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Technological, sensory and microbiological impacts of sodium reduction in frankfurters

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ABSTRACT

Initially, meat emulsions were studied in a model system to optimize phosphate and potassium chloride concentrations. In the second step, frankfurters containing 1.00%, 1.30% and 1.75% sodium chloride (NaCl) were processed and their stability was monitored over 56 days. In the emulsion tests, the best levels in relation to shear force found in model system were 0.85% and 0.25% of potassium chloride and phosphate, respectively. In the second step, treatments with 1.30% and 1.75% NaCl performed better in most of the analysis, particularly the sensory analysis. Consumers could identify the levels of salt, but this was not the factor that determined the overall acceptability. In some technological parameters, frankfurters with 1.30% NaCl were better than those with 1.75%. This represents a reduction of approximately 25% sodium chloride, or 18% reduction in sodium (916 mg/100 g to 750 mg/100 g), and it appears to be feasible from a technological, microbiological and sensory point of view.

1. Introduction

Excessive sodium intake has been associated with hypertension and leads to an increased risk of strokes and fatal vascular diseases (He & MacGregor, 2010). In addition, it has been associated with other health problems, such as stomach cancer and kidney diseases (Sloan, 2010).

It has been established that the consumption of more than 6 g NaCl/day/person is associated with increased blood pressure with increasing age. Therefore, it is recommended that the total amount of salt (sodium chloride) should be approximately 5 to 6 g/day. Genetically, salt-sensitive and hypertensive individuals would benefit from a diet that is low in sodium, with a sodium chloride content of 1 to 3 g/day (Ruusunen & Puolanne, 2005).

Salt is one of the most commonly used ingredients in processed meat products. Salt impacts a number of functional properties in meat products: it activates proteins to increase hydration and water-binding capacity, it decreases fluids loss in vacuum-packaged products that has been thermally processed; it increases the water and fat binding properties of proteins resulting in the formation of a desirable gel texture upon cooking, it increases the viscosity of meat batters, facilitating the incorporation of fat to form stable batters; it is essential for flavor and is a bacteriostatic at relatively high levels (Terrel, 1983).

Decreasing salt content, therefore, has many implications for muscle food products. The product implications include textural changes, flavor differences, decreased moisture retention (yield) and product appearance (Collins, 1997). Sodium chloride is inhibitory against many spoilage and pathogenic microorganisms in meat because of its ability to reduce water activity. It is expected that reducing NaCl levels below those typically used, without other preservative measures, would result in shortened product shelf-life and reduced safety (Sofos, 1986).

Apart from lowering the level of sodium chloride (NaCl) added to products (Aaslyng, Vestergaard, & Koch, 2014; Tobin, O'Sullivan, Hamill, & Kerry, 2012), there are several approaches for reducing the sodium content in processed meats replacing all or part of the NaCl: (1) with other chloride salts (KCl, $CaCl_2$ and $MgCl_2$) (De Almeida et al., 2015; Horita, Morgano, Celeghini, & Pollonio, 2011); (2) with non-chloride salts, such as phosphates (Ruusunen, Särkkä-Tirkkonen, & Puolanne, 1999; Marchetti, Argel, Andrés, & Califani, 2015); (3) with various ingredients (Ruusunen et al., 2003; Choi et al. (2014); McGough, Sato, Rankin, & Sindelar, 2012; Colmenero, Ayo, & Carballo, 2005; Jiménez-Colmenero et al., 2010); (4) with new processing techniques or process modifications (Kang et al., 2014; Grossi, Søltoft-Jensen, Knudsen, Christensen, & Orlien, 2012); and (5) combinations of any of the above approach.

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Aaslyng et al. (2014) reported that salt reduction from 2.2% to 1.7% did not alter the sensory properties in sausages. According to (Ruusunen & Puolanne, 2005), the sodium chloride content in sausages phosphate free can be reduced to 1.5–1.7%, while adding phosphate to 1.4%, without a loss of quality in terms of technology and yield. These authors related that there are cooked sausages made with salt mixtures on the Finland market where the salt content based on sodium chloride content is 1.2% or lower.

Using other types of salts is one way of reducing NaCl levels. The synergistic effect between sodium chloride and phosphates is well known in the meat industry. Xiong and Mikel (2001) reported that phosphate (at levels above 0.5%) is used in meat products to improve their water holding capacity by increasing the swelling of fibers and the solubilization of proteins. Phosphates function to bind water and improve texture through changes in protein coagulation and fat emulsification (Collins, 1997). Barbut, Maurer, and Lindsay (1988) reported that phosphates significantly improved the texture and acceptability of loss salt (1.5%) in turkey frankfurters. This additive may help to stabilize the flavor and color of the final product by sequestering metallic ions (iron and copper), thereby reducing oxidation.

Potassium chloride (KCl) can be used to replace sodium chloride, despite the lower extraction capacity of myofibrillar proteins, when compared to sodium chloride (Munasinghe & Sakai, 2003). Potassium chloride is probably the most common salt used as a substitute in foods with reduced sodium content. However, at blends of more than 50:50 sodium chloride/potassium chloride solution, a significant increase in bitterness (and loss of saltiness) is observed (Desmond, 2006).

The aim of the present study was to assess the technological, sensory and microbiological impacts of reducing the sodium content, while adding phosphate and potassium chloride, on the storage of frankfurters processed with beef and pork meat. These salts were used as sodium substitutes by their properties to improve product characteristics relating to flavor, texture and water binding that could be impacted by sodium reduction. Thus, this study intends to expand the technological knowledge regarding the reduction of sodium levels, contributing to the meat industry and providing new, healthy options for consumers.

2. Materials and methods

The present study consisted of two steps:

The first step involved the preparation and analysis (emulsion-forming ability and shear force) of meat emulsions in a model system, using various phosphate, potassium chloride and sodium chloride levels.

The second step involved the preparation of frankfurters with the phosphate and potassium chloride levels selected in the first stage of the study. Sodium chloride remained the target of study, by varying the levels added. At this stage, chemical, microbiological, physical and sensory analysis was carried out during storage for 56 days at 4 °C. The storage temperature was consistent with other studies (Aaslyng et al., 2014) using sausages.

In order to choose the salt contents for this test, a preliminary survey of the sodium content in 13 retail frankfurters on the south Brazilian market was carried out. The average of sodium content was 987 mg Na/100 g (corresponding to 2.5% NaCl). The levels of sodium chloride added in the present study were 1%, 1.3% and 1.75%, (corresponding to 1.5%, 1.91% and 2.33% NaCl respectively) which already represents a reduction compared to commercial products.

2.1. Meat emulsion in a model system

In the first step, the technique of factorial central composite rotational design (CCRD) was used to optimize the process, based on response surface methodology. In the model system used, emulsion was obtained using a mini-cutter and all of the ingredients usually used to obtain a frankfurter, with varying levels of phosphate, salt (NaCl) and potassium chloride (KCl) (Table 1). The goal of the first step was to optimize the levels of potassium chloride and phosphate in relation to emulsion-forming ability and shear force. Although the levels of sodium chloride were variable, the objective of the second phase was to determine the influence of NaCl levels.

The experimental design consisted of 20 trials that were performed in random sequence, thereby enabling the acquisition of mathematical models with linear and quadratic parameters (multiple regression) of the variables studied. In the proposed design (CCRD with three variables), the first eight trials refer to all factorial design with levels -1 and $+1$, the function of which was to provide the linear parameters (L) of the regression model. The next six trials refer to the axial points (levels: $-\alpha$; 0 and $+\alpha$), the function of which was to provide the quadratic (Q) regression model parameters. The last six trials (level 0) were replicates at the central point. The responses studied were emulsion-forming ability and shear force.

The phosphate levels recorded were 0% ($-\alpha$), 0.1% (-1), 0.25% (0) 0.4% ($+1$) and 0.5% ($+\alpha$). The NaCl concentrations were 1% ($-\alpha$), 1.3% (-1), 1.75% (0) 2.2 ($+1$) and 2.5% ($+\alpha$). The KCl levels were 0.2% ($-\alpha$), 0.46% (-1) % 0.85 (0) 1.24 ($+1$) and 1.5% ($+\alpha$).

The basic meat emulsion formulation was composed of the following ingredients: 10% beef shoulder, 37% pork shoulder, 18% pork back fat, 3% textured soy protein, 2% cassava starch, 0.05% sodium erythorbate, 0.02% sodium nitrite, 0.25% seasoning unsalted, 0.75% yeast extract, 1% sodium lactate and 0.07% liquid smoke. Twenty different treatments were obtained by varying the amount of sodium chloride, potassium chloride and phosphate added, while the water amount (26%–24.3%) was adjusted so that the sum totaled 100%.

