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Sensory and physicochemical characteristics of low sodium salami

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ABSTRACT: The aim of the present study was to develop low sodium salami prepared with pork, low-fat beef and a small quantity of pork back fat (150 g kg^{-1}). Sodium chloride (NaCl) was replaced by potassium chloride (KCl) and calcium chloride ($CaCl_2$), and salamis were tasted to obtain low-salt salami with sensory characteristics similar to those found in commercial ones. Salamis were prepared following seven different treatments. Treatments included five different combinations of KCl and $CaCl_2$ which varied from 5 g kg^{-1} to 10 g kg^{-1} and two controls containing high (25 g kg^{-1}) and low (10 g kg^{-1}) concentrations of NaCl. The right level of saltiness of each treatment was evaluated on "just-about-right" (JAR) scales and analyzed by Penalty Analysis. The results showed differences in pH and Aw (water activity) due to NaCl reduction. Salt replacement mixtures of KCl/$CaCl_2$ in salamis did not affect this process technologically (slicing, appearance and texture), and the decrease in Na content was approximately 55 %. Although no significant differences were observed in appearance, treatments differed ($p \leq 0.05$) in flavor, texture, and overall liking. As regards salt content of salami, consumers considered treatments with low NaCl content and replacers KCl and $CaCl_2$ (% Na) as having an acceptable level of saltiness. However, this replacement produced a strange taste. Thus, the production of low sodium salamis using salt replacers (KCl and $CaCl_2$) or salamis without replacers with a value higher than 1 % of NaCl can be used effectively without compromising major sensorial attributes.
Keywords: salt reducing, consumers testing, potassium chloride, calcium chloride, penalty analysis

Introduction

High intake of salt has been associated with a high risk of non-communicable diseases, including hypertension, cardiovascular disease and stroke (WHO, 2012). According to Quilaqueo et al. (2015), the main source of Na in diets is sodium chloride (NaCl). In general, a traditional consumption of more than 6 g of NaCl person d^{-1} is associated with health problems, such as high blood pressure levels, thereby contributing to an increased risk of cardiovascular diseases in the population (Choi et al., 2014; Desmond, 2006; Ruusunen and Puolanne, 2005, WHO, 2003).

Among meat products, dry fermented sausages such as various types of salami have high added value. However, this product is an important source of Na, since between 2 -3 % of NaCl is added during its preparation. After dehydration, NaCl concentration usually increases from 3 to 5 % (Cichoski et al., 2011; Toldrá, 2007).

It is during the preparation phase of salami that most physical and biochemical changes occur, the fractions of sarcoplasmic proteins begin a denaturing process, which influence the solubilization of myofibrillar proteins, actin and myosin in meat. These biochemical changes occur at the end of the drying and at the beginning of the ripening process, and contribute to firmness consistency and appropriate sliceability of the product (Beriaín et al., 1993; Buckenhüskes, 1993).

The sensory quality of low sodium salami developed in this research includes different sensory attributes such as appearance, flavor and texture as compared with a traditional salami. According to Fellendorf et al. (2015), the perception of saltiness has the greatest influence on sensory acceptability in this type of product (meat products with low sodium content). In order to formulate a process to reduce sodium content, saltiness can be directly related to the type of salt substitute used during formulation. JAR scales were used to assess the saltiness intensity perceived by the consumer, in terms of being above or below ideal levels for that attribute. Additionally, reduction of acceptability with saltiness perception was associated with penalty analysis (Popper, 2014). According to Agudelo et al. (2015), the penalty analysis helps to identify possible improvements in the sensory characteristics of products, by identifying ideal levels of attributes, and thereby increase their acceptability.

The aim of this study was to evaluate the effects of lower Na concentration and salt replacers on sensory and physicochemical characteristics including saltiness perception, and consumers'purchase intention of salami.

Materials and Methods

Treatments

Treatments were prepared with five replacement levels of NaCl by KCl mixed with $CaCl_2$. One control was prepared with the usual level of 25 g kg^{-1} NaCl (CH) and another control with the addition of 10 g kg^{-1} NaCl (CL) without replacers (Table 1).

Production process

The raw materials used in this study were purchased from a slaughterhouse under the Government

Table 1 – Levels of salt replacers and NaCl reduction in the different treatments.

Treatments	Amount of salts added in g kg^{-1}		
	Sodium chloride (NaCl)	Potassium chloride (KCl)	Calcium chloride ($CaCl_2$)
T1	10.0	5.0	5.0
T2	10.0	4.5	4.5
T3	10.0	4.0	4.0
T4	10.0	3.5	3.5
T5	10.0	2.5	2.5
CH	25.0	0.0	0.0
CL	10.0	0.0	0.0

T1 - 10 g kg^{-1} NaCl + 5 g kg^{-1} KCl + 5 g kg^{-1} $CaCl_2$; T2 - 10 g kg^{-1} NaCl + 4.5 g kg^{-1} KCl + 4.5 g kg^{-1} $CaCl_2$; T3 – 10 g kg^{-1} NaCl + 4 g kg^{-1} KCl + 4 g kg^{-1} $CaCl_2$; T4 – 10 g kg^{-1} NaCl + 3.5 g kg^{-1} KCl + 3.5 g kg^{-1} $CaCl_2$; T5 – 10 g kg^{-1} NaCl + 2.5 g kg^{-1} KCl + 2.5 g kg^{-1} $CaCl_2$; CH – 25 g kg^{-1} NaCl; CL – 10 g kg^{-1} NaCl.

