Is There a Potential Consumer Market for Low-Sodium Fermented Sausages?

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Abstract: The NaCl levels in dry fermented sausages were reduced by 50% or were substituted with KCl, $CaCl_2$, or a blend of KCl and $CaCl_2$ (1:1). The quality, safety, and the potential consumer market of dry fermented sausages were assessed. Neither 50% reduction of the NaCl content nor the substitution of 50% of the NaCl with KCl influenced the fermentation and maturation process. However, when $CaCl_2$ was used as the substitute salt (50%), there was a significant decrease in pH, an increase in the water activity, and a decrease in lactic acid and micrococcus bacterial counts. Overall, the sensory acceptance decreased in dry fermented sausages with reduced sodium content. However, cluster analysis and internal preference mapping revealed potential for commercialization of samples with 50% of the NaCl content substituted with KCl or with a mixture of KCl and $CaCl_2$ (1:1).

Keywords: calcium chloride, consumer study, dry fermented sausages, potassium chloride, sodium chloride reduction

Practical Application: Excess consumption of sodium chloride, the primary source of dietary sodium in human diet, is associated with increased blood pressure, cardiovascular disease, and some types of cancer. Fermented sausages are among the meat products, with higher sodium contents. The current results are of major importance for the meat industry, once they demonstrate that the low-sodium fermented sausages can potentially appeal to certain types of consumers and provide a way forward for future research and product development.

Introduction

Excess consumption of sodium chloride (NaCl), the main source of sodium in the human diet, is associated with increased blood pressure, cardiovascular disease, and some types of cancer (He and MacGregor 2010; Felicio and others, 2013). For these reasons, over the past few decades, public health bodies and regulatory authorities have established programs to promote the reduction in dietary NaCl intake (Food Standard Agency (FSA) 2006; World Health Organization (WHO) 2012), so as to decrease the incidence of chronic diseases related to high sodium levels. Processed food contributes to approximately 80% of sodium consumed by people in industrialized countries (He and MacGregor 2010).

Because of widespread concerns about current eating habits and the struggle to decrease sodium intake, it has become imperative for the meat industry to reduce the sodium content in its products. Of all food products, fermented sausages are among those with highest sodium content. Depending on the formulation, fermentation, and maturation conditions, this type of product may contain approximately 60% of the recommended sodium intake as stated by the World Health Organization (Campagnol and others 2012; World Health Organization (WHO) 2012) in a 50 g portion.

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Sodium chloride is the main source of sodium in dry fermented sausages, and therefore, in order to obtain healthier products, this ingredient must be eliminated or reduced. However, its reduction is a huge challenge because NaCl significantly affects technological and sensory quality. By solubilizing myofibril proteins, NaCl makes products easier to slice (Barbut 2011). It also influences microbiological stability because reducing the initial water activity favors the development of starter cultures and reduces microbiota contamination (Fontán and others 2007). These functions of NaCl are essential to produce products that will be stable at room temperature with long shelf life. Furthermore, NaCl is very important for sensory quality. In addition to providing the characteristic salty taste of meat, NaCl also accentuates the taste and flavor of other components and reduces the perception of other stimulants, such as the bitter taste of some compounds (Coultate 2002).

Consequently, research on sodium content reduction in fermented sausages without compromising the technological, microbiological, and sensory qualities, currently focuses on using other chloride salts. Potassium chloride (KCl) is renowned for being safe (Generally Recognized as Safe) and for having an antimicrobial activity similar to that of NaCl (Bidlas and Lambert 2008). Therefore, it is one of the ingredients most often used to reduce the sodium content (Gou and others 1996; Armenteros and others 2009; Cruz and others 2011; Campagnol and others 2012; Dos Santos and others 2014). However, a decline in sensory quality related to emerging bitterness and decreased saltiness have been reported when KCl is used as a sole substitute, constituting the main limitations of its use as a substitute for NaCl in fermented meat products (Gou and others 1996; Gimeno and others 1998; Campagnol and others 2011a; Dos Santos and others 2014).