The following specifications for ingredients and additives were used in the preparation of meat emulsions and second stage: phosphate (in 100 g: 19.1 g of phosphorus, 2.3 g of sodium e 45.6 g of potassium) (Budenheim, Abastol 452, Germany), potassium chloride (in 100 g: 0.98 mg of phosphorus, 32.5 mg of sodium e 44.5 g of potassium) (Nu-tek, 15,000, Minnetonka, United States), salt-free seasonings for frankfurters (Kraki, Santo André, Brazil), cassava starch (Amafil, Cianorte, Brazil), textured soy protein (Solae, Centex 4010, St. Louis, United States), 65% sodium lactate (Corbion), yeast extract, sodium erythorbate (Kraki, Santo André, Brazil), sodium nitrite (Kraki, Santo André, Brazil) and liquid smoke (Ibrac, Aroma Flavor Smoke # 50C, São Paulo, Brazil).

Raw meat (kept at -17 °C), beef, pork and pork back fat were coarsely ground (Hermann, 106, São Paulo, Brazil) using a 12 mm plate in order to obtain meat emulsions in a mini-cutter (Skymsen, Brusque, Brazil). The beef and pork (except back fat) were placed in a mini-cutter, before adding NaCl, KCl, nitrite, phosphate, seasoning, yeast extract, sodium lactate, liquid smoke, half amount of water/ice and comminuting for two minutes. Then, fat and the remaining water/ice were added and chopped for 2 min. Sodium erythorbate, textured soy protein and cassava starch were added and comminuted for 1 min.

2.1.1. Emulsion-forming ability measurements

This test was performed as described by Parks and Carpenter (1987): 45 to 50 g of newly processed batter was placed in bag of nylon/polyethylene film, which was sealed without vacuum and heated for 1 h in water at 70 °C. After cooling the samples, they were removed from the package and weighed. The liquid volume exudates were calculated as a percentage loss in relation of the initial sample weight.

2.1.2. Shear force

A texture analyzer (Stable Micro Systems, TA XT-2i, Surrey, England), coupled to a Warner Bratzler device (3 mm), was used to shear the heat-treated emulsions. The equipment was calibrated with a 5 kg weight and a 25 kg load cell was used for the test. The speed of the test was 0.8 mm per second. Five units of heat-treated emulsions per treatment were cut into 2 cm (length) × 2 cm (width) × 1 cm (height) pieces, after 24 h storage at 4 °C.

2.2. Frankfurter processing

In the second step of the present study, the levels of phosphate (0.25%) and potassium chloride (0.85%), selected from meat emulsion model systems, were fixed and three levels of sodium chloride remained the target (1%, 1.3% and 1.75%). The treatments were processed and the samples were then vacuum-packed in barrier shrink bags, stored at 4 °C and monitored over five distinct periods (1, 14, 28, 42 and 56 days) based on the 45 days expected shelf life for frankfurter in Brazilian market. The sampling points were every 14 days, in this way at 56 days one more point of sampling after 45 days storage was performed. The frankfurters sensory acceptance with consumers was assessed. The processing and analysis of frankfurter treatments were performed three times on different days using raw material from different meat, thereby decreasing the effects of processing, raw materials and other conditions on the results of the study. Thus, the results of the second step are based on the results of three processing replicates, the exception being sensory analysis.

The treatments were defined as follows:

F 1	frankfurter containing 1% sodium chloride
F 1.3	frankfurter containing 1.3% sodium chloride
F 1.75	frankfurter containing 1.75% sodium chloride

The frankfurter meat and non-meat ingredients were the same as those used in meat emulsions. The levels of 0.25% phosphate and 0.85% KCl optimized in the first stage of the study were fixed. The water/ice ranged from 25.0% to 25.7% in order to provide a total formulation of 100%.

Each treatment was processed to obtain 18 kg in each replication of the process. The frozen raw meat (beef, pork and pork back fat) were portioned, and ground (Hermann, 106, São Paulo, Brazil) into 12 mm disks. The frozen ground raw meat was placed in the cutter (Kramer & Grebe Karl Ernst Zippel, Biedenkopt-Wallau, Germany) before adding NaCl, KCl, phosphate, sodium nitrite, yeast extract, seasoning, sodium lactate, liquid smoke and half of the ice. The ingredients were comminuted until a temperature of 2 °C was reached, at which point the pork back fat was added and homogenized. Finally the sodium erythorbate, textured soy protein, cassava starch and the remaining ice were added and the batter was comminuted until reaching 16 °C.

The batter was then transferred to rotary-vane vacuum filler (Handtmann, VF 610, Baienfurt, Germany) and stuffed into 22 mm cellulose casings (Viscofan Inc., Montgomery, USA). The heat treatment was conducted in a steam oven (Heinz Becker, Dr. Kompakt, Hamburg, Germany), at an initial inside temperature of 50 °C for 15 min and 60 °C for a further 15 min. Subsequently, the temperature was raised by 5 °C every 5 min to reach a final core temperature of 72 °C within the product. A thermocouple was placed in the center of the samples to monitor and control the internal temperature. After cooking, the products were immediately cooled in a water shower for 10 min and another 15 min in the cooling chamber at 10 °C.

The products were vacuum-packed (BB 2620 CB, 200 mm × 340 mm, Sealed Air Corporation, Cryovac, Duncan, SC) (6 sausages/package) and the packages were subjected to thermo-shrinking in water at 85 °C for 3 s. They were then stored in a cooling chamber at 4 °C and analyzed in terms of their technological, microbiological and sensory aspects.

The emulsion-forming ability in the raw batter and the shear force of the frankfurters in the transverse section were analyzed with the same methodology as in the first step. The following paragraphs discuss the other sets of analysis performed.

2.2.1. Proximate analysis, pH, mineral and nitrite content

All these proximate analysis, pH, mineral and nitrite content were performed in three cooked frankfurter samples of each treatment. Protein, moisture, ash, carbohydrates and total fat content (g/100 g) were measured (AOAC, 2005).

Cooked frankfurter pH was measured using a pH meter (DM 21, Digimed, São Paulo, Brazil) and a glass penetration electrode (Digimed, São Paulo, Brazil), calibrated with 4.0 and 7.0 phosphate buffers.

Sodium, potassium and phosphorus content (mg/100 g) were determined in all treatments according to the procedures of the (AOAC, 2005). The quantification of inorganic elements was performed using an emission spectrometer with inductively coupled plasma (ICP OES) (Vista MPX, Varian, Mulgrave Victoria, Australia).

The nitrite content (mg/kg) was determined as described in Brasil (2005), where the absorbance value of each sample was measured in a spectrophotometer at 540 nm and the concentration of nitrite was calculated based on the interpolation on the standard curve, using a standard solution of sodium nitrite.

2.2.2. Cooking loss

The cooking loss was performed in triplicate of approximately 1 kg of frankfurters links of each treatment. Cooking loss of frankfurters was calculated by weighing the raw frankfurter prior to thermal processing and reweighing after thermal processing and cooling (Colmenero et al., 2005).

2.2.3. Purge loss

For purge loss analysis, packaged frankfurters were weighed, opened and then drained. The bags and frankfurters were blotted dry with a paper towel. The bag weight and frankfurter weight were recorded and the percentage of purge was determined (McGough et al., 2012). This analysis was conducted on products stored at 4 °C for 1, 14, 28, 42 and 56 days.

2.2.4. Texture profile analysis (TPA)

Texture of frankfurters stored for 24 h at 4 °C was assessed using texture profile analysis (TPA). The measurements were performed at room temperature (22 °C) using a texture analyzer TA-XT 2i, (Stable Micro Systems, Surrey, England). The equipment was calibrated with a weight of 5 kg, and a 25 kg load cell was used for the test. The frankfurters samples were cut into cylinders (20 mm) and placed vertically on the platform (HDP/90) of the analyzer. Ten (10) pieces of each treatment were subjected to a two-cycle compression strength (50% of their original height) was measured with a cylindrical probe of 35 mm in diameter (P/35), (Stable Micro Systems, Surrey, England) at a constant speed of 0.8 mm/s. Data were collected and TPA curves were created using Texture Expert software, version 2.64 (Stable Micro Systems, Surrey, UK). The parameters were calculated as recommended by Bourne (1978) for this type of product.

