Qannari, 2014) and finally the ideal product (Ares, Varela, Rado, & Giménez, 2011). Classically, the ideal product is obtained using the external preference mapping (*PrefMap*). The aim of *PrefMap* is to determine which sensory attributes explain the differences in overall liking (Lê & Worch, 2014) and is constructed in two steps (Ellen van Kleef, van Trijp, & Luning, 2006): (a) determining the sensory space of the product via multivariate procedure, and (b) regressing the hedonic rating in this space (Cariou et al., 2014) using polynomial models. External preference mapping was used in a wide variety of products ranging from *dulce de leche* (Ares, Giménez, & Gámbaro, 2006) to plain yogurts (Masson, Saint-Eve, Delarue, & Blumenthal, 2016). In the meat science field, the *PrefMap* was applied to obtain the sensory attributes that drive the consumers liking of dry-cured ham (Resano, Sanjuán, Cilla, Roncalés, & Albisu, 2010). On the other hand, Arditti (1997) applied preference mapping to investigate chicken nuggets using a *sensometric* perspective. This study included the selection of dimensions and models involved in the polynomial regression. Oltra et al. (2015) used the preference mapping to identify the quality attributes that drive consumers' preferences for grilled lamb *Longissimus lumborum*. Despite all the advantages presented by the *PrefMap*, this technique has some limitations:

- a) The first two dimensions of the product space are not always relevant to predict the overall liking of the consumers. However, the use of more dimensions will increase the number of parameters of the model, compromising the number of samples evaluated in a study;
- b) The product space considered in the regression to model the liking is provided by trained assessors, and this space is not always relevant for consumer responses (Cariou et al., 2014; Worch, 2013). This fact can lead to irrelevant models for some consumers and therefore to a low predictive power.

In the current study, the last limitation will be addressed. Fitting liking in sensory space is risky, since the sensory space will not represent the ideal product in hedonic terms. To overcome these limitations, Worch (2013) presented a solution taking the best of the internal and external preference mapping techniques: the *PrefMFA* was born. This new technique of preference mapping uses the Multiple Factor Analysis (MFA) to give

the same importance to the sensory and hedonic data in the construction of the perceptual space of the *PrefMFA*. Nevertheless, few applications of this technique have been reported in the development of foods.

As previously mentioned, the *PrefMap* is the influence of the product sensory space on the description of the ideal product. For this reason, the following question arises: Is the product sensory space provided by a trained panel the same as that given by the consumers? The answer is no. Consistent with this disadvantage and considering the development of new sensory methods performed by consumers (Ares & Varela, 2017; Valentin, Chollet, & Lelie, 2012), it seems appropriate to use sensory spaces provided directly by consumers. The construction of external preference maps based on consumer sensory space is not a new idea, since Parente, Manzoni, & Ares (2011) successfully developed external preference maps based on the first two dimensions of the Multiple Factor Analysis performed on the CATA questions data. However, to date, there are no scientific reports that have examined the influence of the sensory space of the product obtained by different consumers sensory methods in the identification and description of the ideal product.

In this context, this study aimed to evaluate the influence of the product space provided by DA, PM, and CATA questions to identify and describe the ideal smoked bacon through the application of *PrefMFA* and *PrefMap*.

5.2. Materials and methods

5.2.1. Samples

Six smoked bacon samples were considered in the present study: two were smoked using liquid smoke (LS1 and LS2), three were conventionally smoked using Brazilian woods from reforestation (Bamboo, Eucalyptus and Acacia), and the last one corresponded to a commercial smoked bacon (CS) (Saldaña, Saldarriaga, et al., 2018). Samples manufactured at the University processing plant (LS1, LS2, Bamboo, Eucalyptus and Acacia) were prepared in three independent processing and stored at -18 °C until one day before the sensory evaluation, when they were thawed at 4 °C.

To guarantee the chemical characteristics required by the Brazilian legislation, moisture and lipid content of the bacon samples was determined according to the AOAC guidelines (AOAC, 1995). Water activity (A_w) was measured at 25 °C using a water activity meter (AquaLab 4TE, Decagon Devices, Inc., USA). The pH was measured using a pH-meter with a puncture electrode inserted into the sample (Saldaña et al., 2015). All measurements were performed in triplicate. Before carrying out the sensory tests, microbiological analyses of the bacon samples were performed to safeguard the integrity of the participants.

5.2.2. Sensory space of the products

The study was carried out by the *Sensory Analysis and Consumer Study Group* (SACSGroup), which belongs to the *Laboratório de Qualidade e Processamento de Carnes* of the *Departamento de Agroindústria, Alimentos e Nutrição (LAN)* of the *Escola Superior de Agricultura "Luiz de Queiroz" - Universidade de São Paulo (ESALQ-USP)*. The Human Research Ethics Committee of the ESALQ-USP (protocol No. 1.550.783) approved this study. All participants read and signed an informed consent form. Samples coded with three-digit random numbers were served to the consumers following a Williams Latin Square design to avoid order presentation bias. Water was used for rinsing between samples. The sensory methods were performed according to Figure 5.1. The sensory space provided by the DA and PM was used as a baseline to select the words used in the CATA questions.

Figure 5.1. Three sensory methods used to obtain the product sensory space: Descriptive Analysis, Projective Mapping, and CATA questions.

5.2.2.1. Descriptive analysis

The sensory space of the bacon samples was determined through the DA (Lawless & Heymann, 2010), using ten trained assessors, considering eight sensory attributes (shine, fat content, redness, yellowness, saltiness, fattiness, smokiness and succulence), tasted during three different sessions. Further details of the DA are available in the study of Saldaña et al. (2018).

5.2.2.2. Projective Mapping

The consensus configuration of the samples of the PM method was used as the sensory space of the samples. Ninety-three consumers (55% women and 45% men, aged between 18-62 years) received 6 samples of smoked bacon and evaluated the similarities and differences between them according to their own criteria (Saldaña, Castillo, et al., 2018). Consumers placed the samples on a A3 sheet so that if two samples are similar, they should be close to each other and if they are different, they should be distant to each other (Valentin et al., 2012). When this step was completed,

consumers were asked to write a few words close to the product to describe their sensory characteristics, as shown in Figure 5.1.

5.2.2.3. CATA questions and overall liking

One hundred habitual bacon consumers (40 men and 60 women, aged between 18 - 57 years) tasted monadically 6 bacon samples and answered the CATA questions checking all the terms that they considered appropriate to describe each bacon (Saldaña et al., 2019). The CATA questions were composed of 32 terms related to the sensory profile (Descriptive Analysis) and consumer perception (Projective Mapping) of the bacon samples. To avoid biases due to the long list of terms, the words were presented by category (appearance, odor, texture, and taste). Subsequently, consumers were asked to evaluate their overall liking (OL) using a structured nine-point hedonic scale, ranging from dislike extremely (1) to like extremely (9).

5.2.3. Data analysis

All data analyses were performed in the R environment using FactoMineR (Lê, Josse, & Husson, 2008) (MFA, CA, and, and RV coefficient), SensoMineR (Lê & Husson, 2008) (*PrefMap* and *PrefMFA*) and CVAS (Canonical Variate Analysis) (Peltier, 2015).

5.2.3.1. Chemical analysis and overall liking

An analysis of variance (ANOVA) followed by the Tukey's HSD test ($p < 0.05$) on the chemical and liking data were performed. For the chemical data, the one-way ANOVA was considered. For the liking data, the ANOVA model involved sample, consumer, and sample's presentation order as sources of variation. The normality of the residues and homogeneity of the variances were checked before performing the ANOVA test.

5.2.3.2. Sensory space of the products

The DA data were analyzed by CVA based on the Multivariate Analysis of Variance to obtain the sensory space of the products following the guidelines of Peltier, Visalli, & Schlich (2015). MFA was used to provide the sensory space of the product based on the responses of ninety-three consumers who performed the PM. CATA questions data were analyzed by nonparametric Cochran's Q test on the contingency table to identify the significantly different attributes between bacon samples. Afterwards, correspondence analysis (CA) was performed on the contingency table of the significant terms (Vidal, Tárrega, Antúnez, Ares, & Jaeger, 2015).

5.2.3.3. Construction of the preference maps

The *prefMap* was carried out according to Macfie (2007) using the coordinates of the sensory space provided by the DA, MP and CATA questions. The *prefMFA* was analyzed following the recommendations of Worch (2013). The coordinates of the first two dimensions of the *prefMFA* were based on the MFA, considering sensory (DA, MP and CATA questions) and hedonic (OL) groups as active variables. For both *PrefMap* and *PrefMFA*, the OL of each consumer was individually regressed using the first two dimensions (Dim_1 and Dim_2) using the circular ideal point model (equation 1) (Danzart, Sieffermann, & Delarue, 2004), since it has only 4 parameters (a , b , c , and d). A complete quadratic model is not suitable due to the high number of parameters and the low number of samples.

$$\text{Liking} = a + b * Dim_1 + c * Dim_2 + d * (Dim_1^2 + Dim_2^2) \quad (1)$$

Where a is the intercept, b and c are the regression coefficients for the first two dimensions, and d is the quadratic parameter. This model was used because the consumers' preferences are not linear (Schlich, 1995), involving four types of consumers: those who express like and dislike, the eclectics, and the non-discriminators (Danzart et al., 2004). Once the regression model was defined, the overall liking of each consumer was modeled using the first two dimensions of the CVA, MFA, and CA, corresponding for DA, PM and CATA questions, respectively. Subsequently, the OL areas were discretized in 1 if the estimated liking score was greater than the mean liking provided by the target consumer, and in 0 if the estimated liking was lower than the mean liking (Danzart et al., 2004). Finally, a density plot was created by overlaying all

individual consumers areas. In the plot, areas with maximum density of preference were identified, corresponding to the coordinates of the ideal bacon.

5.2.3.4. Comparison of the ideal smoked bacon positioning

The RV coefficient was used to compare the configuration of the ideal smoked bacon obtained by three sensory product spaces (DA, PM and CATA questions) and two multivariate procedures (*prefMap* and *prefMFA*). The RV coefficient indicates the proximity between two configurations resulting from the multivariate analysis (Robert & Escoufier, 1976) and assumes values between 0 (total disagreement) and 1 (total agreement) (El Ghaziri & Qannari, 2015). In addition, each ideal product was characterized by the sensory attributes from each independent method.

5.3. Results and discussion

5.3.1. Chemical characteristics of bacon

All bacon samples manufactured in the processing plant of the University were similar in the chemical characteristics evaluated (Table 1), indicating that pork bellies were homogeneous, and the manufacturing process was similar for all samples. Therefore, it is assumed that changes in the sensory profile are due to the wood or liquid smoke used in the smoking process.

Table 5.1. Chemical characteristics of the smoked bacon samples

Sample	Moisture (%)	pH	Lipid (%)
Acacia	44.6±3.23	5.91±0.01	38.20±3.53
Bamboo	45.7±2.48	6.01±0.11	36.65±1.30
Eucalyptus	46.1±0.77	5.94±0.11	37.39±2.01
LS1	44.6±2.37	5.88±0.14	39.98±1.64
LS2	46.7±1.13	6.08±0.06	38.47±1.30

No significant differences were found between samples by the ANOVA. LS1 and LS2 are samples smoked using two different brands of commercial liquid smoke.

All the chemical characteristics showed values similar to those reported in the literature. The moisture content and pH values of the samples were similar to those reported by Huang, Li, Huang, Li, & Sun (2014) and the lipid content of the samples were within the range indicated by Soladoye et al. (2017) (30.71% – 68.74%).

5.3.2. Sensory analysis of bacon

Before analyzing the preference maps, it is convenient to present the results of the overall liking, since the products with greater acceptance are expected to be close to the ideal product (if there is an ideal product). Figure 5.2 indicates that the commercial and LS2 samples had the highest OL, while LS1 was the least liked. The remaining samples showed an intermediate liking.

Figure 5.2. Boxplots of the mean overall liking of smoked bacon samples. Means with the same letter (or with the same color) are not significantly different at 5% of significance. M: Mean overall liking; N: Number of consumers.

5.3.2.1. Descriptive analysis

Figure 5.3 shows the preference mapping according to the *PrefMap* and *PrefMFA* for the DA. Subtle differences were observed in the positioning of the samples in the sensory spaces, although they were obtained by different multivariate methods. In the *PrefMap*, LS2, Bamboo, Commercial and Acacia samples were positioned in the region of greater acceptance (60-70% of consumers liked these products), while LS1 (20-30% of consumers liked these products) and Eucalyptus (30-40% of consumers liked these products) samples were positioned in the region of lower acceptance. In the *PrefMFA*, the samples placed in the areas of greater acceptance were commercial, bamboo and S2, and those placed in the less accepted region were Eucalyptus, Acacia and S1. Both methods showed optimal regions, where the preference would be greater in the red part of the sensory map, ie, in this place would be the ideal product. However, the *PrefMFA* showed a larger red area, even positioned in the barycenter of three real products. The small differences in the positioning of the samples in both sensory spaces are due to the fact that they share the same perceptual space. Considering that the experiment was carried out in individual sensory booths and that DA was performed by trained assessors who evaluated the sensory profile analytically, it can be stated that the liking of the bacon is based on its sensory properties. From this, Tuorila, (2007) argued that the sensory properties of foods and beverages are the basis of their acceptance and consumption.

Figure 5.3. Positioning of the samples (left) and preference maps (right) for the descriptive analysis.

5.3.2.2. Projective Mapping

Figure 5.4 shows the positioning of the samples considering the projective mapping as sensory technique. The positioning of the samples was different when the hedonic information was included in the MFA. This can be explained by the nature of the PM, which studies the sample representation. Representation from the social point of view is related to concepts, phrases, ideas, opinions, attitudes and values (Gómez-Corona, Lelievre-Desmas, Escalona Buendía, Chollet, & Valentin, 2016).

When *PrefMap* was used, two clearly separated regions were observed: the red region composed of the most preferred samples (LS2, Bamboo, Commercial, Acacia) and the blue region composed of the least preferred samples (Eucalyptus and LS1). This arrangement of samples with high preferences was like that of the DA. It was also

observed that no sample was close to the region of maximum preference. On the other hand, the *PrefMFA* also showed two clear regions of preference, where Eucalyptus, Acacia and LS1 had the lowest preference, while LS2, commercial and Bamboo had the highest preference. It is necessary to emphasize that *PrefMFA* showed samples very close to the region of maximum preference, ie, close to the ideal product. This is probably due to the fact that this map contains perceptual information based on consumer coupled with consumer-based hedonic perception. Therefore, joining information provided only by consumers seems to improve the identification of the ideal bacon.

Figure 5.4. Positioning of the samples (left) and preference maps (right) for the projective mapping.

5.3.2.3. CATA questions

The positioning of the samples obtained by CA and MFA was similar for both multivariate procedures. As in the case of the DA, this is due to the fact that the sensory properties were the main drivers of liking. According to Figure 5, *PrefMap* and *PrefMFA* found similar preferred patterns, with commercial, bamboo and LS2 being the most preferred samples and Acacia, eucalyptus and LS1 the least preferred ones. In both multivariate methods the ideal product is close to bamboo, LS2 and the commercial bacons. The CATA method explicitly showed the ideal product coinciding with the position with the highest density preference in its respective preference map.

Figure 5.5. Positioning of the samples (left) and preference maps (right) for the CATA questions.