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Table 1–Levels of sodium chloride, potassium chloride, and calcium chloride used in dry fermented sausage formulations.

	Treatments (%)				
	Control	F1	F2	F3	F4
Sodium chloride (NaCl)	2.5	1.25	1.25	1.25	1.25
Potassium chloride (KCl)	–	–	1.25	–	0.625
Calcium chloride ($CaCl_2$)	–	–	–	1.25	0.625

Control, 100% NaCl; F1, 50% NaCl; F2, 50% NaCl and 50% KCl; F3, 50% NaCl and 50% $CaCl_2$; F4, 50% NaCl, 25% KCl and 25% $CaCl_2$.

Calcium chloride ($CaCl_2$) is another ingredient that may be used as a NaCl substitute in meat products. Some studies assessed the use of $CaCl_2$ combined with other chloride salts as a strategy to reduce sodium in dry fermented sausages (Gimeno and others 1998, 1999, Gimeno et al. 2001a; Flores and others 2005; Zanardi and others 2010). In general, these studies report the effect of mono- and divalent salts (KCl, $CaCl_2$, and $MgCl_2$) as salt substitutes on the technological, microbiological, and sensory quality of fermented meat products. However, there is little information about the effect of using $CaCl_2$ alone or in conjunction with KCl on the quality and safety parameters of dry fermented sausages with reduced NaCl content.

Clearly, the collective experience with sodium-reduced fermented sausages shows that these products are not optimum and acceptable to most consumers. Thus, the aim of this study was to assess the quality, safety, and the potential consumer market of dry fermented sausages with 50% of their NaCl content reduced or substituted with KCl, $CaCl_2$, or a blend of KCl and $CaCl_2$ (1:1).

Materials and Methods

Dry fermented sausages processing

The NaCl content in the dry fermented sausages was reduced, or 50% of the salt content was replaced by 50% KCl, 50% $CaCl_2$, and a blend containing 25% KCl and 25% $CaCl_2$. The treatments used are listed in Table 1.

The dry fermented sausages were produced using the following main ingredients: pork meat (650 g/kg; moisture: 76.08% ± 0.26, protein: 18.00% ± 0.82, lipids: 4.43% ± 0.10, and ash: 1.07% ± 0.61), beef (200 g/kg; moisture: 77.12% ± 0.22, protein: 18.57% ± 0.12, lipids: 2.20% ± 0.02, and ash: 1.01% ash ± 0.61), and pork back fat (150 g/kg; moisture: 17.28% ± 1.24, protein: 6.54% ± 0.94, lipids: 75.39% ± 0.51, and ash: 0.36% ± 0.55). The raw material was ground with a disk (8 mm) and mixed with the correct amount of NaCl and other ingredients for each treatment described in Table 1. The following ingredients were added to the meat mixture in each treatment: glucose (5 g/kg), sucrose (5 g/kg), sodium nitrate (0.15 g/kg), sodium nitrite (0.15 g/kg), sodium ascorbate (0.25 g/kg), white pepper (2 g/kg), garlic (3 g/kg), nutmeg (0.02 g/kg), and starter culture (0.25 g/kg; SPX Floracarn; Chr Hansen, São Paulo, SP, Brazil.). After complete homogenization, the treatments were stuffed in collagen casings (diameter of 60 mm), and they were cut into slices of approximately 15 cm in length. In total, 60 pieces (approximately 300 g each) were prepared for each treatment. After being stuffed, the samples were subjected to a bath containing a 20% solution of potassium sorbate, and the samples were then ripened in a laboratory ripening cabinet (Menoncin, Erechim, Brazil). The temperature and relative humidity (T°/UR%) were set as follows: 1st day, temperature 25 °C/95%; 2nd day, 24 °C/93%; 3rd day, 23 °C/90%; 4th day, 22 °C/85%; 5th day, 21 °C/80%; 6th day, 20 °C/75%; and from the 7th day though the 19th day, 18 °C/75%. The air speed remained at 5 m/s throughout the processing.