Agency for Inspection of Animal Products and three production processes were carried out. The salami was prepared with pork shoulder (600 g kg^{-1}), beef rib (250 g kg^{-1}) and pork backfat from the lumbar region (150 g kg^{-1}). Chilled beef and pork were pre-weighed and cut. Raw materials were ground separately in a grinder using 10, 5, and 8 mm plates for pork, beef, and backfat, respectively. We initially added pork and beef, followed by pork back fat. After mixing the raw meat, non-meat ingredients were added (NaCl) and other ingredients (KCl and $CaCl_2$) according to each treatment (Table 1).

Additionally, the following common ingredients were added to the meat mixture in each treatment: sodium nitrite (0.15 g kg^{-1}) and nitrate (0.15 g kg^{-1}), sodium erythorbate (0.3 g kg^{-1}), condiments (7.0 g kg^{-1}), dextrose (0.70 g kg^{-1}), a commercial starter culture (0.25g kg^{-1}) containing *Pediococcus pentosaceus* and *Staphylococcus xylosus*. The meat batter was stuffed into reconstituted collagen casings measuring 45 mm in diameter. Sausages were hand-linked to standard sizes (400 g), hung from metal rods and placed in a ripening chamber at 23 ± 1 °C for 60 h, with RH (Relative humidity) between 85 – 90 % to reach a pH between 4.9 - 5.2. Later, the sausages were taken to a ripening chamber at 16-18 °C and RH 65 – 75 % where they remained for 26 days until water activity was 0.88 - 0.92 for all treatments. Casings were removed and salamis were vacuum packed and frozen at -25 ± 1 °C until analysis.

Experimental design

Physicochemical data was analyzed as a completely randomized design where a batch weighing 6 kg was considered the experimental unit. We used three batches on different days of processing. Each treatment was processed in triplicate: T1 (treatment 1) with 10 g kg^{-1} NaCl + 5 g kg^{-1} KCl and 5 g kg^{-1} $CaCl_2$; T2 (treatment 2) with 10 g kg^{-1} NaCl + 4.5 g kg^{-1} KCl and 4.5 g kg^{-1} $CaCl_2$; T3 (Treatment 3) – 10 g kg^{-1} NaCl + 4 g kg^{-1} KCl + 4 g kg^{-1} $CaCl_2$; T4 (Treatment 4) – 10 g kg^{-1} NaCl + 3.5 g kg^{-1} KCl + 3.5 g kg^{-1} $CaCl_2$; T5 (Treatment 5) – 10 g kg^{-1} NaCl + 2.5 g kg^{-1} KCl + 2.5 g kg^{-1} $CaCl_2$; CH (High control) – 25 g kg^{-1} NaCl; CL (Low control) – 10 g kg^{-1} NaCl. Samples of raw sausages (sausage batter) and ripening/dry sausages were subjected to pH, water activity, Na content, lipid content, moisture content and total protein content. Sensory data was analyzed as a Complete Block Design where consumers were considered blocks.

Physicochemical analyses

The pH was determined by a calibrated portable pH meter with automatic temperature compensation and an electrode with a penetration probe. The analysis was performed at the beginning of the manufacturing process (before stuffing), after fermentation (2.5 days) and at the end of processing (28 days). The samples were analyzed in triplicate per treatment to obtain mean values.

Water activity (Aw) of salami samples was determined using a 4T Aqualab water activity meter at the beginning of the production process (before stuffing) and at the end of processing (28 days). Salami slices measuring approximately 3 mm thick, were placed in capsules suitable for analysis, with the exception of the raw sausage, which was spread before analysis on the bottom of the capsules.

Moisture was determined by the difference between the moist and the dry material, using a stove at 105 °C, as per the AOAC methodology (2005). Total protein content was determined in accordance with the method described by Kjeldahl (AOAC, 2005): the calculation was made with the dry base and then transformed into a moist base. The determination of lipids was performed as described by Soxhlet (AOAC, 2005), with the results expressed in percentages. This analysis was conducted 28 days after the salami was processed. Three sausages per treatment were used for evaluation and each analysis was performed in triplicate.

In order to determine the sodium content in the salami, the analysis was conducted following the AOAC methodology (2005). Five grams of the sample were weighed directly on the porcelain capsule, previously heated in a muffle at 550 °C, before being cooled and weighed. The capsule with the sample was carbonized on a hot plate and then calcined in a muffle at 550 °C. When the capsules had cooled, the ashes were dissolved with 2.5 mL of nitric acid and transferred to a volumetric flask of 50 mL. A blank sample was used as a control. The readings were recorded using a flame photometer, 28 days after the salami was processed.

Consumer study

Consumers of different ages (21 - 60 years old) and from different regions of the country were recruited in Piracicaba, SP, Brazil. The 52 consumers recruited indicated that they were regular salami consumers. The sensory analyses were designed in accordance with ISO 8589 (ISO, 2007). The consumers were placed in individual tasting booths, where they received instructions on the use of the scale, the nature of the products and the type of evaluation to be carried out. The seven salami samples were served in a monadic way, according to the sample presentation order, and were evaluated under white light on disposable white plates coded with random three-digit numbers. During the sensory evaluation, an interval of two hours was allowed between the 4th and 5th samples to avoid sensory fatigue. Mineral water and unsalted crackers were used to clear the palate between samples.