5.3.2.4. Comparison of the sensory methods and multivariate procedures

To compare the different sensory spaces in function of the sensory method and multivariate technique, the MFA using the coordinates of each sensory space was used. Figure 5.6 (which maintained 74.82% of the explained variance) shows, on the one hand, the position of each sensory method coupled to a given multivariate technique considering all samples (group representation) (Saldaña et al., 2015) and, on the other hand, the representation of each sample considering the different sensory techniques and statistical procedure used to obtain the sensory space (map of individual factors) (Pagès & Husson, 2014).

According to the "group representation", sensory space was the main cause of variations in the preference mapping, where the descriptive analysis performed by trained assessors was different from the consumer-based methods. This result was expected, since consumers and trained assessors use different cognitive strategies to evaluate the samples; while judges are analytical, consumers are holistic and intuitive. Similar results were found by Dooley, Lee, & Meullenet (2010), who reported that, despite the spatial similarity between the samples, the description of the ideal product was different. Sensory methods based on consumer response (PM and CATA) were similar. This is explained, as already mentioned, by the cognitive process used by consumers. This behavior was previously reported by other studies (Cadena et al., 2014; Hopfer & Heymann, 2013).

Despite the small differences between multivariate techniques, they did not show a clear pattern of behavior for the consumer-based methods. For DA, the results were similar.

Figure 5.6. Multiple Factor analysis of the perceptual space of DA, PM, and CATA questions considering the *PrefMap* and *PrefMFA* procedures.

The "individual factor map" showed that the main differences between the sensory methods and the multivariate techniques for each sample are specifically in the second dimension. It is necessary to emphasize that for the most (LS2) and least (LS1) preferred products by consumers, there were no variations in the perceptual space. Therefore, if it is desired to find the ideal product from the position of the preferred products, little variation will be found between the sensory methods and multivariate techniques used to calculate the sensory space.

Overall, the ideal product is between the commercial product, LS2 and Bamboo. From this information, detailed explorations should be carried out based on the consumer's perception considering their individual differences, i.e., identifying possible groups of consumers with their respective ideal products.

5.4. Conclusion

All preference maps showed two large regions, those of high and low preference. The most accepted bacon samples (according to the hedonic test) were always located in the high preference region. Our findings indicate that the sensory method had greater

impact to obtain the sensory space than the multivariate technique. Therefore, the inclusion of hedonic scores in the calculation of the sensory space will not have a great effect on the identification of the ideal product. Subsequent studies with other food matrices are still necessary in order to generalize our results.

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6. EFFECT OF SMOKING AND FAT CONTENT ON THE DYNAMIC PERCEPTION OF BACON BY BRAZILIAN CONSUMERS⁵

Abstract

The high heterogeneity of meat and meat products can influence the sensory perception of the consumers, being necessary to measure the real impact of these non-controllable variables on the dynamic sensory properties of the smoked bacon during tasting. The aim of this study was to evaluate the effect of smoking and fat content on the dynamic sensory perception of bacon by Brazilian consumers. For this, four different samples were prepared, varying the fat content (from “low” to “high”) and the type of smoking shown on the product label (natural and artificial). Thirty-five habitual smoked bacon consumers evaluated the dynamic sensory properties of the product using the Temporal Dominance of Sensations (DTS) method. The results were submitted to univariate (bandplot by attribute) and multivariate analyzes (Principal Component Analysis) to study both the dominance rate and its duration, respectively. The main attributes modified during tasting were “salty,” “fatty,” and “succulent,” thus showing that the dynamic sensory perception of smoked bacon was modified by the type of smoking and the fat content of the sample.

Keywords: *Sensory properties; Temporal Dominance of Sensations; Brazilian consumers.*

6.1. Introduction

According to the annual report of the Brazilian Association of Animal Proteins for 2016, 89% of the pork meat produced in Brazil was destined to the production of industrialized products, and among them, the bacon stands out (Saldaña et al., 2019). Therefore, this product is noteworthy from a sensometric perspective, since any change in its composition and/or processing will modify its sensory properties, which will reflect on product sales (Saldaña et al., 2018a).

The sensory properties of meat products are very important intrinsic factors, since they are responsible for the formation of preference and, consequently, for consumers’ purchase intention (Tuorila; Monteleone, 2009). Descriptive analysis is the most sophisticated method for the quantitative description of the sensory properties of food, allowing to obtain the sensory profile of the product (Alcantara; Freitas-sá, 2018). The sensory profile obtained by a well-trained assessor’s panel depends mainly on the

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products and the assessors. Commonly, the products are subjected to different treatments using a certain statistical design, for example "to reduce the content of sodium chloride of salamis, a randomized block design was used " (De almeida et al., 2016) and "to modify the content of fat and salt in cooked bologna type sausages, a factorial design was used" (Ventanas; Puolanne; Tuorila, 2010). However, it is not always possible to develop a homogeneous product within the same treatment, as there are factors that we cannot control as we would like. In this regard, Bavay et al., (2014) demonstrated the inherent heterogeneity within the same variety of apples. In an analogous way to products of plant origin, products of animal origin are subject to variations in the proportion of fat and meat. Bacon is a product in which this characteristic is intensified, since the proportion of meat and fat in the pork belly is very variable. This heterogeneity can cause changes in sensory properties related to texture, aroma and taste. For example, within the same treatment, a high-fat bacon smoked with Eucalyptus wood, may have a lower salt taste intensity, since fat is usually a barrier to rapid dissolution of salt in saliva.

In this sense, the sensory profile of a meat product not only depends on the type of smoking (Saldaña et al., 2018b) but also on the fat content (Lorido et al., 2015). However, few researchers have addressed the impact of these variables on the dynamic sensory profile of a product. The sensory changes due to different smoking process, as well as the variations in the meat/fat ratio are even more evident when studying the dynamic sensory properties of a meat product, which involve chewing and flavor release (Galmarini et al., 2016). In addition, the dynamic sensory methodologies are considered more realistic due to the possibility of studying the evolution of the sensory characteristics during tasting. The past decade has witnessed the development of different dynamic sensory methodologies to investigate changes in products over time. Among them, the Temporal Dominance of Sensations (TDS) has become fairly popular (Schlich, 2017). TDS is a dynamic multi-attribute methodology used to evaluate the temporal perception of dominant attributes of a product during consumption (Pineau et al., 2009). This methodology consists in the selection of dominant attributes by the consumers (an attribute is automatically deselected upon selection of another one) until all the sensations end.

Considering this panorama, the aim of this work was to evaluate the impact of the type of smoking and fat content on the dynamic sensory perception of bacon by Brazilian consumers using TDS.

6.2. Materials and methods

6.2.1. Samples

Two commercial bacons were purchased in a local market (São Paulo – Brazil), based on the smoking claim of the product label: a naturally and an artificially smoked product. Two meat/fat ratios were obtained for each smoking claim, summarizing 4 samples as shown in Figure 6.1.

Figure 6.1. Smoked bacon samples used in the current work.

6.2.2. Dynamic sensory evaluation

TDS test was performed in standardized sensory booths of the *Escola Superior de Agricultura “Luiz de Queiroz” (ESALQ) / Universidade de São Paulo (USP)*. Samples were cut into cubes of approximately 2.5 g, cooked in a hot plate (300 °C) for five minutes, subsequently served monadically in disposable plastic plates coded with three-

digit random numbers following a William's Latin Square design to avoid biases. The data were collected using *SensoMaker* software (Pinheiro; Nunes; Vietoris, 2013).

6.2.2.1. Attributes

The selected attributes (Table 6.1), based on previous studies (Saldaña et al., 2018b, 2019), were presented to the consumers according to Williams design to avoid biases, but each consumer received the same presentation order to facilitate attribute location (Merlo et al., 2018).

Table 6.1. Attributes and definitions used to describe the samples over time.

Attribute	Definition
Salty	Basic taste related to sodium chloride (NaCl)
Fatty	Perception of fat content during chewing
Smoky	Characteristic taste of smoke
Crunchy	Characteristic noise emitted during chewing
Succulent	Liquid released during chewing
Stringy	Presence of fibers perceived during chewing
Salty aftertaste	Residual salty taste after bacon intake
Smoky aftertaste	Residual smoked taste after bacon intake

6.2.2.2. Participants

A total of 45 consumers were recruited at *ESALQ/USP* according to their frequency of bacon consumption (at least once a month), as well as according to their motivation and availability of time to participate in the familiarization and formal evaluation. However, only 35 consumers (18 – 59 years old) performed the test adequately. This amount of participants still represents a number higher than the minimum recommended (Pineau; Schilch, 2015).

6.2.2.3. Familiarization

A 30-minute familiarization session consisted of an introduction to sensory analysis of foods, followed by a presentation of the TDS test to consumers. A strawberry-flavored chocolate was used to help consumers to fix the concept of dominant sensation, defined as "the sensation that catches/triggers your attention at a

given time, while testing a product" (Pineau et al., 2009). In addition, a previous test was done with a sample of cereal bar prior to performing the formal evaluation, to make sure that the consumers understood the test.

6.2.2.4. Evaluation protocol

Attributes were presented simultaneously on the computer screen (Figure 6.2). Then, the participants were instructed to start the test clicking on the "start" button and to choose the dominant sensation. Participants could select as many dominant sensations as they wanted or never select a sensation. After 60 seconds the test was finished. Water and bread were used for rinsing between bacon samples.

6.2.3. Data analysis

Data analysis was performed using TimeSense software (INRA, Dijon, France). Time was standardized between 0 (start of the test) and 1 (60 seconds) to align the tasting duration, allowing the comparison of the individual results. A bandplot by descriptor was used to represent the sequence of dominant sensations in each sample. The height of the bars corresponded to the dominance rate of the sample (Galmarini; Visalli; Schlich, 2017). In addition, the standardized duration of the dominances was represented by a biplot Principal Component Analysis (PCA), based on a covariance matrix (Thomas et al., 2016).

Figure 6.2. Temporal Dominance of Sensations: from data acquisition to data analysis.

6.3. Results and discussion

Different dominant attributes during tasting (different sequence and dominance rate) was observed (Figure 6.3), indicating that the dynamic sensory profile of bacon samples was affected by the smoking method and the meat/fat content.

Bacon naturally smoked presented differences in the salty flavor, smoky aftertaste, and stringy attributes due to differences in the proportion of fat. Interestingly, there was no noticeable change in the fatty attribute. This is probably because, at the time of cooking, a large part of the fat content was melted, reducing the changes in the perception of the fatty attribute. For the “artificial” samples, the fatty, succulent, salty, smoky and salty aftertaste attributes presented differences in the sequence and dominance rate due to the fat content. At the beginning of the tasting, the artificialM (artificial sample with the highest fat content) was perceived as fatty and succulent, while the artificialL (artificial sample with lower fat content) was perceived as smoky and salty. From half of the tasting onwards, the artificialL presented the highest rate and duration for the salty aftertaste and smoky aftertaste attributes. It is clear, then, that there is an interaction between the fat content and the type of smoking in bacons. In artificial smoking, differences in the fat/meat content of the bacons are even more pronounced.

Figure 6.3. Bandsplot by attribute of the smoked bacon samples.

Once the effect of the type of smoking and the meat/fat ratio on the dynamic sensory perception of consumers has been demonstrated, it is necessary to study the standardized duration of the dominance. In Figure 6.4, the four samples and the eight attributes are displayed from a multivariate perspective. The confidence ellipses indicate whether two samples are similar (overlapping) or not (not overlapping).

First, the standardized duration of the succulent and fatty attributes was similar, since both vectors presented the same module and direction. These attributes were associated with samples with high fat content, both for the artificial and natural smoking process. This result was expected since they had a higher fat content. On the other hand, salty and smoky aftertaste attributes are opposed to succulent and fatty and, at the same time, are associated with products with less fat content. This behavior may be due to the fact that bacons with higher fat content leave a fatty mouth coating during

product chewing, reducing the contact of the salt crystals with the saliva, decreasing dissolution and, therefore, the perception of saltiness (Chabanet et al., 2013; Lorido et al., 2015). The smoky aftertaste attribute, which characterizes the samples with low fat content, presented a behavior similar to the salty attribute. Probably the same phenomenon described in the salt particles occurred, ie, fat prevented the molecules associated with the smoky aftertaste attribute from being easily released from the fat matrix, and considering that the chewing process lasts a few seconds, this sensation lasted a short time (Ventanas; Puolanne; Tuorila, 2010). The smoky and salty aftertaste attributes had an intermediate importance, varying only in the second dimension, which explained 17.3% of the variance of the data. Finally, the crunchy and stringy attributes were poorly represented by the first two dimensions; therefore, they did not have great relevance in the present study.

Figure 6.4. PCA of the duration of dominance for bacon samples.

The evidence from this study suggests that standardizing the meat/fat content is essential for the study of the dynamic sensory properties of meat products.

6.4. Conclusion

The type of smoking and the fat content modified the dynamic sensory perception of bacons. Samples with high fat content had higher rate and duration of dominance for the fatty and succulent attributes, whereas for the low-fat samples these characteristics were observed for the salty attribute. The type of smoking also modified the sensory dynamics, without a clear pattern of increase or decrease of specific attributes.

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7. UNDERSTANDING CONSUMERS' DYNAMIC SENSORY PERCEPTION FOR BACON SMOKED WITH DIFFERENT BRAZILIAN WOODS⁶

Abstract

The aim of the present study was to obtain the dynamic sensory profile of smoked bacon using Temporal Dominance of Sensations (TDS). Eight samples were studied considering different smoking process: six samples were submitted to conventional smoking using different woods from reforestation and two samples were manufactured with liquid smoke. Seventy-eight regular bacon consumers evaluated the samples using the TDS methodology. TDS data were analyzed based on the sequence (bandplot by attribute and trajectory map) and dominance duration (univariate and multivariate techniques). TDS results showed differences between samples in terms of rate, trajectory and duration of dominant sensations. These differences can be mainly explained by the smoking processes used in their manufacture and by the oral work involved in the mastication task. Overall, TDS was a promising method for capturing temporal sensory changes in smoked bacon.

Keywords: Temporal dominance of sensations; Smoking process; Smoked bacon, Reforested woods

7.1. Introduction

In 2017, Brazil was the fourth largest producer and exporter of pork meat in the world, with a production of 387.5 million tons (ANUALPEC, 2017), 80.4% of which remains in the domestic market, being largely destined to the manufacture of meat products (ABPA, 2017). Among these products, bacon is very consumed by the Brazilian population because of its sensory properties resulting from the smoking process. The sensory characteristics of smoked bacon depend mainly on the chemical composition of the wood used in smoking process (Saldaña, Castillo, Cabrera, et al., 2018). Therefore, studying the differences in the sensory characteristics of bacon in relation to the wood used during smoking is very important to reach consumers' expectations.

Sensory analysis has been widely used as a decisive tool for the food industry. Through sensory analysis it is possible to select and improve raw materials and

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processes, develop/redesign new products, packaging systems, labeling, among others (Miller, 2017). Classically, sensory analysis of meat products is carried out by a panel trained to profile their sensory properties (Selani et al., 2016). However, descriptive sensory measurements based on consumer response have become increasingly important, since the response is obtained from the consumer, who ultimately decides the success or failure of a product (Saldaña, de Oliveira Garcia, et al., 2018). In the last ten years, consumers-based sensory methodologies have been improved and optimized. Among these methods, the *Flash Profile*, *Check-all-that-apply questions*, *Free Sorting Task*, *Projective Mapping*, *Polarized Sensory Positioning* and recently the *Pivot profile*® (Lelièvre-Desmas, Valentin, & Chollet, 2017; Valentin, Chollet, & Lelie, 2012; Rios-Mera et al., 2019) have stood out. Despite the advances in the sensory methods performed by consumers, studies on the temporal dimension are still scarce, since the sensory attributes are modified during tasting (Dijksterhuis & Piggott, 2000). In order to meet this need, the TDS method has emerged (Schlich, 2017).