Physicochemical analyses

The pH was determined by direct insertion of a pH meter MA 130 (Mettler Toledo Indústria e Comércio Ltd., SP, Brazil). Water activity (A_w) was measured by using a Decagon Aqualab instrument (Decagon Devices Inc., Pullman, USA). The pH and A_w were determined on days 0, 7, and 19 of production. Five pieces of dry fermented sausages from each treatment were used to determine the A_w and pH. Weight loss was defined as the difference in weight of the remaining pieces of meat at sausage formation (day 0) and the product weight at the end of production. Ten pieces of dry fermented sausages per treatment were used to determine weight loss. Sodium, potassium, and calcium contents were determined at the end of production, according to the method described by AOAC (2005), by using 3 pieces of dry fermented sausages per treatment.

Texture profile analysis (TPA) was performed at the end of the manufacturing process using the Texturometer TA-TX2 (Stable Micro Systems Ltd., Surrey, England) with a load cell of 10 kg. Each sample was cut into 3-cm cylinders and stretched axially into 2 consecutive circles compressed at 30% with a probe of 30 mm in diameter, moving at a constant test velocity of 1 mm/s. The data were collected, and the texture profile curves were drawn using the program Texture Expert, version 1.11 (Stable Micro Systems Ltd.). The following parameters were calculated: hardness, springiness, cohesiveness, and chewiness. For each treatment, 5 pieces of dry fermented sausages were used in the instrumental texture analysis.

Color was determined at the end of the manufacturing process, using a spectrophotometer-colorimeter model CM-5 (Konica Minolta) with spectral reflectance included as a calibration mode, Standard Illuminant D65, and an observation angle of 10°, while operating in the system CIE ($L^*a^*b^*$). The values of L^*(luminosity), a^* (intensity of red), and b^* (intensity of yellow) were determined. Five pieces of dry fermented sausages were used per treatment to determine color, with the color parameters being assessed for each sausage at 4 points in the center of 5 slices.

Microbiological analyses

The microbiological characteristics of dry fermented sausages were assessed on days 0, 7, and 19 of manufacturing, according to the methodology described by Downes and Ito (2001) in triplicate. Aliquots of 25 g were collected, homogenized with 225 mL of 0.1% peptone water (Oxoid Unipath Ltd., Basingstoke, Hampshire, UK), and serially diluted to a decimal scale. Lactic acid bacteria (LAB) were quantified using De Man Rogosa Sharpe agar (Oxoid; 37 °C/48 h), aerobic mesophyll bacteria on a standard agar medium for counting (Oxoid; 35 °C/48 h), micrococcus bacteria on manitol salt agar (Oxoid; 37 °C/48 h), total coliforms on violet red neutron-bile crystal agar (Oxoid; 37 °C/24 h), and fecal coliforms bacteria in EC broth (Oxoid; 45 °C/48 h).

Consumer study

The study protocol was approved by the Research Ethics Committee of the University of Campinas under number 130260. Two sensory tests with consumers were applied on different dates at Univ. of Campinas, in the Sensory Analysis Laboratory, Dept. of Food Technology, in the Faculty of Food Engineering. A consumer acceptability testing was performed using a non-structured 9-point hedonic scale (1 = dislike extremely to 9 = like extremely; Morais and others 2014a). The color, aroma, flavor, and texture

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of the samples were assessed via 196 dry fermented sausage consumers (Meilgaard and others 2006), with 53% being female and 47% male, ranging in age from 18 to 54 y old. In the second consumer test, the JAR and overall acceptability sensory test were used with 106 dry fermented sausage consumers, with 57% being women and 43% being men, ranging in age from 18 to 54 y (Esmerino and others 2013, Paixão and others 2014). The overall acceptability sensory was performed using a non-structured 9-point hedonic scale (1 = dislike extremely to 9 = like extremely). JAR questions were answered on a 9-point scale, where 1 to 4 was extremely less than optimal, 5 was optimal, and 6 to 9 was extremely more than optimal. This scale was used to assess salty flavor and the texture of dry fermented sausages (Canto and others 2014). In both the tests, samples were assigned a 3-digit code and were evaluated by each consumer in a monadic order, and the order of presentation followed a complete balanced design as described by Stone and others (2012). No additional information concerning the samples was provided to the consumers, in order to prevent errors (Thompson and others 2009). After tasting each sample, all participants were asked to eat a cream-cracker biscuit and drink water. The consumer study was performed in normalized booths under fluorescent lighting.