After appearance evaluation, consumers were asked to taste the product and evaluate to what extent they liked or disliked each sample in terms of texture, flavor and overall liking (OL) using a nine-point hedonic scale (1 = disliked extremely, 5 = Neither liked nor disliked, 9 = extremely liked) (Meilgaard et al., 2007). Afterwards, consumers evaluated the salt content of the samples by using a Just-About-Right scale (JAR) (7 = much too high, 4 = just about right and 1 = much too low) (Popper, 2014). Finally, consumers assessed their purchase intent to the tested products by using a five-point structured scale (1 = certainly will not buy, 3 = may or may not buy and 5 = certainly will buy). This study was registered and approved by the Ethics in Research Committee of ESALQ-USP under protocol No.104/2012.

Statistical analysis

The physicochemical measurements of the experimental treatments were analyzed using analyses of variance (ANOVA) ($p \leq 0.05$) considering sample and block as sources of variation. The acceptability responses of the attributes evaluated were analyzed using a three-way ANOVA ($p \leq 0.05$), which considered samples, consumers and presentation order of samples as sources of variation. To evaluate the differences in sensory and physicochemical characteristics between the samples, paired comparisons of the means were made using the Tukey HSD test ($p \leq 0.05$). The physicochemical and sensory characteristics were correlated by way of partial least square (PLS) regression analysis (Cadena et al., 2013). The JAR results were analyzed by penalty analysis. The statistical data analysis was performed using the SAS (SAS Inst., North Carolina, USA), XLSTAT (Addinsoft, New York, USA) and Statistica™ software (Statsoft Inc., Tulsa, Oklahoma, USA).

Results and Discussion

Physicochemical analyses

The physicochemical characteristics of the salamis produced with replacers of NaCl using KCl combined with $CaCl_2$ are shown in Table 2. The Aw value before stuffing ranged from 0.96 to 0.98, with statistically significant differences between the treatments ($p \leq 0.05$). Treatment CH already showed lower Aw than the other treatments due to the higher amount of NaCl (approximately 55 %) in this treatment. However, this difference caused by a reduction in NaCl and replacers with a mixture of KCl/$CaCl_2$ in salamis did not affect the processing characteristics of the initial stage of the process.

This small difference in Aw in all treatments compared to CH continued to present differences throughout the fermentation, drying and ripening periods of the salami (Table 2), showing that the CH treatment had lower Aw values (0.89) than the other treatments. Therefore, by the end of ripening, the salamis were showing Aw values within the limits required by Brazilian law (maximum Aw 0.92). A safe range of low Aw is one of the major barriers to growth of undesirable microorganisms in the product. Thus, the treatments with reduced NaCl and replacers with a mixture of KCl/$CaCl_2$ were stable during salami production. The CL treatment (10 g kg^{-1}), which contains NaCl was on the threshold of hindering commercial production of salami (Desmond, 2006), had a lower dehydration rate and reached Aw of 0.92. On the other hand, the CL treatment had the appropriate technological characteristics.

During manufacturing, the pH development of all samples (Table 2) showed values between 5.9-6.0 and after fermentation (60 h), pH values of the control and other treatments were below 5.0. Although rapid fermentation is desirable in salami production, in this research, we used a milder fermentation temperature and consequently a longer fermentation period. This reduction in pH (pH lower than 5.2 with 24-60 h of fer-

Table 2 – Means (± SD) of Aw and pH in experimental treatments during salami production.

Treatments	Aw		pH		
	Sausage batter	End ripening	Sausage Bater	After fermentation	End ripening
T1	$0.97^a \pm 0.002$	$0.91^b \pm 0.002$	$5.9^a \pm 0.04$	$5.0^a \pm 0.08$	$5.1^a \pm 0.08$
T2	$0.97^a \pm 0.002$	$0.91^b \pm 0.002$	$5.9^a \pm 0.12$	$5.0^a \pm 0.11$	$5.1^a \pm 0.01$
T3	$0.97^a \pm 0.002$	$0.91^b \pm 0.002$	$5.9^a \pm 0.19$	$5.0^a \pm 0.05$	$5.2^a \pm 0.06$
T4	$0.97^a \pm 0.002$	$0.91^b \pm 0.002$	$5.9^a \pm 0.26$	$5.0^a \pm 0.04$	$5.2^a \pm 0.10$
T5	$0.97^a \pm 0.002$	$0.91^b \pm 0.002$	$5.8^a \pm 0.04$	$5.0^a \pm 0.04$	$5.2^a \pm 0.06$
CL	$0.98^a \pm 0.002$	$0.91^b \pm 0.002$	$6.0^a \pm 0.08$	$5.1^a \pm 0.19$	$5.3^a \pm 0.05$
CH	$0.96^b \pm 0.002$	$0.89^a \pm 0.002$	$5.9^a \pm 0.10$	$5.0^a \pm 0.05$	$5.2^a \pm 0.02$