The TDS method aims to describe the temporal evolution of different sensory attributes during the tasting of a product, in a predefined period, where the consumers should focus their attention on the dominant sensation generated by the sample (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009). It is considered an effective and fast method when compared to the traditional methodologies used in the temporal sensory analysis, such as the Time-Intensity method. Although it has been developed for trained assessors, in recent years this technique has shown great potential when consumers are used as a panel (Ares et al., 2017; Oberrauter, Januszewska, Schlich, & Majchrzak, 2018; van Bommel, Stieger, Schlich, & Jager, 2019). TDS has been used to evaluate the most diverse types of products, such as wine (Meillon, Urbano, & Schlich, 2009), breakfast cereals (Lenfant, Loret, Pineau, Hartmann, & Martin, 2009), fish nuggets (Albert, Salvador, Schlich, & Fiszman, 2012), yogurts (Bruzzzone, Ares, & Giménez, 2013), coffee (Dinnella, Masi, Naes, & Monteleone, 2013), cooked lamb meat (Ma et al., 2016), among others.

Although many applications in food technology have been reported so far, the use of TDS to assess quality attributes of smoked meat products, such as bacon, has not been reported. In view of the above, it is important to evaluate the evolution of taste,

aroma and texture attributes during the tasting of bacon smoked with different reforestation woods, since they can modify the sensory attributes of smoked bacons. Therefore, this study aimed to evaluate the sensory aspects of bacon smoked with reforestation woods and liquid smoke using the TDS methodology.

7.2. Materials and methods

7.2.1. Materials

Sixteen pigs, including crossbred females (1/2 Landrace, 1/2 Large White (Agrocères PIC Camborough®)) and males (Agpic 337) were selected for this study. The animals were fed a diet consisting of corn (70%), soybean meal (26%), oil (1%), vitamin-mineral premix (3%), antioxidant (200g/ton) and ractopamine (16 ppm) and slaughtered at 150 days of age. The raw material used for the bacon processing was the boneless pork belly, cut in "square", corresponding to the belly and rib.

For bacon manufacturing, boneless pork belly (70 kg, pH 5.8, similar proportion fat/meat), weighing 2 to 5 kg, was obtained from a local slaughterhouse. Two different brands of liquid smoke (LS1 and LS2), obtained through the condensation of smoke, were used: LS1 (pH=2.50–4.50, density=0.90–1.15 g·mL⁻¹, Acidity=10.00–11.00%, absence of *Salmonella* in 25 mL, Sodium=2.40 mg·g⁻¹) and LS2 (pH=2.20–3.20, density=1.09–1.19 g·mL⁻¹, Acidity=9.50–11.00%, absence of *Salmonella* in 25 mL, Sodium=1.50 mg·g⁻¹).

Eucalyptus citriodora, *Acacia mangium*, and *Mimosa scabrella* (Bracatinga) woods were obtained from the *Estação Experimental de Ciências Florestais de Itatinga* (Itatinga, SP). *Teca grandis* and *Bambusa vulgaris* (Bamboo) woods were collected at "Fazenda Areão" (Piracicaba, SP). These two experimental stations belong to ESALQ/USP. *Acacia mearnsii* was supplied by a wood chips manufacturer, located in Rio Grande, Brazil.

The characterization of the wood was performed using a series of physical and chemical parameters. The determination of holocellulose, Klason lignin (insoluble, soluble and total), and the content of total extractives followed the recommendations of ABNT NBR 14660 and the Technical Association of Pulp and Paper. The basic density and moisture content of the wood chips were determined according to ABNT NBR

11941. All analyzes were performed in triplicate. Table 7.1 shows the results of the wood characterization, expressed as mean and standard deviation.

Table 7.1. Characterization of the woods used in the smoking process

Wood	Moisture (g/100 g)	Content of total extractive (g/100 g)	Insoluble lignin (g/100 g)	Soluble lignin (g/100 g)	Total lignin (g/100 g)	Holocellulose (g/100 g)	Basic density (g/100 g)
Bamboo	10.45±0.14 ^a	8.85±0.23 ^b	27.97±0.73 ^{ab}	2.22±0.60 ^{ab}	30.19±0.13 ^{bc}	60.96±0.33 ^a	0.55±0.01 ^a
Acacia mearnsii	11.67±0.06 ^a	4.40±0.08 ^a	20.64±0.63 ^a	2.44±0.36 ^{ab}	23.08±0.44 ^a	72.51±0.45 ^b	0.57±0.02 ^{ab}
Acacia mangium	11.37±0.05 ^a	5.63±0.43 ^{ab}	25.89±0.37 ^a	1.16±0.17 ^a	27.05±0.30 ^b	67.32±0.40 ^{ab}	0.62±0.01 ^{bc}
Eucalyptus	12.05±0.06 ^a	3.19±0.09 ^a	25.79±0.61 ^a	1.53±0.35 ^a	27.32±0.95 ^b	69.49±1.01 ^{ab}	0.60±0.01 ^b
Teca	11.63±0.05 ^a	10.45±0.10 ^b	27.56±0.76 ^{ab}	3.42±0.37 ^b	30.98±0.81 ^{bc}	58.57±0.92 ^a	0.77±0.04 ^c
Bracatinga	11.70±0.23 ^a	6.60±0.34 ^{ab}	32.65±0.91 ^b	2.16±0.01 ^{ab}	34.81±0.91 ^c	58.59±0.92 ^a	0.45±0.01 ^a

Different letters indicate significant differences between bacon samples according to the Tukey test at 5% of significance.

7.2.2. Bacon manufacture

Bacons were manufactured using a complete block design, considering two different blocks (each block representing an independent processing). Eight types of bacon were evaluated in this study: six bacon samples were manufactured through conventional smoking, each one using a different wood from reforestation (*Eucalyptus citriodora*, *Acacia mangium*, *Mimosa scabrela*, *Teca grandis*, *Bambusa vulgaris* and *Acacia mearnsii*) and two bacon samples had the conventional smoking replaced by the use of two different brands of liquid smoke (LS1 and LS2).

Brine (3% salt, 0.5% sugar and 0.02% sodium nitrite [w/v]) was injected into the pork bellies in the proportion of 20% of the meat weight. After the brine was injected, samples were stored for 12 h at 1.5 °C to obtain a homogeneous color distribution and flavor development. The heat treatment was performed as described in Table 7.2. Samples manufactured with liquid smoke were processed using the same time-temperature program, except for the stage two (smoking step), where instead of receiving thermal treatment and smoke from the wood burning, the bellies were removed

from the smoker and sprayed with liquid smoke at 1% of the meat weight, as described by the manufacturer.

Table 7.2. Cooking and smoking steps

Step	Temperature	Condition
Drying (dry heat)	65 °C-30 min	Open chimney and high ventilation
Smoking	75 °C-60 min	Semi-open chimney and low ventilation
Cooking (moist heat)	75 °C-30 min	Closed chimney and high ventilation
Cooking (moist heat)	80 °C	Until the internal temperature of 75 °C was reached

After cooking, the bacon samples were removed from the smoker and cooled to room temperature, vacuum packaged and stored at 2 °C for 24 h. After cooling, ~25 g was subjected to microbiological analysis. Samples were then vacuum packaged and frozen at -18 °C until the day before the sensory evaluation.

7.2.3. Microbiological analysis

Microbiological analysis was performed before the sensory analysis, in order to verify the hygienic quality of the bacons. Aerobic mesophilic bacteria (CFU/g) and coagulase positive *Staphylococcus* (CFU/g) counts were performed according to the method described by Morton (2001) and Lancette & Bennett (2001), respectively. The presence/absence of *Salmonella* sp in 25 g of bacon was determined using the Biocontrol™ 1-2 test kit, following the manufacturer's recommendations.

7.2.4. Sensory analysis

7.2.4.1. Consumers

Seventy-eight consumers (mean age 24.7 ± 6.89 years old, 59% women and 41% men) were voluntarily recruited at ESALQ/USP, through advertisements in social media. Participants declared having a frequency of bacon consumption at least once a month,

as well as being healthy and non-smokers. Consumers did not receive any payment for their participation in this study.

7.2.4.2. Conditions of sensory analysis

Bacon samples were thawed under refrigeration at 7 °C the day before the test, cut into strips of approximately 5 cm and prepared in a hot plate for about 5-10 min until sample reaching 75 °C. To maintain and standardize the temperature of the samples, they were kept in an oven until they were offered to consumers. The sensory analysis was carried out in individual booths, under artificial daylight and temperature control (25 °C). Before starting the sensory evaluation, a free and informed consent form was signed by consumers. Then, the samples were served sequentially in a monadic way, using disposable plastic dishes coded with random three-digit numbers, following a Williams' Latin square design. Bread and water were offered to consumers to clean the palate between evaluations. Data collection was performed using *Compusense Cloud* software (Compusense Inc., Guelph, Ontario, Canada) and tablets (Samsung Tab E/SM-T560/9.6") (Visalli, Lange, Mallet, Cordelle, & Schlich, 2016).

7.2.4.3. Selection of sensory attributes

The sensory attributes were selected following the recommendations of Pineau et al. (2012), based on the sensory description of smoked bacon developed in previous studies (Saldaña, Castillo, Cabrera, et al., 2018; Saldaña, Castillo, Sánchez, et al., 2018; Saldaña et al., 2019). The selected attributes (smoked, salty, fatty, crunchy, tender, roasted, juicy, hard, fibrous and woody) were presented in a balanced order between consumers, following a Williams' Latin square design. However, for each consumer, the attributes were presented in the same order for all samples.

7.2.4.4. Training

Prior to the test, a 15-min single session training was conducted, where the TDS method and the definition of the "dominant sensation" were explained to consumers.

Then, a small practical activity was performed using a coffee-flavored candy (butter toffee), to explain the dominant sensation as "the sensation that catches/triggers the attention of the participant at a given time while testing the smoked bacon" (Pineau et al., 2009). This practical activity aimed to demonstrate that the coffee flavor may not be as intense as the "sweet", "milk", or "cream" flavor, but it was enough to be considered the dominant sensation because it triggered the consumers' attention. In addition, a pilot test with a cereal bar was carried out to familiarize consumers with running the TDS on the tablet, using the software for data collection.

7.2.4.5. Tasting protocol

To standardize the evaluation process, a detailed protocol for the evaluation of the smoked bacon during tasting was elaborated. First, the ten attributes were presented simultaneously on the tablet screen. To start the test, consumers were instructed to put the sample in the mouth, click on the "start" button, and then start the chewing process. During the tasting period, consumers were asked to choose the dominant attribute. The test ended in 90 s (or by clicking on the "stop" button, when no dominant attribute was perceived). It is important to emphasize that the participants were not forced to use all the terms in the list of attributes, in addition to being able to select a dominant attribute more than once during the test. To avoid sensory fatigue because of the large number of samples ($n=8$), a 10 to 15-min interval was established at the end of the fourth sample. Fig 7.1 shows a schematic representation of the tasting protocol.

Figure 7.1. Schematic representation of the tasting protocol.

7.2.5. Data analysis

For the TDS results, the dominance rates were calculated by dividing the number of citations of an attribute by the number of consumers. Then, dominance rates and standardized time were plotted by means of bandplots per attribute (Merlo et al., 2018).

To avoid misinterpretations of the trajectory mapping because of the limited number of citations at the end of the tasting period, a Canonical Correspondence Analysis (CanCA) based on X^2 -distances was applied on the contingency table (samples x time point in the rows and attributes in the columns), generating individual representations of attributes, as well as covariates (samples and standardized time). The mathematical calculations of the CanCA are detailed in the study of Beaton & Meyners (2018), which made the R code available on the following website: https://github.com/derekbeaton/Publications/tree/master/TCATA_TemporalConfounds.

In addition, the duration of the standardized dominance of the attributes was calculated by adding all the times in which an attribute was dominant. Then, they were submitted to the analysis of variance (ANOVA), using samples and consumers as factors.

Subsequently, the Tukey test was applied to the attributes that had a significant standardized duration. A multidimensional representation of the standardized duration of dominant sensations was obtained via Canonical Variate Analysis (CVA). This technique also provides the Lawley-Hotelling trace statistic that was used to detect multidimensional significant differences between bacon samples (Galmarini, Loiseau, Visalli, & Schlich, 2016; Peltier, Visalli, & Schlich, 2015).

The trajectory mapping was performed in the R software, using ExPosition and prettyGraphs packages (Beaton, Chin Fatt, & Abdi, 2014) and the other analyzes were performed in TimeSens© software (INRA, Dijon, France).

7.3. Results and discussions

The results of the present work are organized in two parts: the first section explores the sequence and trajectory of the dominant attributes, whereas the second section evaluates the duration of the dominances of the attributes per sample. Both approaches will help us to understand the path followed by the sensory attributes during tasting and the time each sensation was dominant.

7.3.1. Sequenciality of dominances

The bandplot per attribute (Fig 7.2) shows the different rates and sequences of dominant attributes during the tasting of smoked bacon. The “crunchy” attribute was perceived at the beginning of the tasting for all samples. The “hard” attribute was also perceived at the beginning of the tasting, but it presented a lower dominance rate. In addition, this attribute was not perceived in the *Eucalyptus* and *Acacia mearnsii* samples. The “fibrous” attribute was dominant from 0.1 to 1.0 of the tasting period in all samples, except for *Acacia mearnsii* and Bracatinga, in which this attribute was dominant since the beginning of the tasting. The “smoked” attribute was perceived as dominant from half of the tasting for samples manufactured with liquid smoke. Bacons smoked with reforestation woods were perceived as “smoked” from the beginning of the tasting, varying only in the dominance rate. The bacon smoked with Bracatinga presented “smoked” taste throughout the tasting, being perceived by most of the

consumers because of its highest dominance rate. The other dominant attributes were also different between samples; However, a clear pattern of sequence and dominance rate was not observed.

The result obtained by means of the CanCA is presented in Fig 7.3, which shows the sensory space containing the attributes. In addition, the samples and the trajectory over time were also projected. The first two canonical variables summarized 81.7% of the total inertia. The first canonical variable explained 71.3% of the original variance, while the second explained only 10.4%. The sensory space shows the tasting process in the first sensory dimension. At the beginning of the test, consumers perceived the attributes “hard” and “crunchy” as dominant, confirming what was observed in the bandplots. As the oral processing progressed, “roasted”, “fatty”, “tender”, and “juicy” were described as the sensations that caught the attention of the consumers. At the end of the sensory task, the attributes “salty”, “fibrous”, “woody” and “smoked” were dominant. It is important to note that the circles of the sensory attributes have different sizes, indicating their contribution to the total inertia of CanCA. In that sense, the attributes “fatty”, “fibrous” and “roasted” presented the lowest contributions (located in the middle of Fig 3). The path of the sensory description during the tasting process was guided by the tasting time, inserted as a continuous line along the first canonical variable.