Hardness is the peak force during the first compression. Springiness is the height the sample recovered during the time that elapsed between the end of the first compression and the start of the second compression. Cohesiveness is the ratio of the positive force area during the second compression to that of the first compression [calculated as (area2/area1) × 100]. Chewiness is calculated as follows: hardness × (cohesiveness/100) × springiness (McGough et al., 2012).

2.2.5. Microbiological analysis

Microbiological analyses were performed after the samples were cooked to verify the hygienic quality of the sample processing according to the limits specified by the RDC no 12 of the "Agencia Nacional de Vigilancia Sanitaria" (Brasil, 2001) for raw, cooked, cooled or frozen meat products. The determined limits for cooked meat products (bologna, sausage, ham, black pudding and others) are 10^3 CFU/g for thermotolerant coliforms, 3×10^3 CFU/g for coagulase-positive staphylococcus, 5×10^2 CFU/g sulphite-reducing clostridia and absence in 25 g for *Salmonella* sp.

Thermotolerant coliforms analysis was performed according to ISO 7251 (2005) expressing the result as Most Probable Number (MPN); *Salmonella* sp. according to ISO 6579 (2007) expressing the results as presence or absence in 25 g; and total aerobic mesophilic bacteria, lactic acid bacteria, coagulase-positive staphylococcus and sulphite-reducing clostridia were analyzed according to Downes and Ito (2001), the results were expressed as log cfu/g (colony-forming units).

2.2.6. Sensory analysis

The sensory analysis performed in the present study received approval from the Human Research Ethics Committee of the "*Escola Superior de Agricultura Luiz de Queiroz*" (University of Sao Paulo, Piracicaba, SP, Brazil).

In total, 120 consumers of frankfurters were recruited to assess the samples. Habitual frankfurters consumers of different ages (18–60 years old) were recruited from the staff members, trainees and visitors (approximately one third of total consumers) of the Institute of Food Technology (Campinas, SP, Brazil), with no restrictions for gender or socio-economic class. All were selected on the basis that they consume and purchase frankfurters regularly.

For sensory analysis one day process frankfurter was used as sample. Frankfurters were heated in boiling water for 3 min and the sausages were cut into cylinders of 2.5 cm length.

The acceptability of the samples were assessed in terms of "overall acceptability" and in particular for "flavor" and "texture", using a nine-point hedonic scale (9 — liked extremely; 8 — liked very much; 7 — liked moderately; 6 — liked slightly; 5 — neither liked nor disliked; 4 — disliked slightly; 3 — disliked moderately; 2 — disliked very much; 1 — disliked extremely). Consumers also assessed the "sausage flavor", "smoked flavor", "salty flavor" and "texture" using a five-point JAR (Just About Right) scale (5 — much more intense/firm than I like; 4 — more intense/firm than I like; 3 — just about right; 2 — less intense/firm than I like; 1 — much less intense/firm than I like). Finally, they answered the "purchase intent" using a five-point scale: (5 — definitely would buy; 4 — probably would buy; 3 — maybe/maybe not buy; 2 — probably would not buy; 1 — definitely would not buy) (Meilgaard, Civille, & Carr, 2006). By the end, consumers checked the product characteristics using the Check All That Apply (CATA) method to gain an understanding of consumer perceptions as an exploratory investigation (Ares, Barreiro, Deliza, Gimenez, & Gambaro, 2010). In order to do so, a list of 34 attributes was generated by triadic elicitation (Repertory Grid method). This list was then used by 20 assessors with three samples. These attributes were presented at random among the consumers.

The samples were assessed in a sequential monadic order, according to a balanced complete block design, and presented with three random digit codes. The test was conducted in individual booths under fluorescent lamps, equipped with computerized Compusense Five (version 5.4), to collect and analyze data. The data were then subjected to analysis of variance and Tukey's test for comparison of means.

2.3. Statistical analysis

2.3.1. Response surface methodology

Response surface methodology was used to perform the simultaneous assessment of the three independent variables (NaCl, KCl and phosphate). For each variable, the variance was decomposed into linear, quadratic and interaction components in order to assess the second order polynomial equation and the relative importance of each one. Statistical analysis was conducted using STATISTICA® 5.0 software (Statsoft Inc., USA). The effect and significance were assessed based on a 5% probability ($P < 0.05$).

2.3.2. Frankfurter analysis

The data collected from experiments were analyzed by analysis of variance (ANOVA) and Tukey's test to compare the treatment means ($P < 0.05$). The study was a randomized block design, with three blocks (each block corresponding to an independent frankfurter processing). The statistical model included the levels of NaCl and storage time as fixed effects and blocks as random effect. Mean values and standard error of means were reported. Data were analyzed using SAS (V.9.1 SAS Inst. Inc., Cary, NC).

2.3.3. Sensory analysis

Sensory analysis was performed in a single session (one day), therefore, there was no session effect. The statistical model included the level of NaCl as fixed effects and consumers as random effect. Results from the JAR scale were analyzed using Pearson's chi-squared test to compare samples F1 or F1.3 with F1.75. The frequency of citations was assessed for responses to the CATA in a binary combination, before analysis using Cochran's Q test. Attributes that obtained $P < 0.20$ were subjected to Correspondence Analysis (CA) using the Hellinger Distance.

A study considering two age groups (18–30 and 31–60 year-old) using ANOVA to analyze the attributes evaluated for each treatment (F1, F1.3 and F1.75). Salt intensity was studied through hierarchical cluster within the two age groups.

3. Results and discussion

3.1. Analysis of meat emulsions

The chemical composition of the raw materials used in the preparation of meat emulsions were within quality standards. The following results were recorded for beef shoulder: 74.24 ± 0.11 g/100 g of moisture; 5.08 ± 0.08 g/100 g of total fat; 1.11 ± 0.04 g/100 g of ash; 18.92 ± 0.44/100 g of protein and 5.83 ± 0.01 pH. The pork shoulder results were as follows: 75.63 ± 0.12 g/100 g of moisture; 3.25 ± 0.04 g/100 g of fat; 1.31 ± 0.04 g/100 g of ash; 19.45 ± 0.17/100 g of protein and 6.14 ± 0.01 pH.

From the results obtained for emulsion forming ability and shear force (Table 1), it was not possible to develop a mathematical model with the encoded variables, since none of the parameters of the model were significant (95% confidence) and the percentage of explained variance or coefficient of determination (R^2) was lower than 70% (23.15%). In other words, the variables (NaCl, KCl and phosphate levels) did not affect the emulsion forming ability in this meat emulsion model system, under the conditions of this study. And the high emulsion forming ability of myofibrillar protein used (bovine and pork shoulder) together with soy protein and cassava starch that improve gel formation and water binding, may have increased the stability of the emulsion to such an extent that the variation of the salts did not influence this parameter.

Table 1
Emulsion-forming ability and shear force of emulsions in a model system formulated with different concentrations of phosphate, NaCl and KCl.

Trial	Phosphate (%)	NaCl (%)	KCl (%)	Emulsion-forming ability (%)	Shear force (g)
1	0.10	1.30	0.46	8.9	608.6
2	0.40	1.30	0.46	8.6	575.6
3	0.10	2.20	0.46	8.5	561.0
4	0.40	2.20	0.46	8.3	527.6
5	0.10	1.30	1.24	8.4	571.6
6	0.40	1.30	1.24	8.4	580.7
7	0.10	2.20	1.24	8.2	517.7
8	0.40	2.20	1.24	8.2	571.3
9	0.00	1.75	0.85	9.4	565.5
10	0.50	1.75	0.85	9.4	586.2
11	0.25	1.00	0.85	9.4	672.9
12	0.25	2.50	0.85	8.3	580.1
13	0.25	1.75	0.20	9.5	564.1
14	0.25	1.75	1.50	8.5	590.6
15	0.25	1.75	0.85	8.0	586.1
16	0.25	1.75	0.85	7.8	669.7
17	0.25	1.75	0.85	8.4	686.7
18	0.25	1.75	0.85	9.0	670.9
19	0.25	1.75	0.85	8.9	624.1
20	0.25	1.75	0.85	8.8	619.3