Values represent the average ± standard deviation. Averages within the same column, in the same experiment, followed by the same letters did not show any significant difference ($p \geq 0.05$) by the Tukey test. The following treatments were used: T1 - 10 g kg^{-1} NaCl + 5 g kg^{-1} KCl + 5 g kg^{-1} $CaCl_2$; T2 - 10 g kg^{-1} NaCl + 4.5 g kg^{-1} KCl + 4.5 g kg^{-1} $CaCl_2$; T3 – 10 g kg^{-1} NaCl + 4 g kg^{-1} KCl + 4 g kg^{-1} $CaCl_2$; T4 – 10 g kg^{-1} NaCl + 3.5 g kg^{-1} KCl + 3.5 g kg^{-1} $CaCl_2$; T5 – 10 g kg^{-1} NaCl + 2.5 g kg^{-1} KCl + 2.5 g kg^{-1} $CaCl_2$; CH – 25 g kg^{-1} NaCl; CL – 10 g kg^{-1} NaCl.

mentation) is extremely important for fermented meat products because the lactic acid inhibits a large number of pathogenic and spoilage microorganisms, and triggers proteolysis thereby assisting at the commencement of the salami drying process. Low pH causes the protein to reach its isoelectric point and consequently a reduced water binding capacity, which makes it easier for salami to lose water, and thus facilitates its dehydration (Leroy et al., 2006; Toldrá et al., 2007).

During fermentation, lactic acid is produced due to the breakdown of carbohydrates by lactic acid bacteria added via commercial starter culture and natural bacterial flora. The amount of carbohydrate used (0.7 g kg^{-1}) was enough to produce fermentation with pH values near 5.0, similar to those reported by Del Nobile et al. (2009) and Lücke (1994). At the end of the ripening and manufacturing process, pH values increased from 5.1 to 5.3. These values were observed in all treatments and are considered typical of salami aging due to the formation of basic compounds of non-protein nitrogen (NPN) as well as the buffering effect of the protein (Astiasarán et al., 1990).

In the current research, to decrease the impact of a reduction in Na on salami texture, we opted for a smaller addition of lipids, about 28 %, and increased the addition of lean meat to about 25 %, which can be proven by the high protein content in all treatments (between 31 – 32 %, values not shown). Next because of the lean meat having higher protein quantity available, there were more binding pieces of meat which were firmer in the salami. Moisture content between all treatments remained between 33 – 37 %. The level of moisture could also be lowered so as to promote the traditional firmness of salami that is considered ideal by consumers. In all treatments a reduction in NaCl and replacers with a mixture of $KCl/CaCl_2$ (T1-T5) did not affect the processing characteristics. However, certain adjustments are required for the processing, such as protein content, fat content and moisture content in order to optimize the production process of salami. All treatments have values within the limits indicated by Brazilian standards No. 22 of July 31, 2000, for salami (MAPA, 2000).

In the present study, NaCl replacers with different chloride salts KCl + $CaCl_2$ significantly decreased

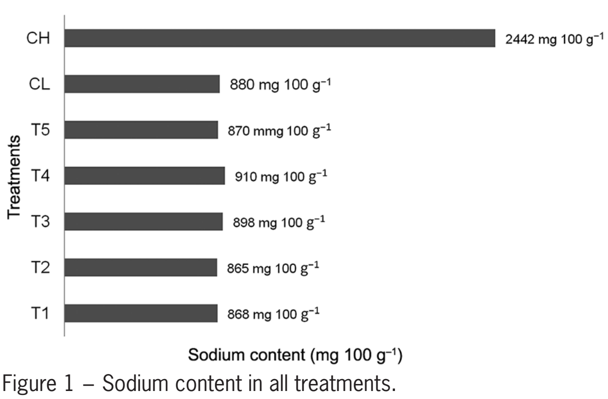


Figure 1 – Sodium content in all treatments.

(p < 0.05) the Na content in products (Figure 1). Treatments T1, T2, T3, T4, T5 and CL, presented Na content between 865 - 898 mg 100 g^{-1} and treatment CH had Na content 2450 mg 100 g^{-1}. Thus, replacing NaCl with KCl + $CaCl_2$ resulted in an approximate 64 % reduction in Na content. This fact is very important due to the particularities of the Brazilian market, where salami are found with an Na content of between 1,610 mg 100 g^{-1} and 2,560 mg 100 g^{-1}. The average Brazilian consumes 3,200 mg Na 100 g^{-1} person d^{-1}, which is higher than the maximum intake recommended by the WHO and the FAO (WHO, 2003). Therefore, marketing a product with low sodium content could be a good option for both the industry and consumers. Consumers are looking for more products with healthy characteristics (e.g. low fat content, without trans fat, low sodium content). Viewed from this perspective, this segment represents an important niche in the market, with potential consumers for the industry. We should also emphasize the health problems caused by high sodium intake.

However, a salt reduction at this level is considered critical because of microbial contamination or risk of hetero fermentation during the fermentation process of salami (Ruusunen and Puolanne, 2005). In this research, replacements with chloride mixtures (KCl + $CaCl_2$) were chosen rather than a replacement of only one type of chloride. Other authors (Campagnol et al., 2012) reported that the replacement of NaCl by KCl (50 %) did not result in significant changes in fermentation and dehydration of salamis. However, it did diminish the sensory quality of their salamis.