Figure 7.2. TDS bandplot by descriptor for smoked bacon.

The discrimination of the samples within the sensory space occurred mainly due to the second canonical variable. The positive part of this variable grouped the Bracatinga, Bamboo, *Acacia magnium* and Teca samples, which were characterized by many dominant attributes (smoked, woody fibrous, fatty, roasted and hard). The

negative side of this canonical variable grouped the *Acacia mearnsii*, Eucalyptus, LS1, and LS2 samples, which were described as “tender”, “juicy”, and “salty”.

Figure 7.3. Samples, attributes, and time points on the first two dimensions of CanCA.

7.3.2. Dominance durations

Table 7.3 shows the TDS durations means for smoked bacon samples. “Smoked”, “hard”, “tender”, “roasted” and “juicy” attributes were statistically different ($p < 0.05$) between samples according to the ANOVA model. *Acacia mangium*, Bamboo, Bracatinga and Teca samples showed the highest standardized duration for the smoked attribute, with approximately 20% of the standardized time. The standardized duration of the dominant attribute “hard” was different between the samples. However, it accounted for less than 10% of the standardized time. The “tender” attribute had a longer duration in the *Acacia mearnsii* sample, followed by Eucalyptus, LS2, and *Acacia mangium*. The samples with the longest duration of the “roasted” attribute were Teca and Eucalyptus. Finally, LS1 and LS2 had the longest duration of the “juicy” attribute.

Table 7.3. Standardized dominance durations of dominant sensations for bacon.

Attribute	<i>Acacia mangium</i>	<i>Acacia mearnsii</i>	Bamboo	Bracatinga	Eucalyptus	LS1	LS2	Teca
Smoked	0.22 ^b	0.16 ^{ab}	0.21 ^b	0.21 ^b	0.14 ^a	0.14 ^a	0.13 ^a	0.20 ^b
Hard	0.03 ^{ab}	0.02 ^a	0.04 ^{ab}	0.04 ^{ab}	0.01 ^a	0.03 ^{ab}	0.07 ^b	0.04 ^{ab}
Tender	0.11 ^{ab}	0.14 ^b	0.10 ^{ab}	0.07 ^{ab}	0.13 ^{ab}	0.09 ^{ab}	0.13 ^{ab}	0.06 ^a
Roasted	0.06 ^a	0.06 ^a	0.07 ^{ab}	0.08 ^{ab}	0.11 ^b	0.08 ^{ab}	0.06 ^a	0.13 ^b
Juicy	0.10 ^{ab}	0.12 ^{ab}	0.10 ^{ab}	0.07 ^a	0.13 ^{ab}	0.14 ^b	0.15 ^b	0.09 ^{ab}
Woody	0.07	0.10	0.13	0.12	0.07	0.06	0.09	0.07
Crunchy	0.09	0.10	0.08	0.06	0.1	0.11	0.1	0.11
Fatty	0.12	0.09	0.08	0.11	0.09	0.13	0.08	0.09
Fibrous	0.16	0.14	0.13	0.19	0.16	0.15	0.15	0.15
Salty	0.06	0.07	0.04	0.06	0.06	0.08	0.06	0.06

Sample means identified by different letters are significantly different according to the Tukey test at 5% of significance.

Table 7.4 shows the p-values for the pairwise comparison of the bacon samples from the MANOVA of the eigenvalue ($W^{-1}B$) of the CVA. Three groups of samples were classified based on their significance. *Acacia mearnsii* and *Acacia mangium* samples were similar to the other samples, as they presented p-values greater than 0.05 for four of them. Similarly, Bamboo, Bracatinga and LS1 bacons were similar to three samples; and the remaining bacons were similar to only two samples. These differences are explained by the duration of the dominances of the sensory attributes. Figure 4 shows the position of the samples in a two-dimensional space considering the standardized duration of all the sensory attributes.

Table 7.4. CVA Hotelling table for smoked bacon samples.

	<i>Acacia mangium</i>	<i>Acacia mearnsii</i>	Bamboo	Bracatinga	Eucalyptus	LS1	LS2	Teca
<i>Acacia mangium</i>	1	0.049	0.218	0.12	0.006	0.012	0	0.309
<i>Acacia mearnsii</i>	0.049	1	0.103	0.001	0.035	0.06	0.074	0.001
Bamboo	0.218	0.103	1	0.165	0	0.001	0	0.009
Bracatinga	0.12	0.001	0.165	1	0	0	0	0.012
Eucalyptus	0.006	0.035	0	0	1	0.96	0.001	0.007
LS1	0.012	0.06	0.001	0	0.96	1	0.002	0.006
LS2	0	0.074	0	0	0.001	0.002	1	0
Teca	0.309	0.001	0.009	0.012	0.007	0.006	0	1

Significant p-values (in bold and with gray background for easy reading) indicate difference between bacon samples.

Based on the position of the samples in the biplot and the confidence ellipses, four groups of samples were identified: the first one (first quadrant) is composed of Bamboo and Bracatinga samples, which were characterized by attributes related to the smoking process, such as “woody” and “smoked”, respectively. The second group (bacon LS1), which was located in the second quadrant, was characterized as “hard” and “tender”. The *Acacia mearnsii* and *Acacia mangium* samples, members of the third group, were located in the middle of the map and characterized as “fibrous”. Finally, the fourth group was located in the negative side of the second canonical variable, composed of the LS2, Teca and Eucalyptus samples. These samples were characterized as “juicy”, “salty”, “crunchy”, “fatty” and “roasted”.

Figure 7.4. CVA of the standardized dominance durations of the bacon samples.

7.4. Discussion

During the TDS task, consumers perceived different dominant attributes in bacons smoked with different reforestation woods and with the application of liquid smokes. Therefore, different dynamic sensory descriptions were outlined. On the one hand, differences were observed for flavor attributes, such as “smoked” and “woody”. These attributes are generated in the smoking process, mainly due to the presence of phenolic compounds generated during the pyrolysis of the lignin that occurs in wood burning (Saldaña, Castillo, Cabrera, et al., 2018). Thus, woods with higher lignin content are precursors of bacons with higher content of phenolic compounds, which are associated with smoked and woody flavor. These two sensory attributes were close both in the sensory trajectory analysis (Fig 7.3) and in the CVA of the dominance duration (Fig 7.4). Moreover, the “smoked” and “woody” attributes were close to the bacon samples smoked with Teca, Bracatinga and Bamboo. This fact was confirmed by the wood composition performed in this study (Table 7.1), since higher lignin contents were found in Bracatinga (34,81%), Teca (30,98%) and Bamboo (30,19%) woods. These associations were previously reported by Flores (2010).

On the other hand, different changes in texture attributes were also observed in the bacon samples. However, these attributes are not associated with the smoking process of the bacon. Changes in these attributes are more related to the oral processing of the samples (Panouillé, Saint-Eve, Délérís, Le Bleis, & Souchon, 2014). Thus, it is worth exploring studies on changes in texture properties of a product during chewing, as they may provide additional insights on static texture measurements. However, for this purpose, it is necessary to use dynamic sensory methods, in which the sensory changes of different attributes are recorded along the consumption time (Rizo, Peña, Alarcon-Rojo, Fiszman, & Tarrega, 2018). In this sense, the sensory pathway of the samples during the consumption time could be observed using the TDS method (Fig 7.2). At the beginning, consumers perceived the bacon as “hard” and “crunchy”, since it is necessary to print more force to start the chewing process, which involves breakdown of the surface crust created during sample preparation in the hot plate. A similar behavior was reported by Lenfant et al. (2009), in which “hardness”, “crackliness” and “crispness” were perceived at the beginning of the mastication of different breakfast

cereals. Then, during chewing, samples were mixed with saliva, resulting in the perception of “fatty”, “roasted” and “tender”. In this study, “smoked”, “woody”, “fibrous” and “salty” attributes were dominant at the end of TDS task. This is associated with the longer time required to dilute the salted and smoked compounds in the saliva, whose dissolution rate is decreased by the fat content of the bacon samples (Ventanas, Puolanne, & Tuorila, 2010). It is important to note that, at this stage, the perception of the “fibrous” attribute indicates that the fat was released from the bacon sample by the chewing process, confirming our previous hypothesis.

The possible consequences of the sensory changes during the tasting of smoked bacon are, obviously, the rejection or acceptance by consumers (Saldaña, de Oliveira Garcia, et al., 2018). The consumers representation is dependent on previous experiences (Valentin, Chollet, Beal, & Patris, 2007) and sensory preferences of the consumers (Almeida et al., 2016). In this sense, Saldaña et al. (2019), reported two large groups of consumers of smoked bacon. The first group penalized the absence of the smoked attribute (ie, they like a smoked product) and the second penalized the absence of texture attributes (ie, these consumers value texture over flavor). According to Saldaña et al. (2019), the attributes associated with the smoking process, such as “woody” and “smoked”, are associated with pleasure and, therefore, could perform better in the market. Thus, this first group of consumers would be our target audience.

7.5. Conclusion

The dynamics of consumers’ perception is quite complex, being affected by the use of liquid smoke and woods from reforestation in the smoking process of bacon. The TDS method showed that both the sequence of dominant attributes and their duration are dependent on the smoking process, type of wood and oral processing during product tasting. According to the results, bacons smoked with woods with high lignin content showed higher dominance of the “smoked” and “woody” attributes. The oral processing during tasting was responsible for the changes in attributes related the texture, which were mainly perceived at the beginning of consumption.

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8. LOOKING AT NON-SENSORY FACTORS UNDERLYING CONSUMERS' PERCEPTION OF SMOKED BACON⁷

Abstract

Smoked bacon is a food consumed everywhere and previous work has focused on the sensory properties and acceptability of the product. However, little attention has been given to the non-sensory factors that drive sensory and hedonic perception of this product. In this context, the aim of this work was to study the influence of non-sensory factors on consumer behavior towards smoked bacon, using projective mapping coupled with conjoint analysis. Eight visual stimuli were created using a full factorial design with three factors (convenience, healthiness, and context of consumption), at two levels each. Ninety-five consumers positioned the stimuli in a two-dimensional space considering their similarities and differences, and then, rated their expected liking and purchase intention. According to the projective mapping, consumers based the representation of the stimuli on the three factors under study, but conjoint analysis indicated that healthiness was the most important factor, followed by the context of consumption and convenience. The findings of this study may help in the selection of future strategies in the process of food development, in order to launch products with greater chance of success in the market.

Keywords: Purchase intention; Expected liking; Smoked bacon; Non-sensory factors

8.1. Introduction

The sensory properties of smoked bacon are responsible for its high acceptance and consumption worldwide (Wang, Zhang, Suo, Zhao, & Kan, 2018). The sensory profile of smoked bacon may change drastically according to the type of wood used in smoking because it is dependent on the volatile compounds, such as aldehydes, phenols and ketones, responsible for attributes such as woody, smoked and, finally for the pleasure of consumers (Saldaña et al., 2018; Saldaña, Castillo, Cabrera et al., 2018). More recently a study reported that the texture and aroma attributes of bacon are the main drivers of liking (Saldaña et al., 2019), affecting even the dynamic sensory properties of the product during consumption (Saldaña, Soletti, et al., 2019). However, the food

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selection process is done before the consumption of the product (Puyares, Ares, & Carrau, 2010) and therefore, it is also necessary to investigate the role of non-sensory factors, such as brand, packaging, information on nutrition and health, price, advertising, convenience, usage, among others, to fully understand consumers' choice of smoked bacon (Font i Furnols et al., 2011; Morales, Guerrero, Aguiar, Guàrdia, & Gou, 2013; Sijtsema, Jesionkowska, Symoneaux, Konopacka, & Snoek, 2012).

Convenience, healthiness, and context of consumption seem to be key factors that drive the consumption of foods (Jaeger, 2006). Convenience is very important, since most consumers are unwilling to spend much time preparing their foods (Bove, Sobal, & Rauschenbach, 2003). For example, cutting thin slices of a piece of smoked bacon could represent additional work and time that consumers are not willing to waste. Therefore, some consumers feel that it is more convenient to buy bacon already cut in slices. However, convenience might depend on the context in which the bacon will be consumed. Context can be considered crucial, since it regulates food choice (Meiselman, 2006), interacting with other factors at the same time (Jaeger, 2006). For example, a smoked bacon cut into slices will be convenient to prepare a hamburger, but not to prepare beans. So, it is important to consider the context, when evaluating the impact of non-sensory factors, such as convenience.

Another important non-sensory factor is healthiness, since the act of eating has been changing from satisfying hunger to satisfying a healthy lifestyle (Carrillo, Varela, Salvador, & Fiszman, 2011; Saba et al., 2010). In the search for healthiness, there is a current demand not only for products with reduced salt, sugar and fat, but also for more natural products, free of additives (Román, Sánchez-Siles, & Siegrist, 2017). In the case of smoked products marketed in Brazil, the "smoked" claim can only be used when the product is naturally smoked by burning the wood, otherwise the term "liquid smoke" should be declared on the label (Brasil, 2012). According to Rocha, Lapa-Guimarães, de Noronha, & Trindade (2018), this term could be associated with a non-natural and unhealthy meat product, and result in consumer rejection; thus, it is important to evaluate the impact of this term in the expected liking, purchase intention as well as in the representation of smoked bacon.

Conjoint analysis (CA) is classically used to study the effect of different levels of non-sensory factors on the expected liking and purchase intention of a particular product or service (Almli & Næs, 2018). The purpose of this technique is to obtain a combination of factors and levels that maximize the response based on the relative importance of factors and the utility of each level (Gustafsson, Herrmann, & Huber, 2007). Utility represents the value that a consumer attributes to a product due to the combination of their factor levels (Ben-Akiva & Lerman, 1985). Although the expected liking and purchase intention provide relevant information about the product, this still seems insufficient, since the perception of a product goes beyond the hedonic responses (Varela et al., 2017) and purchase intention (Ginon, Ares, Issanchou, Laboissière, & Deliza, 2014). For this reason, different techniques have been coupled to CA to understand the different aspects of the perception of a given stimulus. For example, Rocha et al (2019) investigated the consumers' perception of frankfurters with healthy attributes through sorting task, hard laddering, and expected liking using images with descriptions of various types of frankfurter (traditional, with natural antioxidants, reduced sodium, reduced fat, as a source of dietary fiber, with omega 3, no phosphate added, no nitrite added). Clearly, the assembly of projective techniques and CA helps to obtain a complete representation of the stimuli.

The projective techniques present the advantage of providing spontaneous and unconscious responses (Mesías & Escribano, 2018). Among the projective techniques, the projective mapping has been gaining importance in the study of sensory properties of foods (Dehlholm, 2014; Moelich, Muller, Joubert, Næs, & Kidd, 2017; Nestrud & Lawless, 2008; Risvik, McEwan, Colwill, Rogers, & Lyon, 1994; Risvik, McEwan, & Rødbotten, 1997; Torri et al., 2013). However, little attention has been given to how the categorization of stimuli is affected by non-sensory factors associated with food (Aschemann-Witzel, Varela, & Peschel, 2019).