Statistical analysis

Three independent manufacturing curing times for the fermented sausages were carried out with the same formulation and technology. In each manufacture, 3 sample units (dry fermented sausage) were taken per sampling day ($n = 9$). All analyses were performed by triplicate. The results reported in this study are the mean obtained from all the data recorded for each parameter analyzed.

The results of the physicochemical and microbiological analyses and those of the consumer test were analyzed using an ANOVA test, and the mean values were compared using the Tukey post-test, with a significance level of 5% ($P \leq 0.05$). Penalty analysis was performed on overall liking scores based on JAR question responses; Penalty analysis is but one of the several methods used throughout the marketing research industry to reach conclusions related to the effects of a JAR variable on a different product measure (Drake and others 2011; Gaze and others 2015). Agglomerative hierarchical clustering was used to cluster consumer segments, using a dissimilarity matrix with Euclidean distance with Ward's method (Santos and others 2013). An ANOVA was again performed on these overall liking scores to see if differences existed among the consumer clusters, in which cluster and treatment were fixed effects and consumers were random effects.

Internal preference mapping was performed by the principal component analysis (PCA) on the correlation matrix of consumers by products. Internal preference maps transformed consumer acceptance scores into a set of preference dimensions that represent the differences among the samples. Individual acceptance scores are represented by vectors that show the individual directions of increasing preference (Gomes and others 2011). In this method, PCA was first applied on the consumer data in order to interpret the consumer response about the different products. This helped obtain a PCA scores plot and a PCA loadings plot, with the samples as scores and the individual consumer preferences as loadings. Next, all of the sensory attributes were regressed onto the estimated PCA scores from the consumer data, using the linear model (Naes and others 2010).

All the analyses were performed using the software XLSTAT 2013 for Windows (Adinsoft, Paris, France).

Results and Discussion

Physicochemical analyses

A decrease in A_w and the eventual dehydration throughout the process contribute to the stability and safety of fermented meat products, especially dry fermented sausages (Toldrá 2006). In this study, A_w values decreased from 0.978 to 0.968 (day 0) to 0.915 to 0.887 at the end of the manufacturing process (Table 2). A higher A_w was observed during the processing of dry fermented sausages produced with 1.25% NaCl (F1, 50% NaCl). This result is consistent with that of Toldrá and others (2001), who explained that for NaCl to preserve and reduce the initial A_w, it must be added at 2% or 3%. After 7 d of curing, the products from the treatment with 50% NaCl and 50% $CaCl_2$ (F4) had a higher A_w value than the control ($P \leq 0.05$), and this difference persisted until the end of the manufacturing process. This may be explained by the strong bonding between $CaCl_2$ and the proteins in the meat, which make salt penetration more difficult (Aliño and others 2010).

The lowest pH values (Table 2) at the beginning of the process were those recorded during the treatments involving $CaCl_2$, which were significantly different from that of the control. Gimeno and others (1999, 2001b) previously reported the low pH of dry fermented sausages in the presence of calcium when studying the substitution of NaCl with KCl, $CaCl_2$, and calcium ascorbate. This decrease in pH may have occurred because the pH of the sample dropped when the NaCl concentration increased. It could also have been because when $CaCl_2$, $MgCl_2$, and $ZnCl_2$ were added, the isoelectric point appeared to shift to a lower pH as a result of the anionic effect (von Hippel and Schleich 1969). After the 7th day of manufacturing, the pH continued to decline until the end of the process, and the treatments involving the addition of $CaCl_2$ (F3 and F4) had significantly lower pH values than the control ($P \leq 0.05$).