Consumer study

The ANOVA of the acceptability data showed no differences in the appearance (color) of salami (Table 3). However, there were differences ($p \leq 0.05$) in flavor, texture and overall liking. All treatments obtained scores between 5.9 - 7.5, an acceptability average of "like slightly" to "like moderately" for all attributes.

The flavor was negatively affected by reductions in NaCl and replacement with mixtures of $KCl/CaCl_2$. Results showed that the addition of mixtures containing 4g kg^{-1} of KCl + 4g kg^{-1} of $CaCl_2$ led to detrimental effects on salami taste (Table 3). Regarding texture, consumers reported lack of consistency caused by NaCl reduction and the reduction of this ingredient recorded lower scores in all treatments compared to CH. The same trend was observed in consumers OL (overall liking) who liked the treatments less with NaCl reduction and replacement with $KCl/CaCl_2$ compared to CH.

This trend may be attributed to the presence of KCl, $CaCl_2$ or the mixture of these salts. They affect the activity of lipolytic enzymes, changing the flavor of fermented products. Furthermore, the addition of KCl and $CaCl_2$ in meat products is limited by the bitter taste, metallic taste and astringent sensation that high concentrations of these salts provide to meat products (Blesa et al., 2008; Ripollés et al., 2011).

Table 3 – Acceptance values of color, flavor, texture, overall acceptance, salt content, and purchase intention for seven salami formulations.

Attribute	CH	CL	T1	T2	T3	T4	T5
Appearance	$7.3^a \pm 1.2$	$7.4^a \pm 1.4$	$7.0^a \pm 1.4$	$7.0^a \pm 1.3$	$7.5^a \pm 1.1$	$7.1^a \pm 1.3$	$7.3^a \pm 1.3$
Flavor	$7.2^a \pm 1.9$	$6.2^b \pm 1.9$	$5.9^b \pm 1.9$	$6.2^b \pm 1.7$	$6.5^{ab} \pm 1.8$	$6.3^{ab} \pm 1.5$	$6.8^{ab} \pm 1.8$
Texture	$7.5^a \pm 1.2$	$6.7^b \pm 1.5$	$6.2^b \pm 1.8$	$6.3^b \pm 1.6$	$6.6^b \pm 1.7$	$6.3^b \pm 1.6$	$6.7^b \pm 1.5$
Overall acceptance	$7.4^a \pm 1.4$	$6.5^b \pm 1.5$	$6.3^b \pm 1.7$	$6.4^b \pm 1.5$	$6.6^b \pm 1.5$	$6.4^b \pm 1.4$	$6.9^{ab} \pm 1.5$
Saltiness	$4.3^a \pm 1.2$	$3.6^b \pm 1.1$	$4.0^{ab} \pm 1.3$	$3.5^b \pm 1.1$	$4.0^{ab} \pm 1.1$	$3.8^b \pm 1.4$	$3.9^{ab} \pm 1.1$
Purchase intention	$3.9^a \pm 1.1$	$3.2^b \pm 1.1$	$2.9^b \pm 1.2$	$3.1^b \pm 1.2$	$3.2^b \pm 1.2$	$3.0^b \pm 1.1$	$3.4^{ab} \pm 1.2$

T1 - 10 g kg^{-1} NaCl + 5 g kg^{-1} KCl + 5 g kg^{-1} $CaCl_2$; T2 - 10 g kg^{-1} NaCl + 4.5 g kg^{-1} KCl + 4.5 g kg^{-1} $CaCl_2$; T3 – 10 g kg^{-1} NaCl + 4 g kg^{-1} KCl + 4 g kg^{-1} $CaCl_2$; T4 – 10 g kg^{-1} NaCl + 3.5 g kg^{-1} KCl + 3.5 g kg^{-1} $CaCl_2$; T5 – 10 g kg^{-1} NaCl + 2.5 g kg^{-1} KCl + 2.5 g kg^{-1} $CaCl_2$; CH – 25 g kg^{-1} NaCl; CL – 10 g kg^{-1} NaCl.

Treatment CH is the standard for products available on the market, and treatment T5 showed higher flavor and texture scores compared to CH. This shows that the addition of 0.25 % KCl + 0.25 % $CaCl_2$ under the proposed conditions were sufficient to mask the low NaCl content (1 %). In treatment T5, scores for flavor and texture were higher than those obtained by Campagnol et al. (2012) in a treatment with 50 % Na reduction and replacement with KCl. OL obtained in our study was higher than that reported by Gimeno et al. (1998) for low sodium salami (formulation with 1 % NaCl, 0.55 % KCl, 0.23 % $MgCl_2$ and 0.46 % $CaCl_2$) that obtained a 37 % lower OL. In our study with Na reduction, T5 salami had a 64 % Na reduction, resulting in a final NaCl content of 25 g kg^{-1} after a 28-d period of drying and ripening. Thus, since Na content in the products currently available in the market can be as much as 6000 mg Na 100 g^{-1} (Jiménez-Colmenero et al., 2001), the reduction in NaCl content in dried and fermented products remains the main challenge for laboratorial research.