Projective mapping (PM) is a comparative sensory technique that allows the two-dimensional arrangement of products on a paper sheet simulating a sensory space, considering their global similarities and differences (Risvik et al., 1994), without using any explicit quantification (Valentin, Chollet, Nestrud, & Abdi, 2018). Thus, if two

samples are similar, they are close to each other and if two samples are different, they are far from each other in the space. Afterwards, consumers may indicate two or three descriptors that characterize each product (Perrin et al., 2008). The PM is based on the psychological construction of categorization, which is a spontaneous function that people have to organize elements (in this study the elements are the stimuli) into categories based on certain characteristics with minimal cognitive effort (Valentin et al., 2018). The categories in which the elements are organized reflect their concept or the mental representation (Ballester, Patris, Symoneaux, & Valentin, 2008; Goldstone et al., 2012). For example, if a category of labels has in common the image of the hamburger, it means that the categorization was based on the context of consumption

Therefore, the mental representation of the stimuli, the hedonic value and the purchase intention are important to better understand the impact of extrinsic factors on consumers' perception (Abdi, Valentin, Chollet, & Chrea, 2007; Solomon, Medin, & Lynch, 1999). For this reason, Conjoint Analysis (CA) and Projective Mapping (PM) seem to be complementary techniques to study the impact of non-sensory factors beyond the expected liking and choice of products (Ares, Giménez, & Deliza, 2010; Carrillo, Varela, & Fiszman, 2012).

From this perspective, the aims of the present study were: (a) to study the effect of the convenience, healthiness, and context of consumption on the relative importance and utility values of expected liking and purchase intention of bacons as well as the representation of their labels; (b) to explore the representation of bacon labels by consumers based on PM categories.

8.2. Materials and methods

8.2.1. Pre-test: choice of context

A word association task (WAT) in a web interface (Google forms) was used prior to the conjoint analysis to assess the different contexts in which bacon are usually consumed in Brazil. The WAT was performed by 150 regular consumers of bacon (68.46% female) with ages ranging from 18 to 55 years old (average=26.7), residents in Piracicaba, Brazil. Participants were asked to indicate the four meals that came to their

minds when they thought of smoked bacon (Guerrero et al., 2010). The 411 different meals generated during task were grouped by two researchers with experience in analyzing qualitative research. The analysis consisted of grouping the different forms of expressing the meals in defined categories (For example, “hamburger”, and “sandwich” words were grouped in the category “hamburger”). Fifteen categories were obtained and showed in Figure 8.1. Then, the frequency of word citation was calculated. As the word “hamburger” was the most cited by consumers it was then selected to represent the “context of consumption” factor in the PM and CA.

Figure 8.1. Frequency of mention of the meals prepared by consumers using smoked bacon. *Farofa (in Brazilian Portuguese) is a toasted cassava flour eaten in Brazil.

8.2.2. Participants

Participants were recruited at two food retailers located in Piracicaba, Brazil. To participate in the research, participants had to meet the following requirements: (1) be over eighteen years old; (2) be habitual consumers of bacon (at least once a month); and (3) read and sign a consent form, agreeing to participate in the study. A total of 101

consumers participated in the study, but only 95 individuals finished the test. The characteristics of consumers are given in Table 8.1.

8.2.3. Stimuli

The selected factors and levels were: a) healthiness (text about smoke): natural (natural smoking) and artificial (smoke flavor); b) convenience (shape): image of bacon in piece and in slices; c) context of consumption (hamburger image): presence and absence. The stimuli were created using a *full factorial design* ($2^3 = 8$, *three factors and 2 levels*), considering all possible combinations of each level of each factor, totalizing eight visual stimuli (Table 8.2).

Table 8.1. Characteristics of participants (n = 95).

Characteristic	%
Gender	
Female	59
Male	41
Age (years)	
18-25	21
26-35	25
36-45	19
46-55	17
>55	18
Frequency of bacon consumption	
Daily	1
Twice a week	11
Once a week	21
Every 15 days	29
Once a month	34
Other	4
Education level	
Primary school	8
Secondary school	12
University	80
Body Mass Index (BMI, kg/m²)*	
Underweight (< 18.5)	3
Normal weight (18.5 – 24.9)	32
Overweight (25 – 29.9)	43
Obese (> 30)	20
Social class**	
Upper	25
Middle	48
Lower	27

* The BMI was calculated with height and weight self-reported by consumers, **Social class was calculated using the new Brazilian Economic Classification Criteria in force since the beginning of 2015 (ABEP, 2015).

Table 8.2. Stimuli obtained by means of the full factorial design of the healthiness, convenience and context of consumption factors.

Stimuli (code)	Factors		
	Healthiness	Context of consumption	Shape
1 (NPrPi)	Natural	Presence	Piece
2 (ArPrPi)	Artificial	Presence	Piece
3 (NAbPi)	Natural	Absence	Piece
4 (ArAbPi)	Artificial	Absence	Piece
5 (NPrS)	Natural	Presence	Sliced
6 (ArPrS)	Artificial	Presence	Sliced
7 (NAbS)	Natural	Absence	Sliced
8 (ArAbS)	Artificial	Absence	Sliced

The stimuli were designed in *Adobe photoshop CC 2017* by a professional graphic designer with experience with food packaging. The stimuli were printed on card-stock paper (11.5 x 19.5 cm) simulating bacon packages for the CA task (Figure 8.2), while for PM the stimuli were presented in digital format because the data collection was performed in a Tablet.

Figure 8.2. Example of a visual stimulus presented to the consumers.

8.2.4. General procedure

The study was conducted in two stages: firstly, consumers performed the PM test, and then, the CA task (expected liking and purchase intention) was carried out. At the end of the experiment, consumers filled a socio-demographic and bacon consumption habit questionnaire (Table 8.1).

8.2.5. Projective mapping

The experimental design of the PM task was carried out using the Holos environment (Lê, Brard, & Lê, 2017), a software for collection and storage of Napping data, available at: <http://napping.agrocampus-ouest.fr>. Stimuli were presented simultaneously to consumers as icons to be tactilely dragged on the tablet's screen (Samsung Galaxy Tab E T560). Consumers were instructed to move the stimuli on the screen with complete freedom, considering that close stimuli are similar and distant stimuli are different. In addition, a brief verbal description of the stimuli was requested at the end of the test.

8.2.6. Conjoint analysis

Consumers assessed each stimulus for its expected liking and purchase intention using a 10-point hybrid scale (a combination of structured and unstructured scale, ranging from “disliked extremely” to “liked extremely”) and a 5-point scale (ranging from “I would definitively not purchase it” to “I would definitively purchase it”), respectively (Fizman, Carrillo, & Varela, 2015; Villanueva, Petenate, & Da Silva, 2005). The stimuli were coded with three-digit random numbers and presented monadically following a Williams Latin Square design.

8.2.3. Data analysis

8.2.3.1. Projective mapping

PM data were analyzed through Multiple Factor Analysis (MFA) (Escofier & Pagès, 1994). First, the coordinates of each stimulus were obtained based on the perceptual map of each consumer, considering the lower left corner of each map as the origin of the coordinates. Confidence ellipses at 95% were built by parametric resampling (bootstrapping) to evaluate the stability of the configurations using the script provided by Dehlholm, Brockhoff, & Bredie (2012). The attributes used by consumers to describe the samples were analyzed by lemmatization (grouping the different forms of a word to be analyzed as a single attribute) and categorization (grouping the attributes in a same family). Then, a frequency table was obtained, which was considered as supplementary variable in the MFA (Abdi, Williams, & Valentin, 2013).

8.2.3.2. Conjoint analysis

The expected liking and purchase intention were treated using a mixed model ANOVA, following the recommendations of Næs, Brockhoff, & Tomic (2010). The mixed model included the three conjoint factors as fixed factors (based on Satterthwaite’s approximation to calculate the degree of freedom), while gender, body mass index (BMI), and age were considered as random factors. The differences of least squares means were constructed as pairwise differences of factor levels (Kuznetsova,

Christensen, Bavay, & Brockhoff, 2014). This analysis was performed at 95% confidence.

The relative importance of each factor and the utility associated with each level were determined following Lima Filho, Della Lucia, Lima, & Minim (2015). According to these authors, to determine the utility of each level of a given factor, an individual additive model with dummy variables is used, where the contributions of the factors are added together to generate the total utilities for the expected liking and purchase intention. The structure of this model, for m_j factors and n levels, is shown in Equation 8.1.

$$U = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \varepsilon \quad (8.1)$$

The U is the theoretical total utility, b_0, b_1, b_2, b_3 are the partial utilities corresponding to the j -th level of the i -th factor, X_1, X_2, X_3 are the dummy variables of the j -th level and the i -th factor in the stimulus, and ε is the random error of the model. Once the utility of each level (U) was obtained, the relative importance of each factor is expressed as a percentage according to Equation 8.2.

$$RI_m = \frac{I_n}{\sum_1 I_n} \cdot 100 \quad (8.2)$$

The I_n (Maximum utility - Minimum utility) is the importance of the i -th factor. The sum of the amounts for all factors is 100% (Raz et al., 2008).

8.2.3.3. Software

The data analysis of the expected liking and purchase intention was performed in the R environment (R Development Core Team, 2017) using the *lmerTest* package (Kuznetsova, Brockhoff, & Christensen, 2016) for the mixed model ANOVA. The *Conjoint* package (Bak & Bartlomowicz, 2012) was used to obtain the utility and relative importance in the CA data, and the *FactoMineR* package (Lê, Josse, & Husson, 2008) was used to obtain the sensory map via MFA.

8.3. Results

8.3.1. Projective mapping

Figure 8.3 shows the consensus representation of the stimuli and their associated descriptions, considering the first four dimensions of the MFA (81.44% explained variance). The first three dimensions presented high explained variance ($> 20\%$ each), while the fourth dimension showed only 8.13%. This is probably because the first three dimensions are related to each of the non-sensory factors under study. Therefore, it is assumed that the positioning of the stimuli by consumers was mainly based on these three dimensions, i.e., on the three non-sensory factors.

The first dimension (i.e., the horizontal axis of Figure 8.3A) explained 28.19% of the total variance and separated the stimuli in function of the convenience. The samples in "piece" projected on the left of the first dimension and were described as fatty, while the "sliced" products projected on the right and were described as little fatty. The second dimension explained 23.26% of the total variance and was mainly related to healthiness, since it separated the stimuli designed with the natural smoking claim (negative side) from those designed with the artificial smoked claim (positive side). The description of the stimuli indicated that the samples smoked by the conventional method (wood burning) were perceived as natural, while those with liquid smoke were perceived as artificial. Figure 8.3C shows the third and last dimension that explained 21.86% of the original variance. This dimension represents the context of consumption, since it separated the stimuli designed with a hamburger image (left) from those designed without the image (right).

Figure 8.3. Representation of the stimuli and attributes considering the first four dimensions of the MFA. Ab = Absence; Ar = Artificial; N = Natural; Pr = Presence; Pi = Piece; S = Sliced.

Overall, the three non-sensory factors affected the information processing and the categorization of the stimuli according to the first three dimensions of MFA (73.31% of the explained variance). The high variance of non-sensory factors associated with each dimension of the MFA indicates that these factors represented the reasons for the categorization. This is a clear indicator that consumers had a similar representation among them. To complement the consumers' mental representation of the stimuli, its effect on the expected liking and purchase intention will be presented in the next section.

8.3.2. Conjoint analysis

The ANOVA results (Table 8.3) show that only healthiness had a significant effect on expected liking and purchase intention of consumers. The characteristics of the participants (gender, age, BMI) did not significantly affect the responses. The context presented significance close to 5% and, therefore, we could consider that it has a slight effect on the responses.

Table 8.3. Fixed factors of mixed model ANOVA for expected liking and purchase intention of the stimuli

Response	Factor	SS	Num.DF	Den.DF	F-value	P-value
Expected liking	Healthiness	109.358	1.000	3.290	15.393	0.025*
	Convenience	1.067	1.000	1.940	0.150	0.737
	Context of consumption	43.775	1.000	3.310	6.162	0.081
Purchase intention	Healthiness	34.454	1.000	4.640	15.954	0.012*
	Convenience	0.485	1.000	1.930	0.225	0.684
	Context of consumption	5.580	1.000	6.880	2.584	0.153

*Significant factor at $p < 0.05$. SS = sum of squares, Num.DF = numerator degrees of freedom, Den.DF = denominator degrees of freedom.

The mean differences between the levels for the CA factors on the expected liking and purchase intention are shown in Figure 8.4. For the healthiness factor, the natural smoking showed significantly higher values than the artificial smoking for these two measurements.

Figure 8.4. Barplots of mean differences of the expected liking and purchase intention of the stimuli. Bars are 95% confidence intervals. Ab = Absence; Ar = Artificial; N = Natural; Pr = Presence; Pi = Piece; S = Sliced.

According to Figure 8.5A, the healthiness factor contributed positively to the expected liking and purchase intention, when the word “natural” appeared on the label and negatively when the artificial level was used (Fig 8.5B). For the “context of consumption” factor, the presence of the image helped to increase the intensity of the responses, while its absence showed an opposite effect (Fig 8.5B). Despite the low relative importance of the “convenience” factor (Fig 8.5A), its utility shows that when bacon is presented in “piece”, the answers were negatively affected and when it was presented in slices, the liking and purchase intention were favored.

Figure 8.5. Relative importance and utility values for each level of the factors studied in the CA.

8.4. Discussion

Based on the PM and CA, the factor with the greatest influence on the expected liking and purchase intention was “healthiness” while the least influential was the “convenience”. On the other hand, “convenience” was the second most important factor for PM, while “context of consumption” was for CA. This divergence occurs because the information contained in the PM is based on the global similarities and/or dissimilarities, while the expected liking and purchase intention represent a specific dimension. Therefore, it is evident that the use of both information will serve to better understand the consumers’ perception for non-sensory factors.

The healthiness had a strong impact on the representation of stimuli in the perceptual space, showing that consumers were able to identify the word “natural”. In food context, the naturalness is defined as “the absence of certain “negative” features (e.g., additives, pollution, human intervention), rather than the presence of certain positive features” (Rozin, Fischler, & Shields-Argelès, 2012). Although the absence of negative features of a product does not mean that a food is less risky, healthier or tastier there is a close connection between natural and healthy (Román et al., 2017) for different products, as fresh and dried fruits (Sijtsema et al., 2012) and biscuits (Tarancón, Sanz, Fiszman, & Tárrega, 2014), etc. Meat products deserve special attention as they are strongly associated with non-communicable diseases, such as cancer and cardiovascular diseases (WHO). Any modification in the composition of the meat product, such as the reduction of sodium and/or lipid content (De Almeida, Villanueva, Pinto, Saldaña, & Contreras-Castillo, 2016; Saldaña, de Oliveira Garcia, et al., 2018; Saldaña, Lúcia, Ana Lemos, et al., 2015), as well as the substitution of synthetic additives by natural extracts (Serrano-León et al., 2018) may encourage the consumer to prefer a healthy product over a conventional one (Font-i-Furnols & Guerrero, 2014).