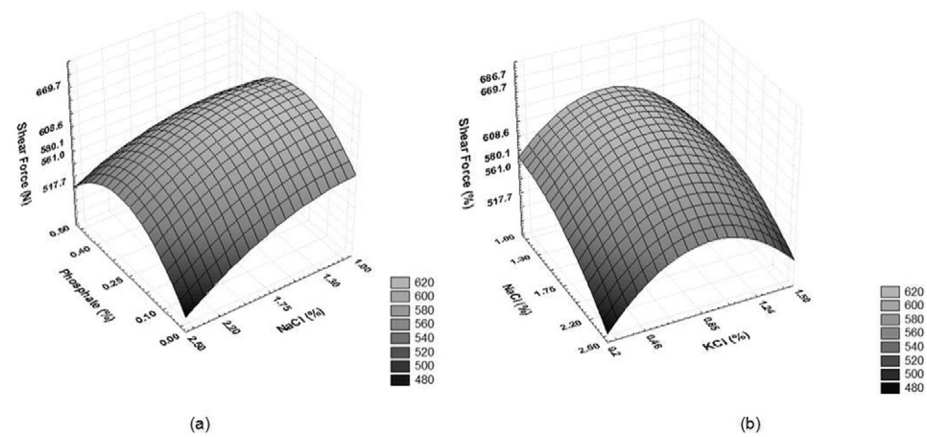

Fig. 1. Surface response for shear force as a function of the ratio of NaCl, phosphate and potassium in meat emulsions. (a) KCl fixed at 0.85%; and (b) phosphate was fixed at 0.25%.

The percentage of variance for the coefficient of determination (R^2) was 75.56%. The calculated F (47.99) of regression was three times greater than the tabulated F (3.02), which means that the predictive model could calculate the F lack of fit value (0.39), which was less than the tabulated F (5.05) and thus, was not significant.

Fig. 1 shows that NaCl concentrations between 1% and 1.75% increased the shear force. Phosphate exhibited higher values of shear force at the level of 0.25% and KCl at the level of 0.85%, when the KCl was fixed at 0.85% (a) and the phosphate was fixed at 0.25% (b).

In the meat emulsion system in which the raw material was beef and pork shoulder, only the shear force was influenced by the variation of salts.

3.2. Assessment of sausages

3.2.1. Proximate analysis and mineral contents

Table 2 displays the proximate analysis and contents of sodium, phosphorus and potassium chloride in the final product. The analysis of minerals was important to confirm the final concentration of each salt in the products. The table shows that sodium, phosphate and potassium were consistent with the levels added for each treatment and represents 18% reduction of sodium when comparing treatments with 1.75% of NaCl with 1.3% of NaCl, and 36% reduction of sodium when comparing treatments with 1.75% of NaCl with 1% of NaCl treatment.

3.2.2. Physical and chemical analysis

No differences were found between treatments for cooking loss ($P > 0.05$) presented in Table 3, it could be due to the use of beef and pork meat (that have high emulsion forming ability), soy protein and cassava starch in the formulation, that increase the gel forming and water binding capacity. Other factor that could influence the results of all the treatments in relation to cooking loss is the addition of phosphate. There is agreement that cooking losses, in fine meat homogenate, are much reduced in meat treated with polyphosphates in addition to NaCl (Offer & Knight, 1988).

Tobin, O'Sullivan, Hamill, and Kerry (2013) reported that increasing the salt content from 0.8% to 2.4% improves the cooking loss and water retention capacity of pork sausages. Choi et al. (2014) also found no significant difference ($P > 0.05$) in the analysis of cooking loss of frankfurters with reduced sodium chloride. Aaslyng et al. (2014) showed low production yields at 1.23% salt but not at 1.74% salt compared with the control at 2.19%, while reduction from 2.25% to 1.75% did not change the yield (McGough et al., 2012), similar as in the present study with frankfurters containing 2.33%, 1.91% and 1.49% NaCl. The suggested limit for salt reduction emulsion sausages (below 1.74% and above 1.23% salt) at which the functional properties seen to be affected (Aaslyng et al., 2014) may be or could be extended considering products with different ingredients included in the formula.

Table 2
Proximate analysis and mineral contents of the sausages with different salt content.

	F1	F1.3	F1.75
Moisture (g/100 g)	63.6 ± 0.4	62.3 ± 0.5	64.7 ± 0.3
Fat (g/100 g)	15.8 ± 0.6	16.6 ± 0.7	13.9 ± 0.0
Protein (g/100 g)	13.3 ± 0.2	13.1 ± 0.3	13.7 ± 0.1
Ash (g/100 g)	2.9 ± 0.0	3.3 ± 0.0	3.6 ± 0.1
Carbohydrate (g/100 g)	2.5 ± 0.1	2.6 ± 0.0	2.4 ± 0.0
Sodium (mg/100 g)	587.3 ± 21.2	749.9 ± 24.2	916.7 ± 64.0
Phosphorus (mg/100 g)	221.5 ± 11.1	210.1 ± 9.8	188.4 ± 12.2
Potassium (mg/100 g)	715.1 ± 5.5	739.7 ± 3.0	725.1 ± 17.6

Values are mean ± standard error of triplicate of the process at different times; n = 9.
F 1 = frankfurter containing 1% of sodium chloride; F 1.3 = frankfurter containing 1.3% of sodium chloride; F 1.75 = frankfurter containing 1.75% of sodium chloride.

Table 3
Physical and chemical analysis, shear force (SF) and texture profile of frankfurters with different salt content.

Analysis	Day	F1	F1.3	F1.75	*P* value
% cooking loss (n = 12)	–	4.6 ± 0.4^{Aa}	4.7 ± 0.3^{Aa}	5.2 ± 0.4^{Aa}	0.30
% emulsion-forming ability (n = 45)	–	4.2 ± 0.1^{Ab}	4.1 ± 0.1^{Ab}	5.0 ± 0.5^{Aa}	<0.01
pH (n = 9)	1	6.2 ± 0.1^{Ca}	6.1 ± 0.0^{Ba}	6.1 ± 0.0^{Ba}	0.20
	14	6.3 ± 0.0^{BCa}	6.2 ± 0.0^{Aab}	6.2 ± 0.0^{ABb}	<0.01
	28	6.4 ± 0.0^{Aa}	6.2 ± 0.1^{ABb}	6.3 ± 0.0^{Aab}	<0.01
	42	6.3 ± 0.0^{ABa}	6.3 ± 0.0^{Ab}	6.2 ± 0.0^{ABb}	<0.01
	56	6.4 ± 0.0^{ABa}	6.3 ± 0.0^{Aa}	6.2 ± 0.1^{Bb}	<0.01
P value		<0.01	<0.01	<0.01	
Residual nitrite (mg/kg)	1	148.4 ± 3.4^{Aa}	147.9 ± 2.8^{Aa}	150.5 ± 4.1^{Aa}	0.80
	14	117.7 ± 5.7^{Ba}	110.5 ± 4.2^{Ba}	110.7 ± 4.9^{Ba}	0.50
	28	97.0 ± 4.7^{Ca}	76.6 ± 4.3^{Cb}	84.7 ± 3.9^{Cab}	<0.01
	42	76.0 ± 3.6^{Da}	64.0 ± 2.1^{CDb}	63.7 ± 3.2^{Db}	0.01
	56	65.1 ± 3.3^{Da}	53.6 ± 1.9^{Db}	49.1 ± 2.8^{Db}	<0.01
P value		<0.01	<0.01	<0.01	
% purge loss (n = 9)	1	1.5 ± 0.2^{Ba}	1.8 ± 0.2^{Aa}	1.4 ± 0.3^{Aa}	0.50
	14	1.6 ± 0.2^{Ba}	1.8 ± 0.3^{Aa}	1.7 ± 0.2^{Aa}	0.90
	28	2.8 ± 0.3^{Aa}	2.0 ± 0.4^{Aa}	2.9 ± 0.7^{Aa}	0.30
	42	1.9 ± 0.1^{Ba}	1.9 ± 0.3^{Aa}	1.7 ± 0.3^{Aa}	0.70
	56	1.9 ± 0.2^{Ba}	1.5 ± 0.3^{Aa}	1.9 ± 0.2^{Aa}	0.40
P value		<0.01	0.80	0.10	
Shear force (N)	–	1.7 ± 0.1^{b}	1.9 ± 0.2^{a}	1.7 ± 0.1^{b}	<0.01
Hardness (N)	–	3.1 ± 0.7^{a}	3.4 ± 0.7^{a}	3.1 ± 0.5^{a}	0.20
Springiness	–	0.8 ± 0.0^{a}	0.8 ± 0.0^{a}	0.8 ± 0.0^{a}	0.02
Cohesiveness	–	0.6 ± 0.0^{a}	0.6 ± 0.0^{a}	0.6 ± 0.0^{a}	0.60
Chewiness (N)		1.7 ± 0.4^{a}	1.8 ± 0.3^{a}	1.7 ± 0.2^{a}	0.10

Values are mean ± standard error of triplicate of the process at different times.
Different lower case letters in the same rows indicate significant differences ($P < 0.05$).
Different capital letters in the same columns for the same parameter indicate significant differences ($P < 0.05$).
F 1 = frankfurter containing 1% of sodium chloride; F 1.3 = frankfurter containing 1.3% of sodium chloride; F 1.75 = frankfurter containing 1.75% of sodium chloride.