The weight loss of dry fermented sausages during the manufacturing process due to water loss was approximately 42% (Table 2). A similar result was found by other researchers when studying NaCl substitution using other chloride salts in dry fermented sausages (Flores and others 2005; Campagnol and others 2011a, Campagnol and others 2012). No significant difference was observed between treatments that reduced NaCl content and 50% of replaced the NaCl with KCl and/or $CaCl_2$ and the control.

Decreasing sodium intake as well as increasing potassium and calcium in the diet helps regulate blood pressure (Sacks and others 1998). In this study, reducing sodium and increasing potassium and calcium makes the reformulated sausages a healthier option. The control dry fermented sausages had a sodium concentration of 1729.70 mg/100 g (Table 2). As expected, substituting NaCl with KCl and/or $CaCl_2$ reduced the overall NaCl content of the reformulated sausages by 42%. A 50 g portion of the modified sausages would account for 18% of the total daily sodium recommended intake for a healthy diet (WHO 2012) in comparison with approximately 60% from regular sausages. These findings are in accordance with those of the studies on the reduction of NaCl and the addition of other chloride salts in dry fermented sausages (Campagnol and others 2011a) and mortadella (Horita and others 2011). Dry fermented sausages produced with a 50% reduction in NaCl and addition of 50% (F2) or 25% KCl (F4) had 135% and 75% increased potassium, respectively. The dry fermented sausages with added $CaCl_2$ contained 432.13 mg/100 g (F3; 50% $CaCl_2$) and 293.93 mg/100 g (F4; 25% KCl and 25% $CaCl_2$) calcium, which represents, for a 50 g portion of dry fermented sausages,

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Table 2–Physicochemical properties (±standard deviation) of dry fermented sausages with 50% NaCl substituted with KCl and/or $CaCl_2$.

	Days*	Control**	F1	F2	F3	F4
A_w	0	0.968 ± 0.00^{b}	0.978 ± 0.00^{a}	0.973 ± 0.00^{b}	0.973 ± 0.00^{b}	0.972 ± 0.00^{b}
	7	0.942 ± 0.01^{b}	0.960 ± 0.00^{a}	0.942 ± 0.00^{b}	0.952 ± 0.00^{a}	0.942 ± 0.01^{b}
	19	0.882 ± 0.01^{b}	0.915 ± 0.00^{a}	0.873 ± 0.02^{b}	0.907 ± 0.01^{a}	0.887 ± 0.01^{b}
pH	0	5.78 ± 0.04^{b}	5.85 ± 0.02^{a}	5.92 ± 0.11^{a}	5.29 ± 0.14^{d}	5.51 ± 0.07^{c}
	7	4.67 ± 0.03^{a}	4.64 ± 0.03^{a}	4.68 ± 0.04^{a}	4.42 ± 0.05^{c}	4.54 ± 0.02^{b}
	19	4.81 ± 0.06^{ab}	4.76 ± 0.05^{b}	4.85 ± 0.04^{a}	4.51 ± 0.04^{d}	4.69 ± 0.06^{c}
Weight loss (%)	19	41.52 ± 1.47^{a}	41.53 ± 1.95^{a}	42.47 ± 2.07^{a}	42.18 ± 0.85^{a}	42.64 ± 0.73^{a}
Sodium (mg/100 g)	19	1729.70 ± 2.87^{a}	1021.43 ± 2.50^{b}	933.07 ± 3.05^{b}	1021.13 ± 2.39^{b}	1006.43 ± 2.72^{b}
Potassium (mg/100 g)	19	795.51 ± 2.10^{d}	776.41 ± 3.21^{d}	1870.37 ± 3.81^{a}	$873.82^{c} \pm 3.02^{c}$	1389.98 ± 3.64^{b}
Calcium (mg/100 g)	19	12.63 ± 0.95^{c}	11.37 ± 0.30^{c}	9.71 ± 1.09^{c}	432.13 ± 2.81^{a}	293.93 ± 1.69^{b}
Hardness (N)	19	34.90 ± 2.99^{ab}	29.71 ± 5.07^{b}	40.07 ± 9.81^{a}	35.47 ± 7.18^{ab}	41.74 ± 9.07^{a}
Elasticity (mm)	19	0.63 ± 0.04^{a}	0.66 ± 0.03^{a}	0.63 ± 0.03^{a}	0.63 ± 0.02^{a}	0.66 ± 0.03^{a}
Cohesiveness	19	0.64 ± 0.02^{a}	0.64 ± 0.01^{a}	0.64 ± 0.03^{a}	0.66 ± 0.03^{a}	0.64 ± 0.03^{a}
Chewiness (N)	19	14.96 ± 2.25^{a}	12.00 ± 2.34^{b}	16.33 ± 5.57^{a}	15.56 ± 3.21^{a}	17.70 ± 4.10^{a}
L	19	48.91 ± 0.58^{ab}	49.21 ± 0.70^{a}	46.77 ± 0.92^{b}	49.39 ± 0.95^{a}	49.72 ± 1.09^{a}
a^*	19	11.88 ± 0.65^{b}	13.03 ± 0.60^{ab}	13.85 ± 0.67^{a}	12.99 ± 0.57^{ab}	13.50 ± 0.78^{a}
b^*	19	7.20 ± 0.37^{b}	7.28 ± 0.32^{b}	7.68 ± 0.25^{ab}	8.20 ± 0.30^{a}	8.15 ± 0.39^{a}

