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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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A R T I C L E I N F O

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A B S T R A C T

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

1. Introduction

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

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

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

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

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

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

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

2. Materials and methods

2.1. Samples

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

2.2. Bacon manufacture

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

Table 1
Description of the bacon samples.

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

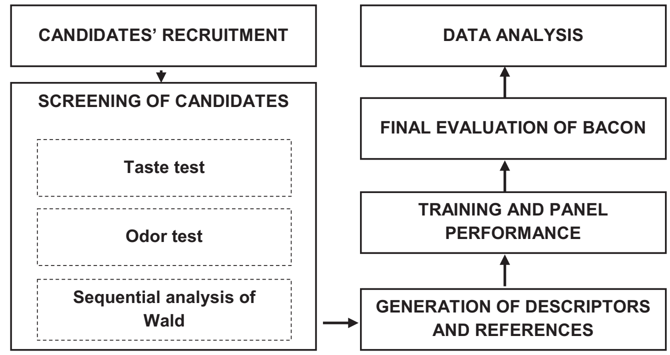

Fig. 1. Flowchart of the steps of the generic descriptive analysis.

2.3. Descriptive analysis

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

2.3.1. Candidates' recruitment

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

2.3.2. Screening of candidates

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

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