In studies of sodium chloride reduction in meat products, emulsion-forming ability is an important parameter that influences the sensory properties and shelf life of products (Horita et al., 2011). With regards to emulsion-forming ability (Table 3), significant differences ($P < 0.05$) were found between F1.75 and the others (F1 and F1.3) treatments.

The treatments with 1% and 1.3% did not differ, it could be due to a number of ingredients, both protein and nonprotein, frequently added to processed meat products for the proposes of increasing bind, often at a reduced cost from muscle tissue as soy protein sources. Soy protein has been added to processed meats as a binder (Matulis, McKeith, Sutherland, & Brewer, 1995). In finely ground meat products, soy protein gels to form a matrix entrapping moisture and lipid droplets, resulting in improved emulsion stability. And cassava starch was often added to this type of products to increase the gel forming and water binding capacity, which also occurred in the analyses of meat emulsion in this study (item 3.1).

The F 1.75 treatment exhibited the highest values (higher values means worse emulsion-forming ability), which means that the treatment with higher sodium content exhibited the lowest emulsion-forming ability in this test. More studies should be performed in relation to the synergism among salts, particularly between NaCl and phosphates, since the F1 and F1.3 presented better results or equivalent technological characteristics compared to F1.75, which was not expected. Offer and Knight (1988) reported that the increase in extraction protein from minced meat when pyrophosphate was added was more marked at lower concentrations of NaCl.

In relation to effect of potassium chloride in water holding, and consequently in emulsion-forming ability, Puolanne and Halonen (2010) reported that in curing meat the NaCl may be partly substituted by KCl to reducing sodium of the product. The fact that NaCl behaves very differently compared with KCl is often totally ignored. NaCl is formed from a kosmotropic cation and a chaotropic anion, while in KCl, both the cation and anion are chaotropic. In this way, these two salts affect the cell protein structures in quite a different manner. Once, kosmotropic ions have a positive hydration effect, because the water molecules is more structured due to enforced hydrogen bound between molecules, and chaotropic ions have a negative hydration effect, because the water is less structured due to the hydrogen bound between water molecules is weak (Puolanne & Halonen, 2010).

At the point of characterization (first day), there was no pH difference between the treatments (Table 3). The salt content does not influence the pH of the frankfurter, as reported by Puolanne, Ruusunen, and Vainionpaa (2001) that studied a range of 0.5 to 2.5% of NaCl. The F1 treatment exhibited the highest mean pH values at the second assessment point (14 days). Thus, one can assume that the lower content of NaCl, under the conditions studied, maintained higher pH values compared to the treatments with higher concentrations of sodium chloride.

There were no significant differences ($P > 0.05$) among the treatments for purge loss. One factor that may have influenced this result was the use of shrink packing. Most shrink films are composed of POs (polyolefin including polypropylene or polyethylene), polyvinyl chloride and polyvinylidene copolymer. It has been reported that shrink packing after evacuation by passing through a hot air tunnel (around 150 °C) or hot water tank (80–90 °C) for several seconds could reduce the drip loss, when compared with non-shrink film (Aspe, Roeckel, Marti, & Jimenez, 2008). These effects could be attributed to the environment of shrink film allowing less space for exudates, or the more flexible and soft nature of the packaging (Payne, Durham, Scott, & Devine, 1998).

When compared with common vacuum packaging, heat-shrinking package molds the content and increases the contact between the product and the packaging, thereby providing a better presentation of the final product for the consumer and minimizing exudation problems (Zarate & Zaritzky, 1985). Still according to these authors the use of heat-shrinking package reduces the purge loss. The fact that the purge loss was not influenced by the reduction of sodium chloride is positive, given that a higher purge loss increases the possibility of microbial growth, depending on the time and temperature of storage. Considering the microbial growth in a “solid-state” (Leistner, 1994) are arrested in little cavities of the product, microorganisms probably wither away because metabolites accumulate and nutrients deplete in the nests. However, with a high purge loss, metabolites and nutrients could disseminate easier than in solid-state, and the microbial growth could be higher. Purge accumulation in the packaged product during retail storage, is undesirable for esthetic and microbiological reasons (Salcedo-Sandoval, Cofrades, Ruiz-Capillas, & Jiménez-Colmenero, 2015).

Based on the assessment period for purge loss, only the F1 treatment exhibited a difference between the treatments throughout the study, with the highest purge loss observed after 28 days in all treatments. Results on the study of Pintado et al. (2015) that at 27 days the frankfurters purge loss means was higher and differ statistically through shelf life, and on the study of (Salcedo-Sandoval et al., 2015) this increase and decrease through purge loss is also observed, at same manner as occurred in this study, the analysis of subsequent days presented lower values.

3.2.3. Shear force (SF) and texture profile

Treatment F1.3 recorded the highest shear force values. The higher values of shear force exhibited by frankfurters (Table 3), as compared with the emulsion in model systems (Table 1), it could be due to that emulsions were heat-treated in a water bath, in waterproof bags. In other words, they did not experience the steam oven, where they suffer the drying process, forming a skin surface layer that is responsible for the force peaks in the shear force analysis. Another important factor is the loss of moisture in the process of cooking in a steam oven, which could be to a firmer texture. This does not occur in the meat emulsion model system.

More studies should be performed in relation to the synergism among salts, particularly between NaCl and phosphates, since the F1.3 presented better results or equivalent technological characteristics compared to F1.75, which was not expected. This fact is reinforced by response surface results in the present study (Fig. 1), which shows that an excess of salt concentration may decrease shear force values. And also by the study of emulsion-forming ability, in which the F1.75 had worse results in relation to F1 and F1.3. Phosphates are similar to NaCl exhibiting improved elasticity of meat gels with a synergistic effect on gel strength when both are used together (Fernandez-Martin, Cofrades, Carballo, & Jiménez-Colmenero, 2002). Ionic strength has an important effect on the gelatinization of proteins as a result of its effect on the solubility of myofibrillar proteins, which could be reached by the addition of certain levels of phosphate. At lower ionic strength, better gel networks are formed in meat systems with more rigid and fine-stranded gels than those in higher ionic strength (Yang, Zhou, Xu, & Wang, 2007).

In emulsified meat products, texture is related to the ability to bind water with the fat that should develop during batter preparation and maintained after heat treatment. Furthermore, the NaCl concentration normally added to meat products produces the ionic strength required for the dissolution and extraction of the myofibrillar proteins responsible for emulsification, gelatinization and water-holding capacity, among others (Horita et al., 2011).

The parameters of hardness, springiness, cohesiveness and chewiness were not affected by the different treatments. It could be due to the soy protein that has been added to processed meats as a binder (Matulis, McKeith, Sutherland, & Brewer, 1995). And cassava starch was often added to this type of products to increase the gel forming and water binding capacity, which also occurred in the analyses of meat emulsion in this study (item 3.1). In a study by Choi et al. (2014), these parameters of TPA also did not change when comparing treatment with 20 g/kg (100%) of sodium chloride and treatment with only 60% NaCl.