In the present study, the declaration of natural was sufficient to direct the positioning pattern of the samples, which can later modify their hedonic perception (de Andrade et al., 2017). In fact, the “natural smoking” level was the most highly rated by consumers. This is due, on the one hand, to the expected sensory properties of a

conventional smoked bacon (wood burning), such as "smoked", "pleasant", "woody" (Saldaña et al., 2019; Saldaña, Castillo, Sánchez, et al., 2018); and on the other hand, to the consumer demand for more natural meat products (Schnettler, Sepúlveda, Bravo, Grunert, & Hueche, 2018), which are associated to healthy foods (Olmedilla-Alonso, Jiménez-Colmenero, & Sánchez-Muniz, 2013) and to well-being. Therefore, we can affirm that consumers were influenced by the "natural" declaration used in some of the stimuli, which is associated with "credence quality" in meat products (Issanchou, 1996). Andrade, Giongo, Barcellos, & Deliza (2017) showed that the smoking process has a high relative importance in the development of sheep meat products, being dependent on the type of product and the context of consumption. It is necessary to mention that the levels of this factor are not completely opposite, since "natural smoking" was declared on the label for the natural level and "smoke flavor" for the artificial level. Theoretically, "natural and artificial smoking" should have been used. However, the current Brazilian standard establishes the levels used in this study. Despite this semantic divergence, consumers confirmed the opposite significance of the levels during the PM task (Fig 8.3B).

The second factor under study, i.e. the "context of consumption", was expressed as images and symbols, which are known to be more effective vehicles than claims or phrases to convey information to consumers through the label (Carrillo, Fiszman, Lähteenmäki, & Varela, 2014). This is probably due to the fact that the image on the label is associated with pleasant sensory characteristics, which increased the consumers' positive expectations. Also, eating a hamburger refers to a special moment that involves, for example, eating out with friends, and this context is capable of modifying the mental representation of consumers. In this regard, Merlo (2018), showed that eating a hamburger not only modifies the sensory perception, but also the emotions evoked by the hamburger. The third dimension of the PM showed that consumers positioned the eight stimuli in a coherent way (according to the experimental design). Therefore, the context of consumption can be considered as a key factor in the design of smoked bacon labels. The verbalization task performed by consumers revealed an important detail: when the hamburger image is not present, the product was perceived as little fatty. Despite this, the expected liking and purchase intention was high, which

shows that consumers are still not willing to accept any decrease in sensory quality to consume a healthier product (Saldaña, de Oliveira Garcia, et al., 2018). In the present study, the presence of a hamburger image on the label increased the expected liking and purchase intention of consumers of smoked bacon; since, for hamburger and bacon match, the bacon is a relevant part of the whole flavor of the dish/preparation. A similar result was found by Fiszman et al. (2015), who verified positive results with the presence of images in the packaging of the product, in relation to its absence. Therefore, future strategies for the development of low-fat smoked bacon should take this into account.

Convenience is an important factor when selecting a meat product (Lonergan, Topel, & Marple, 2019) and has been studied over time (Leroy & Degreef, 2015) being defined as “Any fully or partially prepared food in which significant preparation time, culinary skills, or energy inputs have been transferred from the home kitchen to the food processor and distributor” (Candel, 2001). Then, is expected that any decrease in effort/time spent in food preparation will modify the mental representation of consumers, who will tend to prefer stimuli that require less effort/time. Nevertheless, despite modifying the position of the stimuli in the perceptual space, this did not cause significant changes on the expected liking and purchase intention. This is probably because consumers perceived the change in the physical structure of the bacon but did not associate it with any improvement in its daily use.

8.5. Conclusion

Non-sensory factors affected the holistic perception of smoked bacon, as well as the expected liking and purchase intention. Healthiness, context of consumption and convenience were the factors that drove the mental representation of consumers and therefore, the positioning of the stimuli during the PM task, in which one factor was associated with one of the first three dimensions of the MFA. The expected liking and purchase intention helped to understand how the processing of the information contained in the labels influenced the consumer. Healthiness was the most important factor, with preference for the natural smoked bacon. The second most important factor was the context of consumption, in which the presence of the hamburger image showed

the greatest utility. The least important factor was convenience, with slight variations in the responses due to their levels.

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9. WHAT CAN WE LEARN FROM TWEETS? A TEXTUAL ANALYSIS OF TWEETS USING #BACON AS INDUCTOR WORD⁸

Abstract

The analysis of texts is still a challenge since it is born from the meeting of several scientific disciplines such as linguistics, statistics, computer science, among others. This challenge is even greater if we consider the textual diversity contained in social media, more specifically in tweets. In this study, the tweets containing the word bacon posted in the state of Sao Paulo, Brazil, were analyzed lexicometrically. First, non-aggregated lexical tables were analyzed directly using the co-occurrence of words and repeated segments. Next, associations between words and tweets were explored through correspondence analysis and cluster analysis. Subsequently, the tweets were aggregated by cluster and were also analyzed by correspondence analysis. In general, the bacon was associated with the context of consumption and the culinary preparations characteristic of each context. Cluster analysis revealed groups of tweets with similar lexical structures, also characterized by a culinary preparation and context of specific consumption. The textual analysis revealed the meaning of the tweets that contained the word bacon. However, more studies must be done using other inducing words and other aggregation criteria such as culture.

Keywords: Social media; Textual analysis; Bacon

9.1. Introduction

The sensory properties of foods are classically determined by descriptive analysis (DA) using trained assessors (Lawless & Heymann, 2010; Stone, Bleibaum, & Thomas, 2012). However, the DA has some limitations associated with the time and sources consumption. But, especially to the divergences between the vocabulary generated by the trained assessors and the vocabulary used by the regular consumers of a given product (Ares, Giménez, Barreiro, & Gámbaro, 2010). For this reason, in the last decade different methods of sensory profiling have been developed and adapted using the consumers' own vocabulary. Among these methodologies, Free Sorting Task, Free Word Association, Projective Mapping, Pivot profile stand out, since they allow the free

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description of consumers by a stimulus (Valentin, Chollet, Lelièvre, & Abdi, 2012). Despite these advances, some challenges have recently emerged in the sensory and consumer science. Jaeger et al. (2017) highlight the need to increase the ecological validity in sensory and consumer science, increase the interdisciplinary nature of research, and to study individual differences in consumer perception.

In this context, understanding in depth the consumer's perception implies entering in the environment in which it co-exists and expresses itself daily (Köster, 2003). This environment has evolved over time, from conversations and informal meetings between friends to individual or group conversations on different social media, such as Facebook and Twitter (Amichai-Hamburger & Vinitzky, 2010). In recent years, due to its extensive use worldwide (Vidal, Ares, Machín, & Jaeger, 2015), reaching over 340 million tweets per day (Malave & Dhage, 2020), twitter has attracted attention as a source of information to understand consumer's perception (Arellano-Covarrubias, Gómez-Corona, Varela, & Escalona-Buendía, 2019). In addition, tweets have the advantage that they can be recovered from free software as R, thus facilitating the study of the expressions that a target population has regarding a certain issue in social media. However, the coupling of social media and sensory and consumer science is not without problems the biggest one being data processing.

The data processing of social media is a key point to extract reliable information. The data obtained from social media have particular characteristics, such as: (a) the excessive amount of information (related to the number of messages a person uses in a certain social media), and (b) the absolute freedom to use text (slangs and acronyms of each language) and symbols (emoticons and emojis). Therefore, the analyst should use automated (for the processing of a large amount of information) and manual tools (for the identification and elimination of irrelevant information such as advertising) for processing textual data (Vidal, Ares, & Jaeger, 2018).

To date, social media data have not been analyzed through textual statistics. For this reason, this work takes the ideas presented by Monica Becue-Bertaut in her recently published book "Textual Statistics with R" (Bécue-Bertaut, 2019) and applies them to the textual analysis of tweets. In this context, this work presents a lexicometric approach

for analysis and interpretation of Twitter data considering a case study with Brazil as the geographical area and bacon as the inductor word.

9.2. Lexicometric analysis of tweets

The lexicometric approach presented in the present study follows the steps of Figure 9.1: a) data collection, b) data pre-processing, and c) data analysis.

Figure 9.1. Lexicometric approach for the analysis of tweets.

9.2.1. Data collection

Before carrying out the data collection it is necessary to define a geographical area, inducing word and the language of the tweets, depending on the objective of the study. For example, if I am interested in knowing what the French write about red wine in the French language, it is necessary to indicate this since Twitter does not allow access to gender, age, frequency of consumption, and other socio-demographic characteristics of people (information necessary to profile the users of Twitter). These specifications become even more important in intercultural studies. In addition, it is necessary to

indicate if we want to recover the retweets, which, a priori, contain repeated information. It is not recommended to use a very large number of tweets since there is a manual stage (described later), which would be almost impossible to perform. This stage can be done using the `twitteR` package in the R environment or through different payment platforms such as Twitter Archiver where you can select the study's geographical area, as well as the inducing word and the language, without using any programming language. More details on how to collect tweets will be given in the case study in the next section.

9.2.2. Pre-processing

Before performing the data analysis, it is necessary to pre-process the tweets since, by default, they contain a lot of noise such as jokes, ironies, propaganda, etc. The recommended sequence is the following:

- (1) Content analysis tweet by tweet to identify and eliminate the advertisements, jokes and ironies (manual).
- (2) Convert all words to lowercase, eliminate numbers, emoticons and symbols. Note that emoticons and symbols would deserve to be studied as they might enriched the interpretation of the tweets but this is beyond the scope of this work.
- (3) Set and delete the stoplist of the selected language (automatic).
- (4) Set the separation strings for the repeated segments.

9.2.3. Data analysis

9.2.3.1. Lexical table

First, a minimum frequency threshold must be established for a word to be part of the lexical table (LT) in order to keep only the most cited words in the tweets and therefore more relevant in the study. This value will depend on the number of words, which is directly related to the number of tweets. Therefore, if the number of tweets is greater, the higher the threshold. Since a word can have many meanings, it seems important to analyze the words before and after to understand the sense in which it was used. Therefore, repeated segments of text should also be counted.

LT can be aggregate depending on some contextual factor, age, gender, etc. However, this type of information is not available in twitter. Another strategy is aggregate twits by semantic field or themes. This can be done by regrouping segments of tweets with similar lexical characteristics via a cluster analysis carried out on the non-aggregated LT.

Then, a quantitative analysis of the corpus must be done, calculating the co-occurrence of each word and repeated segment. The co-occurrences of words can be represented synthetically through the Pareto chart, showing the distribution of words and their respective co-occurrences in logarithmic scale. The resulting cumulative curve indicates how the frequency of words decreases as the number of repetitions increases, this behavior repeats itself, regardless of the type of text.

9.2.3.2. Correspondence analysis

LTs can be considered as a contingency table, where repeated words or segments are columns and tweets are rows. On this matrix a correspondence analysis is performed to discover the associations between tweets and words. Correspondence analysis is a multivariate technique for binary (qualitative) tables that has the purpose of reducing the dimensionality of the matrix by singular value decomposition (SVD) (Greenacre, 2010).

Figure 9.2. Correspondence analysis of non-aggregate lexical table.

Subsequently, a cluster analysis can be performed on the dimensions of the CA to automatically highlight the main themes emerging from the tweets. The number of dimensions must be large enough to preserve a large amount of the original information, say > 60% (Bécue-Bertaut, 2019). Then the tweets must be aggregate using the cluster to which they belong. Finally, a CA should be made on this new LT, considering the repeated segments as supplementary elements. Based on the information of the repeated segments and words of each cluster, we can understand the meaning of the tweets that use for a given word.

9.3. Here we go! A practical case with the word #bacon

9.3.1. Data collection

Eight hundred fifty-seven tweets containing the word bacon were extracted using the Twitter Archiver (google spreadsheet complement). Only tweets written in Portuguese by people located near of state of São Paulo, Brazil were extracted. Retweets were not used to not include repeated information (Vidal, Ares, Machín, & Jaeger, 2015).

9.3.2. Textual data pre-processing

Firstly, a manual analysis (tweet by tweet) of the content of the corpus was carried out to eliminate irrelevant information, such as restaurant advertisements, etc. Subsequently, the whole corpus was automatically converted into lowercase letters and the numbers and emoticons/emojis were deleted. A predefined stoplist of the Portuguese language contained in the "tm" package was automatically deleted. Some words have also been manually deleted, such as "hand", "mt", "é", "aqui", "tudo", "tá", etc. In addition, repeated segments of text were analyzed using automatic strings ([() ¿? ./: ¡! = +; -] \) to separate them. Freely written texts, such as tweets, have problems stemming from the fact that there are no libraries available that can process texts with grammatical errors - for example, sentences without a verb (Bécue-Bertaut, 2019). This problem is much more relevant when the length of the text is small, since there will be very small sentences, like the tweets "bacon é vida" (bacon is life). For these reasons, we chose not to lemmatize the corpus. In addition, according to Lebart, Salem, & Berry

(1998), the lemmatized and non-lemmatized LT lead to similar results. Finally, LT was automatically created using only the word frequencies by tweet (rows are tweets and words are columns). The minimum length and frequency of a word to be selected was 1 and 5, respectively. These thresholds were established to eliminate little cited words and hapax (words mentioned only once). Additionally, tweets that did not contain at least one of the selected words were considered empty and then deleted (Bécue-Bertaut, Alvarez-Esteban, 2018). No contextual variables were considered due to the restrictions of the Twitter social media.

9.3.4. Data analysis

The corpus was characterized by the number of tweets, occurrences, words, tweets-length, and non-empty tweets. The frequency range of the words was represented in a Pareto chart with the repetition frequency F on the vertical axis (logarithmic scale) and the number of words repeated at least F times in the horizontal axis (logarithmic scale).

As is frequent in textual analysis, a correspondence analysis (CA) was performed on the LT to visualize the association between tweets and words (Greenacre, 2010), using X^2 distances. After the SVD, the first fifteen dimensions (61% of the original variance) were maintained. Confidence ellipses were drawn around the word on the first two dimensions of the textual CA map using the multinomial method to generate the replicate LT (Bécue-Bertaut, 2019). Tweets/words with a contribution greater than 2 times the average tweet/word contribution in any of the two axes were selected. The repeated segments were considered as supplementary columns (Lebart et al., 1998) to better interpret the context and, thus, the meaning of the words.

A cluster analysis was performed on the LT to highlight groups of tweets with similar lexical characteristics. For this purpose, a Hierarchical cluster analysis (HCA) was performed using the Euclidean distances and the ward aggregation method. Subsequently, the words and repeated segments associated with each segment were described and analyzed (Bécue-Bertaut, Kostov, Morin, & Naro, 2014).

A new LT considering the clusters as an aggregation criterion was created. Then, a CA was performed on the contingency table, which was formed by the clusters in the rows and the words in the columns.

9.3.5. Results and discussion

9.3.5.1. Characterization of the corpus

The corpus was composed of 562 tweets (295 tweets were deleted because they contained no words of interest) and 1553 occurrences, while the vocabulary consisted of 33 different words. The mean-length of the tweets was 2.02.

The frequency distribution of words in the corpus is presented in the Pareto diagram (Fig 9.3). The vertical axis (graduated in logarithmic scale) corresponded to the repetition frequency of each word, while the horizontal axis (also graduated in logarithmic scale) corresponded to the number of words related to each frequency. According to Fig 9.3, the word frequency decreases as the number of word repetitions increases, following Zipf's law (Lebart et al., 1998). This behavior was expected since the tweets have 280 characters as the maximum size.

Figure 9.3. Pareto diagram of the frequency range of words in the corpus.

The twenty-five most frequent words (Fig 9.4) were mainly related to the occasions of eating, the foods that accompany or in which the bacon is used, and the positive sensations that it causes. To better understand the words used in the tweets, the most frequent segments were considered (Figure 9.4). The segments with the greatest frequencies were composed of two words, one of which was bacon. The rest of the segments also had the word bacon and expressed the action of eating, desire to eat, food preparations, even the name of a commercial product well known in Brazil, called "McNífico".