To model consumer acceptance of the salami samples studied, a multivariate model called regression by partial least squares (PLS) was used. The PLS allowed for modelling consumer acceptance according to the instrumental measurements and the sensory attributes from the sensory descriptive analysis. This tool was also used by Toscas et al. (1999) to model consumer acceptance according to instrumental measurements of texture in meat.

In this research, only one PLS component was considered because the statistical Q^2 did not increase significantly (Figure 2A), showing a value of 0.81. This can be explained by how the first component commonly describes the behavior of most consumers, making the other components insignificant. According to Tenenhaus et al. (2005), the statistical Q^2 is used to measure the importance of PLS components in predicting consumer acceptance of each sample by cross validation. On the other hand, the R^2Y and R^2X values represent the range of consumer acceptance and physicochemical characteristics according to the PLS component generated, representing 0.988 and 0.404 respectively. It indicates that the model was suitable for predicting consumer acceptance, based on a consideration of these three parameters.

Figure 2B presents the importance of each physicochemical property to the projection considering one component in the PLS. Attributes with a Variable Importance for the Projection (VIP) higher than 0.8 significantly contributed to the model projection (Wold, 1994). Then, the instrumental measurements that most contributed to the projection of the PLS were: texture, flavor, Aw 28 days, sodium, and Aw 0 day.

In Figure 2C it is shown that the predicted values and the observed experimental values were very similar. Thus the model was suitable for predicting consumer acceptance of salami according to sensory and physicochemical properties. The adequacy of the model was also confirmed by the low root-mean-squared-error (RMSE) and the high coefficient of determination (R^2).

The standardized coefficients are presented in Figure 2D, where on the Y axis, sensory and physicochemical properties that are in the positive range represent positive sensory attributes, while the physicochemical properties that were in the negative range on the Y axis represent negative sensory attributes for consumer acceptance of salami. The size of the columns indicates the influence of each attribute on consumer acceptance of the samples, be they positive or negative. Thus, the higher the column, the greater the influence of the descriptor on sample acceptance. Furthermore, it should be noted that if the standard deviation is crossing the X axis, the influence of the attribute cannot be considered with a 95 % confidence interval (Gomes et al., 2014). Therefore, the most important measurements for predicting consumer acceptance of salami were: texture, flavor, Aw 28days, pH 60 h, sodium, and Aw 0 days.

JAR scales

The JAR scale is conventionally used to identify sensory attributes and to what extent a product "failed to deliver" its optimal condition. The implicit assumption is that the JAR scale can be used to "diagnose" the nature of a sensory problem and the approximate direction and magnitude for its correction (Rodríguez-García et al., 2014). The JAR results were analyzed by penalty analysis, relating the saltiness optimal level and its relation to OL. In this analysis, an attribute was considered significant when the correspondent percentage was higher than 20 (Xiong and Meullenet, 2006).

According to Figure 3, the reduction of OL related to the percentage of consumers in each treatment was described differently as regards the salt content using