*Curing times.
**Means ± standard deviation.
Means in the same line with the same lower case letter are not significantly different according to a Tukey post-test ($P \geq 0.05$). Control, 100% NaCl; F1, 50% NaCl; F2, 50% NaCl and 50% KCl; F3, 50% NaCl and 50% $CaCl_2$; F4, 50% NaCl, 25% KCl and 25% $CaCl_2$.

21.5% and 14.65%, respectively, of the recommended daily intake of calcium for adults (1000 mg; Ross and others 2011).

The texture profile evaluation (Table 2) showed that a 50% reduction in NaCl and the addition of potassium and $CaCl_2$ did not change the texture of the dry fermented sausages. The dry fermented sausages produced with 50% NaCl and substitution of 50% NaCl with KCl and/or $CaCl_2$ (F2, F3, and F4) did not significantly differ from the control with regard to the hardness, springiness, cohesiveness, and chewiness. Consistent with these results, Campagnol and others (2011b) did not encounter differences in hardness, cohesion, or chewiness in dry fermented sausages with 50% NaCl substituted with KCl. Similar results were also reported by Dos Santos and others (2014) and Aliño and others (2010). However, the treatment with a 50% NaCl reduction (F1) had a lower chewiness value when compared with the other treatments ($P \leq 0.05$). According to Barbut (2011), the simple reduction in the concentration of NaCl during dry fermented sausage production may affect the extraction and solubilization of myofibril proteins and hence hinder texture development and sliceability of the product.

The color of dry fermented sausages with a reduced salt content may be altered when substituting NaCl with KCl and $CaCl_2$. In this study, the color parameters, luminosity (L^*), red intensity (a^*), and yellow intensity (b^*) were measured at the end of the manufacturing process (Table 2). The addition of potassium and $CaCl_2$ did not affect the L^* of reformulated dry fermented sausages. The a^* values were higher than those of the control ($P \leq 0.05$) in the treatments with 50% KCl (F2) or 25% KCl and 25% $CaCl_2$ (F4). Conversely, the values of b^* were significantly higher than those of the control in treatments with 50% (F3) and 25% $CaCl_2$ (F4). The differences observed may be attributed to the fact that the typical fermented meat product color is rather heterogeneous (Campagnol and others 2011a). This was also observed by Gimeno and others (2001b) when NaCl was partially substituted by calcium ascorbate in dry fermented sausages, observing higher values for a^* and b^*, whereas Gimeno and others (1999) observed higher L^* and b^* values in dry fermented sausages with reduced NaCl, upon the addition of a blend of chloride salts (NaCl, 10 g/kg; KCl, 5.52 g/kg; $CaCl_2$, 7.38 g/kg), even when using an equivalent ionic force.