3.2.4. Residual nitrite

The presence of nitrite in sausages improves the color of meat products and prevents the growth of *Clostridium botulinum*, which produces a potentially fatal toxin (Skrokki, 1995). The Scientific Panel on Biological Hazards (EFSA, 2003) reported that nitrite exert a concentration-dependent antimicrobial effect in cured meat products, including inhibition of the outgrowth of spores of putrefactive and pathogenic bacteria such as *Clostridium botulinum.* Their antimicrobial effects are pH-dependent, increasing ten-fold for each unit fall in pH. The extent of protection provided to cured meats against microbial growth has been attributed by different researches to many factors including the input concentration of nitrite, the residual nitrite concentration, the salt concentration of the product, the addition of sodium ascorbate (or isoascorbate/erythorbate), the heat treatment applied, the storage temperatures, the initial pH of the meat, and the spore load initially present. The extent of protection is due to a combination of factors rather than any single factor. In products with a low salt content and having a prolonged shelf-life, addition of between 50 and 150 mg/kg nitrite is necessary to inhibit the growth of *C. botulinum.* The Panel related that the ingoing amount of nitrite, rather than the residual amount, contributes to the inhibitory activity against *C. botulinum.*

All of the treatments differed over the assessment period: the level of nitrite progressively reduced, regardless of the quantity of sodium chloride added, as shown in Table 3. From 28 days, significant differences ($P < 0.05$) were found between the treatments. The treatment with 1% sodium chloride maintained the highest levels of nitrite compared to the other treatments.

3.2.5. Microbiological assessment

The microbiological assessment of frankfurters in all treatments confirmed no differences for thermotolerant coliforms (<3.0 log MPN/g), coagulase-positive staphylococcus (<2.0 log CFU/g), sulphite-reducing clostridia (<1.0 log CFU/g) or *Salmonella* spp. (absence in 25 g).

No differences ($P > 0.05$) were found between three salt levels in this study as described by Aaslyng et al. (2014) for mesophilic microorganisms and lactic acid bacteria. During refrigerated storage, there was a slightly significant increase in the quantity of these microorganisms. The mesophilic microorganism count was 1.2 log CFU/g on day 1 and reached 5.9 log CFU/g on day 56. Similarly, lactic acid bacteria increased from 1.0 log CFU/g on day 1 to 5.1 log CFU/g after 56 days of refrigerated storage.

Sodium lactate is used by meat industry to improve the shelf life and perceived saltiness when reducing NaCl content and usually adding 1.2% sodium lactate containing 0.24% sodium. This amount of sodium equals to 0.6% NaCl (Ruusunen & Puolanne, 2005). In this study, sodium lactate (1%) was added in all treatments, what would have influenced the results that presented no difference in microbial growing among treatments.

3.2.6. Sensory assessment

In order to carry out the sensory assessment, a group of 120 frankfurter consumers (37 men and 83 women) were recruited. Of these, 77% were classified in economical class B and the rest were equally divided among classes A and C, based on the ABEP social-economic classification (ABEP, 2012). The age of the consumers was broken down as follows: 18–24 years old (44.2%); 25–30 years old (13.3%); 31–40 years old (12.5%); 41–50 years old (19.2%); 51 to 60 years (10.8%). The frequency of frankfurter consumption was: more than once a week — 8%; weekly — 23%; fortnightly — 39%; monthly — 10%; occasionally — 20%.

The acceptability test revealed that the samples were not significantly different ($P > 0.05$) in terms of the texture (Table 4). With regard to the overall acceptability and frankfurter flavor, the treatments with 1.3% and 1.75% NaCl added (corresponding to 1.91% and 2.33% total salt respectively) obtained mean scores corresponding to “liked moderately” and did not differ significantly between each other ($P > 0.05$). Both were more accepted ($P < 0.05$) than the treatment with 1.0% NaCl added (corresponding to 1.5% total salt), which obtained mean scores between “liked slightly” and “liked moderately”, what is according with Tobin et al. (2012) that reported salts below 1.5% had a negative effect on consumer acceptability, with 2.5% salt concentrations franks being the most preferred by consumers.

Table 4
Results of the sensory assessment of frankfurters with different salt content.

Attribute	F1	F1.3	F1.75	*P* value
Overall acceptability[1]	6.6 ± 1.3^{b}	7.0 ± 1.2^{a}	7.0 ± 1.2^{a}	<0.01
Frankfurter flavor[1]	6.4 ± 1.4^{b}	7.0 ± 1.2^{a}	7.0 ± 1.2^{a}	<0.01
Texture[1]	6.5 ± 1.6^{a}	6.8 ± 1.4^{a}	6.8 ± 1.4^{a}	0.10
Purchase intent[2]	3.4 ± 1.1^{b}	3.8 ± 1.0^{a}	3.9 ± 1.0^{a}	<0.01

Mean ± standard deviation of 120 ratings per sample.
Different lower case letters in the same rows indicate significant differences ($P < 0.05$).
[1] (9 liked extremely; 8 liked very much; 7 liked moderately; 6 liked slightly; 5 neither liked nor disliked; 4 disliked slightly; 3 disliked moderately; 2 disliked very much; 1 extremely disliked).
[2] (5 definitely would buy; 4 probably would buy; 3 maybe would buy/maybe would not buy; 2 probably would not buy; 1 definitely would not buy).

The “purchase intent” test confirmed the results observed in the overall acceptability test, indicating that treatments F1.3 and F1.75 did not differ significantly between each other ($P > 0.05$), with both samples obtaining mean scores corresponding to “probably would buy”. Both treatments differed significantly ($P < 0.05$) to the 1.0% NaCl treatment, which obtained mean scores between “maybe would buy/maybe not would buy” and “probably would buy” on the scale used.

The potential for improvement of the product was identified based on the survey performed with the consumers (JAR scale), which confirmed significantly different results (Fig. 2). No significant difference was found between the frankfurters with 1.3% and 1.75% NaCl in terms of the intensity of the attributes of “frankfurter flavor”, “smoked flavor” and “salty”, and both were significantly different to frankfurters with 1% NaCl. In all treatments was added sodium lactate that by Ruusunen and Puolanne (2005) have a perceived saltiness effect, it could be a factor that contributed to found no difference between F1.3 and F1.75. With the exception of “firmness”, none of the samples were significantly different when compared with the others. This results was somewhat expected since most consumers in Brazil are used to “hot dog” type sausages which often contain mechanically separated meat in the formulation and exhibit a relatively low shear force. In other words, these consumers are used to a less firm sausage. Thus, the consumers could detect the intensity of the salt but still accepted products with 1.3% and 1.75% sodium chloride. The data were aggregated into a scale (3 levels) and are displayed in the graphics.

The contingency for the 34 frequencies in a binary combination of CATA was analyzed by Cochran's Q test (data not shown). Check-all-that-apply is a sensory assessment tool that is easier to understand and faster than the methods that use trained evaluators. These questions allow the respondents to select attributes relevant to them rather analyzing all of the attributes of a scale (Ares et al., 2010). Based on CATA analysis, sixteen attributes that presented $P < 0.20$ were assessed using Correspondence Analysis and the Hellinger Distance (Fig. 3). Note that the distances between the products in the plot do not necessarily respect the actual distances of the products. The graphic explained 97% in this survey.

In general, frankfurters with 1.3% NaCl (F1.3) and with 1.75% NaCl (F1.75) were characterized as follows: “good level of seasoning” (okseason); “tasty” and “beautiful appearance” (beautapp). Frankfurters with 1% NaCl (F1) and with 1.75% NaCl (F1.75) were characterized as follows: “pleasant flavor” (pleasflv), “juicy”; “unattractive appearance” (uglyappe) and “light color” (clearcol). Frankfurters with 1% NaCl (F1) and with 1.3% NaCl (F1.3) were characterized as follows: “strange taste” (stranget); “firm skin” (firm skin) and “dry”. Frankfurters with 1% NaCl (F1) were characterized as “tasteless” and “less salty” (less salty). Frankfurters with 1.3% NaCl (F1.3) were characterized

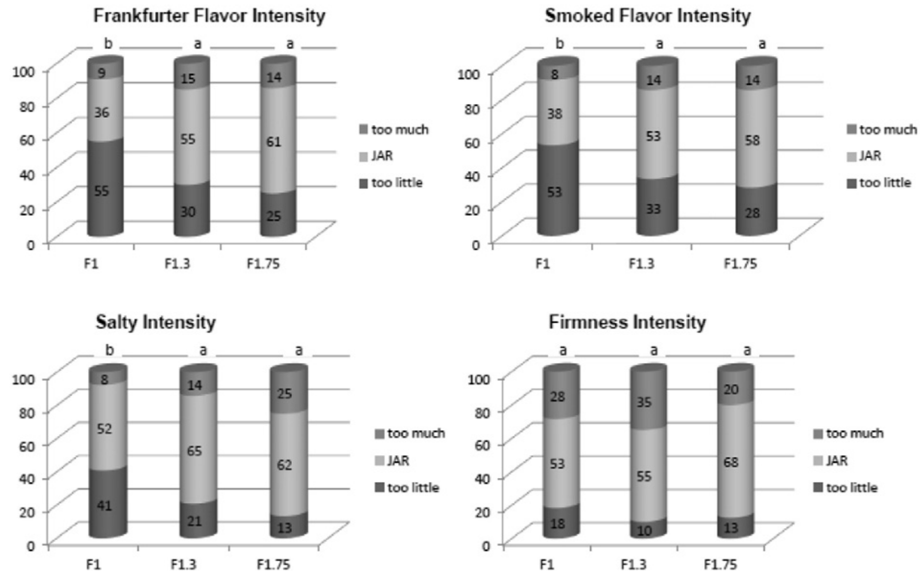

Fig. 2. Intensity on the JAR (Just About Right) scale of "frankfurter flavor", "smoked flavor", "salty" and "firmness" from frankfurters with 1.00% (F1); 1.30% (F1.3) and 1.75% (F1.7) NaCl. Different letters indicate significant differences (Pearson's analysis <0.05) between two samples in the perception of intensity.

as "adequately salty" (oksalt) and "pink". Frankfurters with 1.75% NaCl (F1.75) were characterized as "too salty" (toosalty) and "very spicy" (strngssn). This information, together with the results of the acceptability test, suggest that perceptions of lack of taste and lack of saltiness affect acceptability.