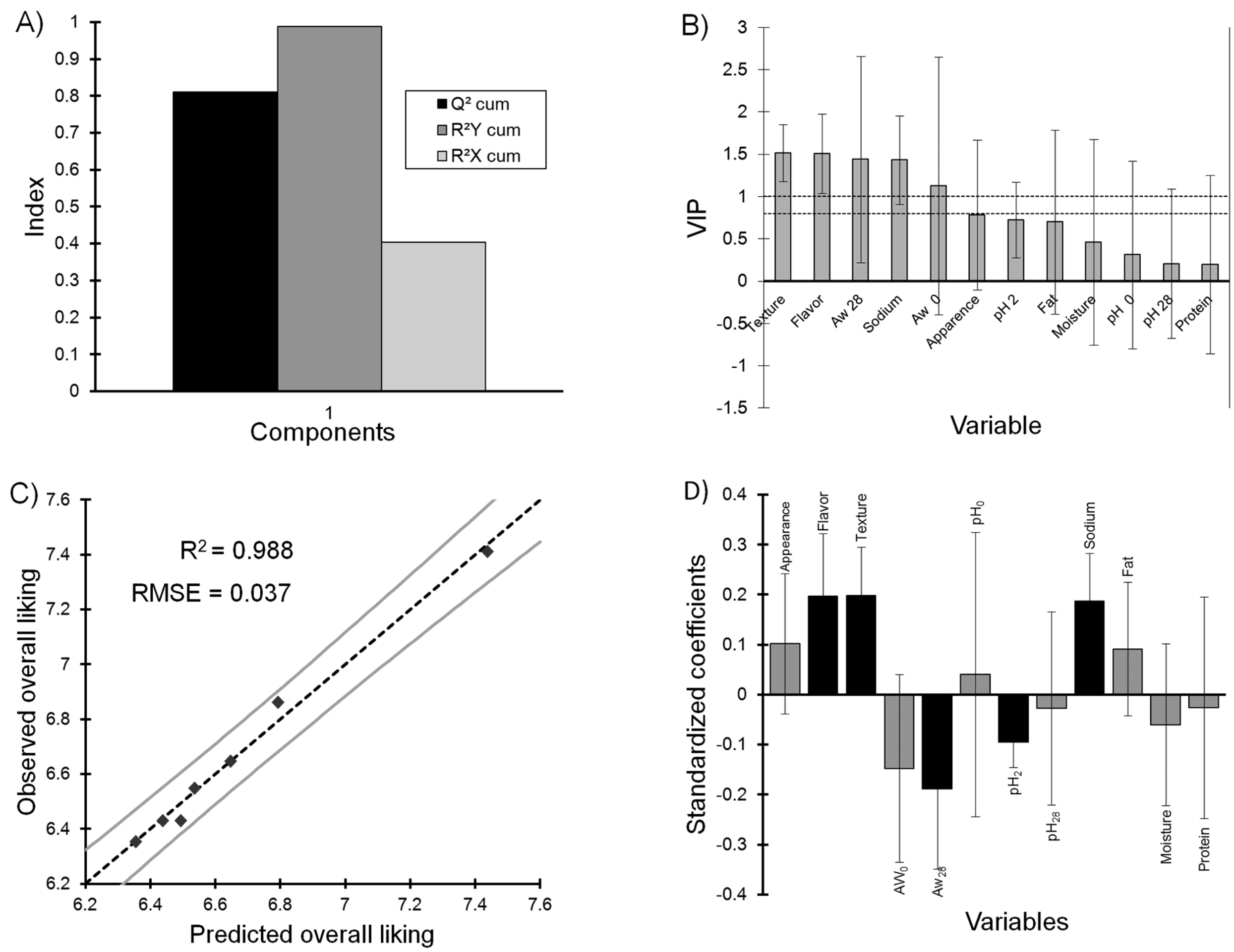


Figure 2 – Partial least squares (PLS) regression considering overall liking (OL) as a dependent variable and physicochemical and sensory parameters as independent variables. (A) Model quality by number of components; (B) Variable Importance in the Projection (VIP); (C) Observed OL vs Predicted OL; (D) Standardized coefficients (95 % of confidence interval).

the JAR scales. For most treatments, except for CH (with 25g kg^{-1} NaCl), a content below the ideal causes a greater drop in acceptability. Conversely, a content above the ideal does not influence the reduction in acceptability (less than 1 point on a 9-point hedonic scale) strongly. This shows that the perception of saltiness below the ideal is a critical point and results in a reduction in acceptability of more than 1 point on a 9-point scale (Figure 3).

As regards salt content, consumers considered the CL treatment with a reduction in NaCl content without the addition of replacers (KCl and $CaCl_2$) as "less salty than the ideal" or "ideal". This is possibly because consumers of this type of product used amounts in excess of 1,600 mg Na 100 g^{-1}, which is probably above the ideal.

Out of the two proposed extreme treatments (CL and CH) in this study, CH was considered to have the ideal salt content and CL the lowest score regarding the ideal scale when compared with the other treatments. This shows that the reduction in NaCl in salami is a complex issue from the sensory point of view, because consumers seek a stronger salt taste and consider it a typical and striking characteristic of the product. When consumers choose the brand or type of salami to buy, they look for a product with stronger saltiness, which can be observed in this study due to high acceptability and the purchase intention score of CH (Figure 4), when 74 % of consumers considered this salami to have the ideal amount of salt (CH).

The penalty analysis applied to consumers and each sample provides information about the importance of salt. This should be considered as a basis for changes in product formulation to improve its acceptability. In treatments with salt replacers (T1, T2, T3, T4 and T5), 25 – 35 % of consumers noticed differences from the ideal by more than one point on a scale of nine points and, it can be concluded that the replacers, in the amounts added, could not replace the intensity of salty taste which made consumers remain in doubt when it came to their buying intent of these salami. This can also be confirmed by the low purchase intention record-