Microbiological analyses

The growth of microorganisms in fermented sausages is directly related to dehydration, fermentation of carbohydrates, and acidification (Fontán and others 2007). Lower counts were observed for aerobic mesophyll microorganisms and LAB (Table 3) in treatments involving $CaCl_2$ addition at the beginning of the process (day 0). However, at the end of processing (19 d), there was no difference between treatments with reduced NaCl and the control.

The micrococcus count at the beginning of processing ranged from 5.99 to 5.47 log UFC/g. A lower count was observed in the treatment with 50% $CaCl_2$ (F3), which significantly differed from that of the control. This may be attributed to the lower initial pH (5.29) of the dry fermented sausages produced with 50% $CaCl_2$, as micrococcus bacteria are sensitive to acidic environments (Fontán and others 2007). The evolution of micrococcus growth during the manufacturing process is characterized by microbial count reduction over time, mainly because of the acidification and dehydration of the products. In this study, this was observed, and at the end of the manufacturing process (19 d), the dry fermented sausages had microbial counts of approximately 4 log UFC/g. A lower micrococcus count (Table 3) was observed in treatments with 50% $CaCl_2$ (F3) or 25% KCl and 25% $CaCl_2$ (F4), which significantly differed from that in the control. A lower micrococcus count may have been affected by the pH (Gimeno and others 2001a) in treatments F3 and F4, with values of 4.51 and 4.69, respectively. Gimeno and others (1998) achieved similar results when studying the replacement of NaCl with KCl, $MgCl_2$, or $CaCl_2$ in dry fermented sausages. Micrococcus bacteria in fermented sausages reduce nitrates and nitrites, develop color, and give aroma (Gimeno and others 2001a; Fontán and others 2007). In this study, the lower micrococcus count may have influenced the higher b^* value (Table 2) in dry fermented sausages produced with $CaCl_2$.

The initial count of thermotolerant coliform bacteria on day 0 (Table 3) was approximately 2 log UFC^{-1}, regardless of

Table 3–Microbiological characteristics (log UFC g^{-1}) of dry fermented sausages with 50% NaCl substituted with KCl and/or $CaCl_2$.

	Days*	Control**	F1	F2	F3	F4
Mesophilic aerobic	0	6.16 ± 0.07^{b}	6.36 ± 0.07^{a}	6.00 ± 0.08^{cd}	5.90 ± 0.08^{d}	6.03 ± 0.04^{c}
	7	7.25 ± 0.02^{cd}	7.64 ± 0.03^{b}	7.19 ± 0.01^{d}	7.98 ± 0.04^{a}	7.35 ± 0.02^{c}
	19	7.04 ± 0.11^{cd}	7.17 ± 0.21^{cd}	6.93 ± 0.31^{d}	7.57 ± 0.05^{a}	7.32 ± 0.21^{b}
Lactic acid bacteria	0	6.12 ± 0.07^{b}	6.20 ± 0.04 a	6.06 ± 0.01^{c}	5.89 ± 0.04^{d}	5.92 ± 0.07^{d}
	7	7.44 ± 0.10^{c}	7.75 ± 0.11^{b}	7.39 ± 0.30^{c}	8.14 ± 0.06^{a}	7.61 ± 0.09^{bc}
	19	7.22 ± 0.13^{a}	7.28 ± 0.15^{a}	7.14 ± 0.26^{a}	7.27 ± 0.01^{a}	7.19 ± 0.12^{a}
Micrococcaceae	0	5.94 ± 0.08^{a}	5.99 ± 0.08^{a}	5.86 ± 0.19^{a}	5.47 ± 0.06^{b}	5.96 ± 0.09^{a}
	7	5.50 ± 0.04^{ab}	5.28 ± 0.09^{c}	5.81 ± 0.11^{a}	4.19 ± 0.24^{e}	4.60 ± 0.29^{d}
	19	4.51 ± 0.32^{a}	4.27 ± 0.21^{ab}	4.35 ± 0.05^{ab}	4.09 ± 0.36^{b}	4.00 ± 0.01^{b}
Total coliforms	0	2.09 ± 0.06^{b}	2.16 ± 0.10^{ab}	2.37 ± 0.10^{a}	2.26 ± 0.04^{ab}	2.34 ± 0.25^{a}
	7	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00
	19	< 1.00	< 1.00	< 1.00	< 1.00	< 1.00