Figure 9.4. Frequency of the first twenty-five words (left) and text segments (right) that characterized the corpus.

9.3.5.2. Analysis of the corpus

The first two dimensions of the CA accounted for almost 10% of the original data (Figure 9.5). The low explained variance is common in non-aggregated textual analyzes (Bécue-Bertaut, 2019). Figure 3 shows the distribution of the tweets in the first factorial plane, which forms an increasing parabola (known as the Guttman effect), with a horseshoe path, i.e. two consecutive parts tend to be closer, insofar as they contain the same frequency of words. Since the position of the tweets is dependent on the words used in them, the characteristic words in each plane are shown in Figure 9.6.

Figure 9.6 shows the words used in the tweets considering the first four CA dimensions. The confidence ellipses around each word show the multivariate stability in the perceptual space. Therefore, if two ellipses are overlapped, they show similarity, which, in this study indicates that the words were often used together in the tweets. To the left of Figure 9.6, the ellipses of the words "coffee (café)" and "morning (manhã)" are superimposed, which was expected, since in Portuguese "café da manhã" is breakfast. In this first plane, the distribution of words is related to the occasions of bacon

consumption (breakfast, lunch, and dinner) and to the raw material (pork). In the second plane, it is related to the positive and familiar attitudes associated with the consumption of bacon, as well as the raw material (pork).

Figure 9.5. Tweets representation on the first two dimension of the CA.

A summary table was constructed by selecting the words whose contribution to the respective CA dimensions is greater than twice the average-tweets contribution. Overall, the first fifteen dimensions of the CA show the tweets related mainly to the occasions of consumption and the different culinary preparations where bacon is used, which, in most cases, have been associated with positive words, like “best”, and “good”. Because the information emerging from this analysis remain somewhat trivial tweets were segmented through the HCA to obtain groups of tweets with similar textual structure. Figure 6 shows the distribution of the tweets in the first two dimensions of the CA, colored by cluster.

Figure 9.6. Representation of the words in the first two planes of the CA on the LT (the first plane is shown to the right and the second plane to the left).

Table 9.1. Meaning of the dimensions based on the words and word segments used by Brazilians in the tweets

Dim	Words	Repeated segments	Meaning
1	Morning, Coffee, Bean	bacon and, with bacon and cheese, in the breakfast	Consumption occasion: breakfast, lunch
2	Bean, Best, Pork, Potato, cheddar	the desire to eat, bacon and, potato with cheddar and bacon, potato with bacon and, potato with cheddar and bacon, potato with cheddar and bacon with, fried potato with bacon, fried potato with bacon and, fried potato with bacon and cheddar, fried potato with cheddar and bacon, with cheddar and bacon, cheddar and bacon with, cheddar and bacon of, with bacon and cheddar, with cheddar and bacon, of bacon, of fried potato with, of fried potato with cheddar and bacon, and bacon, at breakfast, what a desire to eat, all I wanted, a potato with bacon, a potato with cheddar and bacon, a cold coke and, a portion of potato, a desire to eat potato with cheddar and bacon	Desire to eat bacon with french fries and cheddar cheese
3	Bean, Mother, Best, Pork, Life, Popcorn	potato with cheddar and bacon, with cheddar and bacon, at breakfast	Consumption occasion: lunch and snacks
4	Best, Pork	with bacon, of bacon, at breakfast	Consumption occasion: breakfast
5	Yes, Chicken, Mother, Pasta, Sauce	fried potato with cheddar and bacon, with cheddar and bacon, cheddar and bacon with, with bacon and cheddar, with cheddar and bacon, with cheese and bacon, of bacon, of fried potato with cheddar and bacon, and bacon, at breakfast , what a desire to eat, all I wanted, a potato with cheddar and bacon, a desire to eat potato with cheddar and bacon	Different culinary preparations where bacon is used
6	Pasta, Sauce, Yes, Bean	bacon with slices of bacon, bacon and, potato cheddar and bacon, potato with cheddar and bacon, potato with cheddar and bacon with, fried potato with bacon, fried potato with bacon and, fried potato with bacon and cheddar, fried potato with cheddar and bacon, with cheddar and bacon, cheddar and bacon with, with bacon, with bacon and cheddar, with cheddar and bacon, with cheese and bacon, of bacon, of fried potato with, of fried potato with cheddar and bacon, at breakfast, what a desire to eat, all I wanted, a potato with cheddar and bacon, a cold coca, a portion of potato, a desire to eat potato with cheddar and bacon	Different culinary preparations where bacon is used

7	Want, House, Sauce	with cheese and bacon, of bacon, and bacon	Desire to eat bacon with cheese and sauce
8	Yes, Mother, Pizza, Good, Bread	bacon and, with bacon, with cheese and bacon, and bacon, at breakfast	Different culinary preparations where bacon is used + Consumption occasion: breakfast
9	Mother, Bread, Yes, Bean, Sauce	with cheddar and bacon, with cheese and bacon, at breakfast	Different culinary preparations where bacon is used + Consumption occasion: breakfast
10	Snack, Good, Life	cheddar and bacon of, of bacon	Consumption occasion: snacks
11	Eat, Meat, Good, Cheese, Potato	the desire to eat, bacon and, fried potato with bacon, fried potato with bacon and, fried potato with bacon and cheddar, fried potato with cheddar and bacon, with cheddar and bacon, with bacon, with bacon and cheddar, with bacon and cheese, with cheddar and bacon, with cheese and bacon, of bacon, of fried potato with, of fried potato with cheddar and bacon, and bacon, all I wanted, a potato with bacon, a cold coke, a portion of potato	Desire to eat bacon with potato and cheddar cheese
12	Salad, Good, Pizza, Cheese, Bread	the desire to eat, bacon and, with bacon and cheese, with cheese and bacon, what a desire to eat, desire to eat potato with cheddar and bacon	Different culinary preparations where bacon is used
13	Life, Cheese, Best, Diet, Salad	bacon and, with bacon and cheese, with cheese and bacon	Different culinary preparations where bacon is used (diet, salad)
14	Yes, Salad, Pizza, Catupiry, Diet	with bacon and cheese	Different culinary preparations where bacon is used
15	Good, Life, Snack, Sauce, Popcorn	fried potato with bacon, fried potato with cheddar and bacon, with cheddar and bacon, fried potato with, and bacon, all I wanted	Consumption occasion: snacks

Ten different clusters were found, where cluster 6 had the highest proportion of tweets (346), indicating that most of them presented a lexical structure similar to that described in this cluster. The rest of the tweets were located along the first (cluster 10) or second dimensions (cluster 1, 2, 3). To describe the clusters, the words were aggregated by segments to obtain a contingency table, where a CA was subsequently applied.

Figure 9.7. First plane of the CA where the tweets with the same color belong to the same cluster.

Figure 9.8 shows the words and clusters associated with them in the first two dimensions of the CA (explained variance: 27.05). The first cluster was mainly associated with the word mother, reflecting a homemade preparation, while the second cluster was associated with the words beans and pasta, reflecting a relationship of bacon with lunch. Cluster 4 was characterized mainly by the word sauce, and cluster 10 by the word breakfast, obviously associated with the word bacon. On the other hand, in cluster 9, the word pork was frequently mentioned.

Clusters 3, 5, 7 and 8 were associated with similar text structures and, therefore, presented similar word frequencies. Most of the words were positioned in the central part of Figure 8 and reflected mainly culinary preparations and positive attitudes. In general, the results are similar to those obtained in the CA dimensions of the non-aggregated LT. This behavior is probably due to the fact that the word *#bacon* represents a widespread and well-established concept related to consumption contexts and different culinary preparations that present pleasant sensory characteristics. It can also be explained by the small number of words allowed in a tweet, which limits the free access to the representation of the word *#bacon*. Perhaps, one could find marked textual differences between segments if the inductor word had a more regional and particular connotation (Caporale, Policastro, Carlucci, & Monteleone, 2006; Sester, Dacremont, Deroy, & Valentin, 2013), such as wine for French or pisco for Peruvians. Despite these difficulties, this study shows a very useful lexicometric approach to extract relevant information from Twitter, which can be clearly applied to other social networks and products.

Figure 9.8. Representation of clusters and words of the aggregate LT through CA.

9.4. Implications and remaining challenges

Analyzing tweets is becoming a common practice to study the attitude of a certain group of people on a specific topic (Bovet & Makse, 2019). Different studies have shown the advantages of Twitter as a source of information in a natural environment of expression for political-social issues (Del Vicario, Gaito, Quattrociocchi, Zignani, & Zollo, 2017). In order to access the information contained in the tweets, a series of techniques have been used, such as the sentiment analysis (Plunz et al., 2019) and related techniques. However, tweets are textual expressions with particular characteristics. So, analyzing tweets through textual statistics can yield ideas that may have been overlooked.

The present study shows the potential of textual analysis to study tweets, considering not only the automatic cleaning and counting of words, but also a repeated segment analysis to better understand the meaning of the tweets, and highlight the main semantic themes based on the textual structure of the tweets. However, the lexicometric approach depends on the original quality of the data. In this sense, it is necessary to indicate not only the potentialities but also the remaining challenges, which are described below:

- a) **Tweets length:** In the case study it was shown that the average length of the tweets was 2, this shows us a possible limitation when analyzing the text segments. In the case study, the text segments clearly show this behavior.
- b) **Language:** Text analysis is language dependent since automatic processing involves eliminating different words considered as "stoplist". However, there are limited free tools that include several languages within the text analysis. Here the Xplortext R-package, which includes several languages such as English, Portuguese, Spanish, French, among others deserves a special mention.
- c) **Lemmatization:** length, language tweets and above all the freedom and the type of vocabulary used in tweets, bring great difficulty for the lemmatization process. This process aims to reduce and eliminate ambiguities of the words under study by commonly using a library of words. However, how to relate the new words and abbreviations used in the tweets without misinterpreting them? The simplest answer is to "create a new dictionary" and then use it in text analysis. However, there are still non-lemmatizable elements such as symbols. For example, what do three question marks following a word (???), or an emoticon (☹) mean?. Clearly this escape the textual analysis field and passes to the field of symbology.
- d) **Content analysis:** Another important point is the analysis of content necessary to eliminate sarcasms, advertisements and other artifacts that may cloud the data analysis. Therefore, a generic approach to the detection of sarcasm automatically is necessary. However, this approach would be valid only for a certain language.
- e) **Inductor word:** Another important point is the inductor word used to collect the tweets. As mentioned in section 3, it is necessary to do preliminary studies

to identify a word with a distinctive characteristic with particular associations related with a specific topic.

Finally, we have to be aware that tweets are texts that people want the rest to read. Therefore, they do not escape the risk of the "socially accepted" response. So, despite the large number of tweets that can be recovered automatically, we must interpret them with caution.

9.5. Conclusion

This study presented a lexicometric approach to efficiently analyze the meaning of tweets by means of words and repeated segments. The analysis of the non-aggregated LT showed that the bacon was positively described, mainly dealing with culinary preparations and the context in which they were consumed. The LT aggregated per cluster identified groups of tweets that used a certain type of culinary preparation associated with a specific context. However, more research should be done with inductive words that represent regional products characteristic in a certain culture.

Acknowledgments

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10. GENERAL CONCLUSION

The sensory perception of smoked bacon is a complex phenomenon that should be studied from different perspectives. The present doctoral thesis studied the transition from classical descriptive analysis (DA) to the use of social media, also evaluating new sensory methods for the development of smoked bacon. DA showed that the sensory profile of the bacons was modified by the type of wood / liquid smoke used in smoking. According to the Napping method, smoking was responsible for the generation of the majority of the sensory attributes perceived by consumers, having a close relationship with the content of volatile compounds. In addition, the chemical and sensory profile (CATA questions) drove consumers' liking, specifically the attributes related to aroma and texture. The ideal bacon was identified using the external preference mapping, which showed that the sensory space had a great impact on the results.

The smoking process modified not only the static sensory properties but also the dynamic properties. Both the dominance rate and its duration changed according to the fat content, type of smoking and oral processing of the consumers. Our results indicated that the higher the lignin content of the wood used in smoking the greater the dominance of the smoked and woody attributes.

The non-sensory factors also affected the expected liking and the purchase intention of the consumers, as well as the mental representation of the smoked bacon. According to the factors evaluated, the most important was healthiness, followed by the context of consumption and convenience. The lexicometric study conducted on the tweets indicated that culinary preparations with bacon are associated with positive feelings.

The present thesis shows that the transition from classical sensory analysis to the use of social media is, in fact, a complementary process, in which we consider not only the sensory attributes of the product, but also the opinion about the product in an ecologically valid environment. Therefore, if you want to know different aspects of a product, it is recommended to use both classical methods and social media.

APPENDIX

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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 citrio dora*, *Acacia meurnsii*, 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 & Bekd, 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 & Kolakowski, 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 them, *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. meurnsii* and *A. Mangium*), *Bracatinga* (*Mimosa scabrella*) and *Tesla* (*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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Relationship between volatile compounds and consumer-based sensory characteristics of bacon smoked with different Brazilian woods

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ABSTRACT

Bacon is a product made from pork meat that is subjected to curing, drying, and smoking. Researchers aim to associate the worldwide high-acceptance of such a product with the sensory and chemical properties of bacon. In this context, the objective of the present study was to characterize bacon samples smoked with different woods from reforestation using chemical and sensory methodologies, which were subsequently correlated by means of statistical multi-block analysis. Volatile compounds (VCs) of the smoked bacons were studied using solid-phase microextraction (SPME) coupled with gas chromatography-mass spectrometry (GC-MS), and the consumer sensory perception was explored by the Napping technique. VCs were identified in smoked samples, which triggered sensory attributes related to odor, flavor, and texture, such as “smoky flavor”, “salty taste”, “pleasant taste”, “woody flavor”, and “hard texture”. Multi-block analysis showed that the sensory attributes were associated with a group of VCs and not by a single compound.

1. Introduction

The sensory attributes related to the flavor of meat products can influence their acceptance and purchase intent (Calkins & Hodgen, 2007; Font-i-Furnols & Guerrero, 2014; Resano et al., 2011; Yu & Sun, 2005). The peculiar sensory characteristics of meat products are mainly related to the presence of volatile and non-volatile compounds that interact to generate the flavor of meat-based products (Khan, Jo, & Tariq, 2015). In this sense, in smoked products, such as bacon, lipid oxidation and Maillard reaction give rise to volatile compounds (Yu, Sun, Tian, & Qu, 2008), but smoking is the process that most influences the generation of volatile compounds (VCs), and consequently, the bacon flavor (Font-i-Furnols & Guerrero, 2014).

According to the Brazilian Regulation, smoking is a mandatory step in the manufacturing of bacon (Brasil, 2000). In this process, the meat is exposed to the smoke of wood chips that are pyrolysed until temperatures higher than 500 °C are achieved (Ledesma, Laca, Rendueles, & Díaz, 2016; Ledesma, Rendueles, & Díaz, 2017), leading to the

generation of a series of volatile compounds (Aaslyng & Meinert, 2017). According to Flores (2010), aldehydes, pyridines, pyrazines, furans, alcohols, and ketones are the main aroma compounds found in bacon. An alternative to the generation of these compounds from the traditional smoking is the use of wood smoke condensates, commonly known as liquid smoke. The use of liquid smoke allows higher process control, eliminates carcinogenic compounds, such as polycyclic aromatic hydrocarbons, giving much of the desired flavor and aroma of conventional smoking (Lingbeck et al., 2014).