Considering that F1 (frankfurter with 1.00% NaCl added) presented flavor, salty intensity and firmness problems in relation to F1.3 and F1.75, it is important to study either the addition of flavor enhancer, spices, smoke or processing steps to improve the quality of reduced sodium frankfurter.

ANOVA test was performed with consumers in two age groups (18–30 and 31–60 year-old), with two factors (consumers and age group). The analysis indicated significant difference only for "ideal texture intensity" attribute for treatments studied, F1 ($P = 0.043$), F1.3 ($P = 0.021$) and F1.75 ($P = 0.017$). The 31–60 year-old groups considered the texture intensity as "ideal", and 18–30 year-old considered as "slightly above ideal", that is the younger group prefer less firm frankfurters.

A hierarchical cluster was performed by consumer age in two groups (18–30 and 31–60 year-old) to verify "ideal salt intensity". No

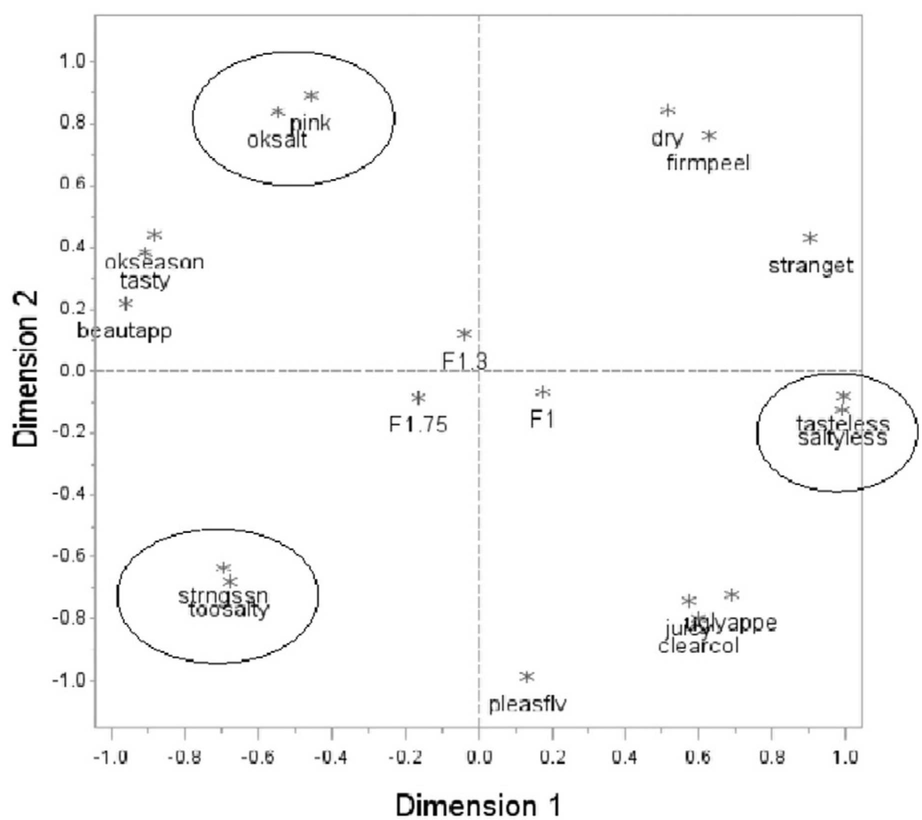

Fig. 3. Correspondence Analysis using the Hellinger Distance explained 67% (Dimension 1) and 31% (Dimension 2) of frankfurters: F1 = 1% NaCl; F1.3 = 1.3% NaCl; F1.75 = 1.75% NaCl.

significant difference was found in 31–60 year-old group in relation to "ideal salt intensity". However, in the 18–30 year-old group, the evaluation showed two thirds of this group preferring the salt intensity of F1.3 treatment, this fact open new perspectives in relation to percentage of reduction sodium in meat products.

4. Conclusion

The reduction of sodium chloride by 25%, from 1.75% to 1.3%, along with the 18% reduction of sodium (916 mg/100 g to 750 mg/100 g), did not affect the yield, purge loss and microbiological quality during storage, nor did it affect the sensory attributes assessed by consumers. The addition of 0.25% of phosphate and 0.85% of potassium chloride may have contributed to the sodium reduction without affecting the technological, microbiological and sensory aspects. Consumers identified differences among product characteristics according to the level of salt. But the sausages added by 1.75% and 1.30% NaCl were not differentiated, and showed good acceptance (liked moderately) by consumers. Thus, the sausage with 750 mg/kg sodium or 1.91% NaCl (F1.3) obtained in this study can be considered an alternative to sodium reduction. The frankfurter with 1.3% NaCl added represents 48% NaCl or 24% sodium reduction when compared with south Brazilian retail frankfurters (2.5% NaCl or 987 mg/100 g Na) and it appears to be feasible from a technological microbiological and sensory point of view. Further study is needed to understand the synergy among salts, especially between NaCl and phosphate; the effect of flavor enhancers, spices and smoke; and process steps to improve the sausages characteristics of reduced sodium content.

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References

Aaslyng, M. D., Vestergaard, C., & Koch, A. G. (2014). The effect of salt reduction on sensory quality and microbial growth in hotdog sausages, bacon, ham and salami. *Meat Science*, *96*(1), 47–55.

ABEP (2012). *Critério de classificação econômica brasil*. Associação brasileira de empresas de pesquisa.

AOAC (2005). *Official methods of analysis*. Washington, DC: Association of Official Analytical Chemists.

Ares, G., Barreiro, C., Deliza, R., Gimenez, A., & Gambaro, A. (2010). Application of a check all-that-apply question to the development of chocolate milk desserts. *Journal of Sensory Studies*, *25*, 67–86. http://dx.doi.org/10.1111/j.1745-459X.2010.00290.x (Article).

Aspe, E., Roeckel, M., Marti, M. C., & Jimenez, R. (2008). Effect of pre-treatment with carbon monoxide and film properties on the quality of vacuum packaging of beef chops. [Article]. *Packaging Technology and Science*, *21*(7), 395–404.

Barbut, S., Maurer, A. J., & Lindsay, R. C. (1988). Effects of reduced sodium chloride and added phosphates on physical and sensory properties of Turkey frankfurters. *Journal of Food Science*, *53*(1), 62–66.

Bourne, M. C. (1978). Texture profile analysis. *Food Technology*, *32*(7), 62–66.

Brasil (2005). Métodos físico-químicos para análise de alimentos. *Adolfo Lutz*.

Brasil. Ministério da Saúde. Agência Nacional de Vigilância Sanitária. Resolução RDC nº 12 de 02 de janeiro de 2001. *Regulamento técnico sobre padrões microbiológicos para alimentos*. Brasília, DF. Diário Oficial [da] República Federativa do Brasil, 10 de jan. 2001. Available at: www.abic.com.br/arquivos/leg_resolucao12_01_anvisa.pdf. Accessed july 23, 2012.

Choi, Y. M., Jung, K. C., Jo, H. M., Nam, K. W., Choe, J. H., Rhee, M. S., & Kim, B. C. (2014). Combined effects of potassium lactate and calcium ascorbate as sodium chloride substitutes on the physicochemical and sensory characteristics of low-sodium frankfurter sausage. *Meat Science*, *96*(1), 21–25.