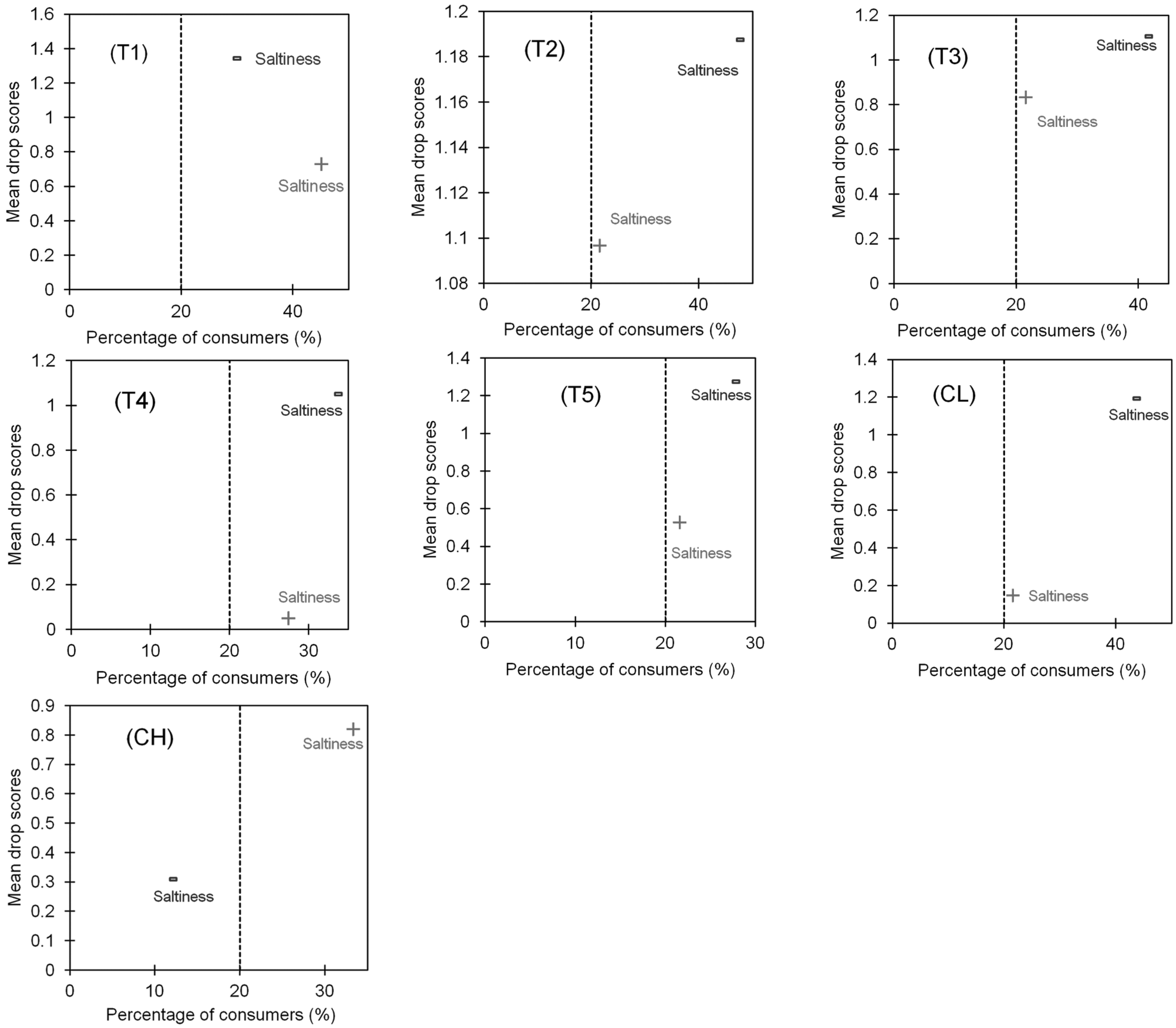
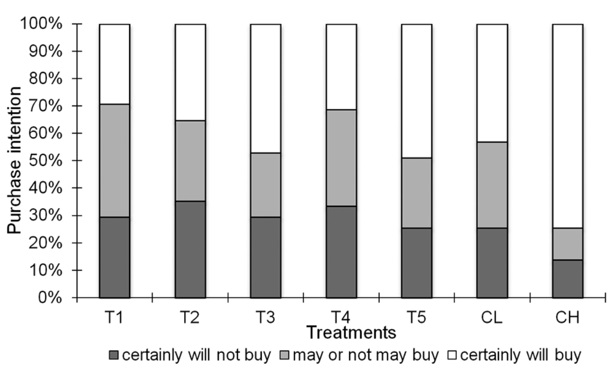


Figure 3 – Representation of drops on overall acceptance by a proportion of consumers using scales JAR (Just About Right); CL = Low Control, CH = High Control.



T1 - 10 g kg^{-1} NaCl + 5 g kg^{-1} KCl + 5 g kg^{-1} $CaCl_2$; T2 - 10 g kg^{-1} NaCl + 4.5 g kg^{-1} KCl+ 4.5 g kg^{-1} $CaCl_2$; T3 – 10 g kg^{-1} NaCl + 4 g kg^{-1} KCl + 4 g kg^{-1} $CaCl_2$; T4 – 10 g kg^{-1} NaCl + 3.5 g kg^{-1} KCl + 3.5 g kg^{-1} $CaCl_2$; T5 – 10 g kg^{-1} NaCl + 2.5 g kg^{-1} KCl + 2.5 g kg^{-1} $CaCl_2$; CH – 25 g kg^{-1} NaCl; CL – 10 g kg^{-1} NaCl.

Figure 4 – Purchase intention of the tested products.

ed for these treatments. Another point that should be considered is the type of formulation used. We opted for a heavier formulation of condiments and a greater use of lean meat, which is not a standard in this type of product. According to Campagnol et al. (2011a), the seasoning has a strong influence on the final results of salami with low sodium content.

According to our study, an alternative would be a small addition of chloride salts to be used as replacements (0.25 % each) combined with other technologies, namely greater flavoring (spices such as onion, garlic, cumin, paprika and others), new more proteolytic starter cultures (Leroy and De Vuyst, 2004), monosodium glutamate, disodium inosinate, disodium guanylate and amino acids (lysine and taurine) (Santos et al., 2014; Campagnol et al., 2011a; Campagnol et al., 2012), and yeast extract (Campagnol et al., 2011b). This could reduce Na content in salami but still yield a product with only 10 g NaCl kg^{-1} of sample, which is acceptable to consumers at a relatively low cost. Moreover, other authors such as Guàrdia et al. (2006) have reported the viability of salami production with only 11 g NaCl kg^{-1} of sample.

Conclusion

This study allowed for salami to be produced with an Na reduction of 64% which was well accepted by consumers. The small addition of replacements showed sensory acceptability near to that of the product with Na content characteristic of commercial salami. The production of salami with only 1 % of NaCl without the addition of replacements is viable; however, the consumer has a tendency to still look for saltier salami at the time of purchase.

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