Sensory characteristics and volatile compounds of smoked bacon mainly depend on the chemical composition of the wood used in smoking process (Montazeri, Himelbloom, Oliveira, Leigh, & Crapo, 2013). Since native flora must be preserved, the use of woods from reforestation seems to be suitable to smoke meat-based products. In Brazil, *Eucalyptus* (*Eucalyptus* spp.) is one of the most used woods in the smoking process (Lorenzo, Carballo, & Franco, 2013), since this species is the most representative among the woods from reforestation (about 75%) (IBGE, 2016). Other reforestation trees can also be used in the

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Descriptive and hedonic sensory perception of Brazilian consumers for smoked bacon

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ABSTRACT

The descriptive and hedonic sensory perception of bacon manufactured using different smoking processes was studied. Six bacon samples were evaluated: three manufactured with woods, two with liquid smokes, and a commercial bacon. Consumers rated their overall liking (OL) and responded the check-all-that-apply (CATA) questions coupled with ideal profile method (IPM).¹ The preliminary result showed that LS2 and Bamboo were the best-rated bacons. However, data analysis indicated two segments of consumers (both $n = 50$), with significant differences in the OL. The first segment liked fatty and smoked bacons, while the second valued the texture and appearance. The drivers of liking in both segments were the attributes related to texture, juiciness and the smoky aroma. The use of different woods in the bacon smoking process modified the descriptive and hedonic sensory perception of consumers.

1. Introduction

Smoked bacon is consumed worldwide for its sensory characteristics, mainly developed during the processes of curing and smoking, which are highly appreciated by consumers (Saldaña et al., 2018c). Smoking is one of the oldest preservation techniques for meat and meat-based products (Toth, 1982). Initially, this technique was used to increase the shelf life of products from the pyrolysis of wood (Bortolomeazzi, Sebastianutto, Toniolo, & Pizzariello, 2007) and dehydration of the product (Fellows, 2009). Today, it is mainly applied to confer sensory properties, since it imparts desirable flavor and color to smoked foods (Suñen, Fernandez-Galian, & Aristimuño, 2001).

The wood used in the smoking process can influence the type and amount of compounds generated in the pyrolysis. It is known that hardwood varieties produce better smoke than softwoods, since the latter tend to produce higher concentrations of polycyclic aromatic hydrocarbons, in addition to having a greater amount of resins, which negatively affect the flavor of the product (Stumpe-Viksna, Bartkevičs, Kukare, & Morozovs, 2008). Despite these facts, there are few studies in the literature relating the type of wood or the use of liquid smokes with

the sensory characteristics of smoked products (Malarut & Vangnai, 2018). Due to availability, cost, and because they are reforestation trees in Brazil, the Eucalyptus, Bambu, Acacia and Bracatinga woods are interesting options for use in traditional smoking and were chosen to be evaluated in this study (Saldaña et al., 2018c).

As it is widely known, the sensory properties of foods drive the consumer's liking (De Almeida, Villanueva, Pinto, Saldaña, & Contreras-Castillo, 2016; Selani et al., 2016), and consequently its success or failure in the competitive market (Giacalone, 2018). Descriptive analysis (DA) is one of the most flexible, powerful, sophisticated and widely used tools in sensory science (Murray, Delahunty, & Baxter, 2001), since it plays an important role to assist the meat scientist in describing the sensory profile of a product. However, DA has some limitations related to the high cost and time demanded to perform all the steps, from the panel screening to the final data analysis (Varela & Ares, 2012). Moreover, it is argued that the sensory profile obtained from DA does not necessarily represent the consumers' perceptions, and consumers are ultimately responsible for the success or failure of a product (Qannari, 2017). To overcome these limitations, in the last decade different sensory methods have been developed, tested, and

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¹ In the ideal profile method, the consumers indicate how they perceive real and ideal samples using a list of previously established attributes (Worch et al., 2013).

Obtaining the ideal smoked bacon: What is the influence of the product space and multivariate procedure to construct the external preference mapping?

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Abstract

Identifying the ideal product is the most important step in new product development and improvement of existing ones. The aim of this study was to identify the ideal smoked bacon using *PrefMFA* and *PrefMap* considering three different sensory spaces obtained via descriptive analysis (DA), projective mapping (PM) and CATA questions. Six smoked bacons were characterized by ten trained assessors using DA, and by two consumers panel using PM (n=93) and CATA questions (n=100). Also, one hundred consumers indicated their overall liking using a nine-point hedonic scale. The results showed that both techniques identified an ideal product. However, the sensory method has a greater effect than the multivariate procedure to obtain the sensory spaces prior to the preference mapping. Subsequent studies with other food matrices are still necessary in order to generalize our results.

Keywords: *PrefMFA*; Sensory profile; Overall liking; Ideal bacon.

1. Introduction

The manufacture and consumption of meat products in the Brazilian market has been increasing in recent years. Bacon is one of the most consumed meat products due to its pleasant sensory characteristics, developed during the curing and smoking processes (Saldaña *et al.*, 2018). The sensory properties of bacon are mainly driven by smoking process that provides the smoke flavor, which is highly appreciated by consumers (Kathrine *et al.*, 2013). For this reason, the sensory profile is considered the best intrinsic predictor of consumers' liking (Saldaña *et al.*, 2018). Listening to "the voice of the consumer" is a decisive step in the development or improvement of a product (van Kleef *et al.*, 2005). Therefore, characterizing the product through sensory (sensory attributes) and hedonic (overall liking) perspectives is necessary, because together these data will identify the "drivers

of liking" (Cariou *et al.*, 2014) and finally the ideal product (Ares *et al.*, 2011). Classically, the ideal product is obtained using the external preference mapping (*PrefMap*). The aim of *PrefMap* is to determine which sensory attributes explain the differences in overall liking (Lê y Worch, 2014) and is constructed in two steps (van Kleef *et al.*, 2006): (a) determining the sensory space of the product via multivariate procedure, and (b) regressing the hedonic rating in this space (Cariou *et al.*, 2014) using polynomial models. External preference mapping was used in a wide variety of products ranging from *dulce de leche* (Ares *et al.*, 2006) to plain yogurts (Masson *et al.*, 2016). In the meat science field, the *PrefMap* was applied to obtain the sensory attributes that drive the consumers liking of dry-cured ham (Resano *et al.*, 2010). On the other hand, Arditti (1997) applied preference mapping to investigate chicken nuggets using a *sensometric*

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Understanding consumers' dynamic sensory perception for bacon smoked with different Brazilian woods

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Temporal Dominance of Sensations
Smoking process
Smoked bacon
Reforested woods

ABSTRACT

The aim of the present study was to obtain the dynamic sensory profile of smoked bacon using Temporal Dominance of Sensations (TDS). Eight samples were studied considering different smoking process: six samples were submitted to conventional smoking using different woods from reforestation and two samples were manufactured with liquid smoke. Seventy-eight regular bacon consumers evaluated the samples using the TDS methodology. TDS data were analyzed based on the sequence (bandplot by attribute and trajectory map) and dominance duration (univariate and multivariate techniques). TDS results showed differences between samples in terms of rate, trajectory and duration of dominant sensations. These differences can be mainly explained by the smoking processes used in their manufacture and by the oral work involved in the mastication task. Overall, TDS was a promising method for capturing temporal sensory changes in smoked bacon.

1. Introduction

In 2017, Brazil was the fourth largest producer and exporter of pork meat in the world, with a production of 387.5 million tons (ANUALPEC, 2017), 80.4% of which remains in the domestic market, being largely destined to the manufacture of meat products (ABPA, 2017). Among these products, bacon is very consumed by the Brazilian population because of its sensory properties resulting from the smoking process. The sensory characteristics of smoked bacon depend mainly on the chemical composition of the wood used in smoking process (Saldaña et al., 2018). Therefore, studying the differences in the sensory characteristics of bacon in relation to the wood used during smoking is very important to reach consumers' expectations.

Sensory analysis has been widely used as a decisive tool for the food industry. Through sensory analysis it is possible to select and improve raw materials and processes, develop/redesign products, packaging systems, labeling, among others (Miller, 2017). Classically, sensory analysis of meat products is carried out by a panel trained to profile their sensory properties (Selani et al., 2016). However, descriptive sensory measurements based on consumer response have become

increasingly important, since the response is obtained from the consumer, who ultimately decides the success or failure of a product (Saldaña et al., 2018). In the last ten years, consumers-based sensory methodologies have been improved and optimized. Among these methods, the *Flash Profile*, *Check-all-that-apply questions*, *Free Sorting Task*, *Projective Mapping*, *Polarized Sensory Positioning* and recently the *Pivot profile* (Lelièvre-Desmas, Valentin, & Chollet, 2017; Rios-Mera et al., 2019; Valentin, Chollet, & Lelie, 2012) have stood out. Despite the advances in the sensory methods performed by consumers, studies on the temporal dimension are still scarce, since the sensory attributes are modified during tasting (Dijksterhuis & Piggott, 2000). In order to meet this need, the TDS method has emerged (Schlich, 2017).

The TDS method aims to describe the temporal evolution of different sensory attributes during the tasting of a product, in a predefined period, where the consumers should focus their attention on the dominant sensation generated by the sample (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009). It is considered an effective and fast method when compared to the traditional methodologies used in the temporal sensory analysis, such as the Time-Intensity method. Although it has been developed for trained assessors, in recent years this technique has

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Ethics Committee for Human Research

ESCOLA SUPERIOR DE
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PARECER CONSUBSTANCIADO DO CEP**DADOS DO PROJETO DE PESQUISA**

Título da Pesquisa: Comportamento do consumidor na avaliação de bacon defumado

Pesquisador: Carmen Josefina Contreras Castillo

Área Temática:

Versão: 2

CAAE: 56209616.4.0000.5395

Instituição Proponente: "Escola Superior de Agricultura "Luiz de Queiroz" - ESALQ da Universidade

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 1.604.926

Apresentação do Projeto:

O projeto está dividido em duas etapas: Na primeira etapa será avaliado o impacto das diferentes características: tipo de defumação, defumação e praticidade na atitude do consumidor em relação à aceitação e intenção de compra. Essa etapa irá envolver 100 provadores, os quais irão fornecer informações sobre a diferença e preferencia de bacon submetido à defumação tradicional, com queima de madeira, em relação ao submetido à fumação líquida. Essas informações serão obtidas mediante a apresentação de figuras expostas ao provador. Portanto, não haverá degustação nessa etapa.

A segunda etapa irá envolver 30 provadores, na avaliação de um atributo dominante durante a degustação. As amostras serão servidas fatiadas, aquecidas em chapa por 5 minutos antes de serem apresentadas. Serão realizadas duas sessões de treinamento seguidas por outras três sessões para avaliação final das amostras. O teste definitivo será realizado em triplicata com 5 amostras.

Na soma dessas duas etapas, é esperado compreender o comportamento do consumidor na escolha de um bacon defumado.

Objetivo da Pesquisa:

O objetivo geral do trabalho será entender o comportamento dos consumidores quanto ao bacon,

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através da aplicação de Análise Conjunta e Digit-Tracking e caracterizar esse produto sensorialmente, através do método descritivo dinâmico DTS. Ou seja, obter visão sobre as expectativas e experiências no consumo de bacon; validar a aplicabilidade da ferramenta Digit-Tracking para a área de produtos cárneos; avaliar a evolução dos atributos sensoriais dominantes durante a degustação do bacon defumado em fumaça tradicional pela queima de madeira e líquida.

Avaliação dos Riscos e Benefícios:

Na primeira etapa do projeto, cada participante irá avaliar de maneira visual e individual 8 cartões (embalagens de bacon) uma única vez. Nessa etapa, os riscos serão mínimos.

Na segunda fase, em DTS, cada provador irá provar 5 diferentes amostras, cada amostra será degustada 3 vezes, resultando em um total de 15 degustações que serão divididas em três sessões (5 degustações por sessão). Cada amostra corresponde a 30g de bacon fatiado, ou seja, por sessão o provador consumirá 150 g de bacon e ao fim do experimento, um total de 450g. Segundo o autor do projeto, esses valores são as quantidades máximas a serem consumidas, uma vez que, o participante estará livre para comer a quantidade que julgar necessária para realização da análise, não sendo obrigado a comer a amostra por completo.

Comentários e Considerações sobre a Pesquisa:

A pesquisa envolve, na primeira etapa, o conceito de imagens para avaliação por 100 indivíduos, da percepção da diferença e conceito sobre bacon obtidos mediante defumação tradicional e obtida de fumaça líquida.

Na segunda etapa será feito, por 30 provadores, o levantamento e avaliação dos principais atributos obtidos de bacon submetido aos dois tratamentos anteriormente citados.

Também objetiva a padronização da percepção do consumidor em relação ao bacon, a fim de obter a validação da metodologia sensorial (Digit-Tracking) para outros tipos de produtos cárneos.

Considerações sobre os Termos de apresentação obrigatória:

O TCLE deixará de forma clara que o produto a ser degustado possui quantidades consideráveis de sódio e gordura. Aqueles que se declararem hipertensos ou possuir outra restrição, não poderão participar da presente pesquisa. Além das informações do TCLE essa questão também será reforçada verbalmente com cada participante.

Recomendações:

Para o autor do projeto verificar se a quantidade máxima de bacon (150g), consumida pelo

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providor, está de acordo com os limites estabelecidos pela legislação para esse tipo de produto.

Conclusões ou Pendências e Lista de Inadequações:

Já avaliadas e descritas nos itens anteriores.

Considerações Finais a critério do CEP:

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_713864.pdf	10/06/2016 15:59:36		Aceito
Outros	sujeito_pesquisa2.docx	10/06/2016 15:44:18	Carmen Josefina Contreras Castillo	Aceito
Projeto Detalhado / Brochura Investigador	ProjetodePesquisa2.docx	10/06/2016 15:42:49	Carmen Josefina Contreras Castillo	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLEREvisado.docx	10/06/2016 15:40:06	Carmen Josefina Contreras Castillo	Aceito
Outros	Declaracao_de_Infraestrutura.pdf	11/05/2016 04:40:25	Carmen Josefina Contreras Castillo	Aceito
Outros	CV_Pesquisador_Responsavel.pdf	11/05/2016 04:38:49	Carmen Josefina Contreras Castillo	Aceito
Orçamento	Orcamento.pdf	11/05/2016 04:34:24	Carmen Josefina Contreras Castillo	Aceito
Outros	Carta_de_Encaminhamento.pdf	11/05/2016 04:30:12	Carmen Josefina Contreras Castillo	Aceito
Declaração de Instituição e Infraestrutura	Declaracao_da_Instituicao.pdf	11/05/2016 04:28:49	Carmen Josefina Contreras Castillo	Aceito
Declaração de Pesquisadores	Declaracao_dos_Pesquisadores.pdf	11/05/2016 04:27:27	Carmen Josefina Contreras Castillo	Aceito
Folha de Rosto	Folha_de_Rosto.pdf	11/05/2016 04:23:57	Carmen Josefina Contreras Castillo	Aceito

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

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Continuação do Parecer: 1.604.926

PIRACICABA, 23 de Junho de 2016

Assinado por:
Maria Elisa de Paula Eduardo Garavello
(Coordenador)

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