Collins, J. E. (1997). Reducing salt (sodium) levels in processed meat, poultry and fish products. In A. M. Pearson, & T. R. Dutson (Eds.), *Production and processing of healthy meat, poultry and fish products. Vol. 11*. (pp. 282–297). London: Springer US.

Colmenero, F. J., Ayo, M. J., & Carballo, J. (2005). Physicochemical properties of low sodium frankfurter with added walnut: Effect of transglutaminase combined with caseinate, KCl and dietary fibre as salt replacers. *Meat Science*, *69*(4), 781–788.

De Almeida, M. A., Villanueva, N. D. M., Ribeiro, F. A., Fadda, S. G., Pinto, J. S. S., & Contreras Castillo, C. J. (2015). Sensory acceptability of partial replacement of sodium chloride by potassium chloride and calcium chloride in production of salami with low sodium. *Meat Science*, *101*, 104–105.

Desmond, E. (2006). Reducing salt: A challenge for the meat industry. *Meat Science*, *74*(1), 188–196.

Downes, F. P., & Ito, K. (2001). *Compendium of methods for the microbiological examination of foods* (4th ed.). American Public Health Association.

EFSA (2003). Opinion of the scientific panel on biological hazards on the request from the commission related to the effects of nitrites/nitrates on the microbiological safety of meat products. *EFSA Journal*, *14*(1), 31.

Fernandez-Martin, F., Cofrades, S., Carballo, J., & Jiménez-Colmenero, F. (2002). Salt and phosphate effects on the gelling process of pressure/heat treated pork batters. *Meat Science*, *61*(1), 15–23.

Grossi, A., Søltoft-Jensen, J., Knudsen, C., Christensen, M., & Orlien, V. (2012). Reduction of salt in pork sausages by the addition of carrot fibre or potato starch and high pressure treatment. *Meat Science*, *92*(4), 481–489.

He, F. J., & MacGregor, G. A. (2010). Reducing population salt intake worldwide: From evidence to implementation. *Progress in Cardiovascular Diseases*, *52*(5), 363–382.

Horita, C. N., Morgano, M. A., Celeghini, R. M. S., & Pollonio, M. A. R. (2011). Physico-chemical and sensory properties of reduced-fat mortadella prepared with blends of calcium, magnesium and potassium chloride as partial substitutes for sodium chloride. *Meat Science*, *89*(4), 426–433.

ISO (2007). *ISO 6579:2002/Amd 1:2007. Detection of Salmonella spp. in animal feces and in environmental samples from the primary production stage, amendment 1, annex D. Microbiology of food and animal feeding stuffs. Horizontal method for the detection of Salmonella spp.*

ISO (2005). *ISO 7251:2005. Microbiology of food and animal feeding stuffs – horizontal method for the detection and enumeration of presumptive Escherichia coli – most probable number technique*. International Organization for Standardization.

Jiménez-Colmenero, F., Cofrades, S., López-López, I., Ruiz-Capillas, C., Pintado, T., & Solas, M. T. (2010). Technological and sensory characteristics of reduced/low-fat, low-salt frankfurters as affected by the addition of konjac and seaweed. *Meat Science*, *84*(3), 356–363.

Kang, Z., Wang, P., Xu, X., Zhu, C., Li, K., & Zhou, G. (2014). Effect of beating processing, as a means of reducing salt content in frankfurters: A physico-chemical and Raman spectroscopic study. *Meat Science*, *98*(2), 171–177.

Leistner, L. (1994). *Food design by hurdle technology and HACCP*. Kulmbach: Adalbert-Raps-Foundation.

Marchetti, L., Argel, N., Andrés, S. C., & Califani, A. N. (2015). Sodium-reduced lean sausages with fish oil optimized by a mixture design approach. *Meat Science*, *104*(1), 67–77.

Matulis, R. J., McKeith, F. K., Sutherland, J. W., & Brewer, M. S. (1995). Sensory characteristics of frankfurters as affected by salt, fat, soy protein, and carrageenan. *Journal of Food Science*, *60*(1), 48–54.

McGough, M. M., Sato, T., Rankin, S. A., & Sindelar, J. J. (2012). Reducing sodium levels in frankfurters using a natural flavor enhancer. *Meat Science*, *91*(2), 185–194.

Meilgaard, M., Civille, G. V., & Carr, B. T. (2006). *Sensory evaluation techniques* (4th ed.). Boca Raton: CRC Press.

Munasinghe, D. M. S., & Sakai, T. (2003). Sodium chloride (0.8 M) as a better protein extractant for fish meat quality assessments. *Journal of Food Science*, *68*(3), 1059–1062.

Offer, G., & Knight, P. (1988). The structural basis of water-holding in meat. In R. Lawrie (Ed.), *Developments in meat science* (pp. 63) (part 61).

Parks, L. L., & Carpenter, J. A. (1987). Functionality of six nonmeat proteins in meat emulsion systems. *Journal of Food Science*, *52*(2), 271–274.

Payne, S. R., Durham, C. J., Scott, S. M., & Devine, C. E. (1998). The effects of non-vacuum packaging systems on drip loss from chilled beef. *Meat Science*, *49*(3), 277–287.

Pintado, T., Herrero, A. M., Ruiz-Capillas, C., Triki, M., Carmona, P., & Jiménez-Colmenero, F. (2015). Effects of emulsion gels containing bioactive compounds on sensorial, technological, and structural properties of frankfurters. *Food Science and Technology International*, *14* (Retrieved from).

Puolanne, E., & Halonen, M. (2010). Theoretical aspects of water-holding in meat. *Meat Science*, *86*(1), 151–165.

Puolanne, E. J., Ruusunen, M. H., & Vainionpaa, J. I. (2001). Combined effects of NaCl and raw meat pH on water-holding in cooked sausage with and without added phosphate. [Article]. *Meat Science*, *58*(1), 1–7. http://dx.doi.org/10.1016/s0309-1740(00)00123-6.

Ruusunen, M., Särkkä-Tirkkonen, M., & Puolanne, E. (1999). The effect of salt reduction on taste pleasantness in cooked 'bologna-type' sausages. *Journal of Sensory Studies*, *14*(2), 265–270.

Ruusunen, M., Vainionpää, J., Puolanne, E., Lyly, M., Lähteenmäki, L., Niemistö, M., & Ahvenainen, R. (2003). Effect of sodium citrate, carboxymethyl cellulose and carrageenan levels on quality characteristics of low-salt and low-fat bologna type sausages. *Meat Science*, *64*(4), 371–381.

Ruusunen, M., & Puolanne, E. (2005). Reducing sodium intake from meat products. *Meat Science*, *70*(3), 531–541.

Salcedo-Sandoval, L., Cofrades, S., Ruiz-Capillas, C., & Jiménez-Colmenero, F. (2015). Filled hydrogel particles as a delivery system for n − 3 long chain PUFA in low-fat frankfurters: Consequences for product characteristics with special reference to lipid oxidation. *Meat Science*, *110*, 160–168.

Skrokki, A. (1995). Additives in Finnish sausages and other meat-products. *Meat Science*, *39*(2), 311–315.
Sloan, A. E. (2010). Top 10 functional food trends. *Food Technology*, *64*(4), 22.
Sofos, J. N. (1986). Use of phosphates in low-sodium meat products. *Food Technology*, *40*.
Terrel, R. N. (1983). Reducing the sodium content of processed metas. *Food Technology*, *37*(7), 66–71.
Tobin, B. D., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2012). Effect of varying salt and fat levels on the sensory and physiochemical quality of frankfurters. *Meat Science*, *92*(4), 659–666.
Tobin, B. D., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2013). The impact of salt and fat level variation on the physiochemical properties and sensory quality of pork breakfast sausages. *Meat Science*, *93*(2), 145–152.
Xiong, Y. L., & Mikel, W. B. (2001). Meat and meat products. In Y. H. Hui, W. K. Nip, R. W. Rogers, & O. A. Young (Eds.), *Meat science and applications* (pp. 351–370). New York: Marcel Dekker.
Yang, Y. L., Zhou, G. H., Xu, X. L., & Wang, Y. (2007). Rheological properties of myosin–gelatin mixtures. *Journal of Food Science*, *72*(5), 270–275.
Zarate, J. R., & Zaritzky, N. E. (1985). Production of weep in packaged refrigerated beef. *Journal of Food Science*, *50*(1), 155–159.