*Curing times.
**Means ± standard deviation.
Means in the same line with the same lower case letter are not significantly different according to a Tukey post-test ($P \geq 0.05$). Control, 100% NaCl; F1, 50% NaCl; F2, 50% NaCl and 50% KCl; F3, 50% NaCl and 50% $CaCl_2$; F4, 50% NaCl, 25% KCl and 25% $CaCl_2$.

the mixture of salts used. Because of the rapid drop in pH and increase in LAB, the thermotolerant coliform bacteria were eliminated after 7 d of curing. No thermotolerant coliform bacteria of fecal origin were detected in any experiment.

Consumer study

Consumer acceptance of the dry fermented sausages with 50% of their NaCl content reduced or substituted with KCl, $CaCl_2$, or a blend of KCl and $CaCl_2$ are shown in Table 4. The color and aroma of dry fermented sausages with 50% $CaCl_2$ (F3) obtained were less well-liked than the control. The poorer color ratings of this treatment may be correlated with a higher yellow intensity (b^*) observed in the instrumental color assessment of the dry fermented sausages in this study (Table 2). The low acceptance of aroma in the dry fermented sausages produced with 50% $CaCl_2$ (F3) may be associated with higher lipid oxidation, which occurs in fermented sausages with added calcium, according to Flores and others (2005) and Zanardi and others (2010).

During the flavor assessment, consumers gave lower ratings to the treatments with 50% NaCl (F1), 50% KCl (F2), 50% $CaCl_2$ (F3), and 25% KCl/ 25% $CaCl_2$ (F4), as compared with the control. Sensory acceptability tests resulted in lower ratings given by consumers to all of the treatment samples compared with the control, with the 50% $CaCl_2$ replacement receiving the lowest overall acceptability scores. Other researchers have reported low sensory acceptance of other types of meat products with NaCl substituted with $CaCl_2$ (Horita and others 2011; Armenteros and others 2012). The presence of calcium ions may give a bitter, metallic, and astringent taste, which may affect the sensory acceptance of reformulated products (Toldrá 2006). Dos Santos and others (2014) and Campagnol and others (2011b) studied the use of flavor enhancers, such as inosinate and disodium guanylate, and the amino acids lysine and taurine to mellow the sensory defects caused by substituting NaCl with KCl. The results were rather promising and may be an alternative to hide the unpleasantness caused when using $CaCl_2$ as a salt substitute for NaCl.

The textures of dry fermented sausages with 50% reduced NaCl substituted with KCl (F2) and/or $CaCl_2$ (F3 and F4) were rated as less well-liked ($P \leq 0.05$) than the control. However, this difference was not observed in the instrumental analysis of the texture profile in this study (Table 2). This behavior is referred to fermented meat products, as reported by Dos Santos and others (2014) and Campagnol and others (2012).

Using JAR scores, no treatment was considered excellent for the analyzed attributes (Table 4). From the sensory standpoint, the acceptance did not reach 70% of the responses in the range of 5 points (Meullenet and others 2007). For salty flavor, values varied from JAR 46.23% (control) to JAR 23.58% (F2 and F3). For texture, these values varied from JAR 52.89% (control) to JAR 32.08 (F3). Penalty analysis indicated that for salty taste, the highest values were recorded for treatments F3 (50% NaCl and 50% $CaCl_2$) and the control, with 2.274 and 1.007 ($P < 0.0001$ and $P < 0.003$, respectively). However, for texture, the value varied between 1.154 ($P < 0.001$, control) and 0.596 ($P < 0.094$, F4; 50% NaCl, 25% KCl, and 25% $CaCl_2$). Generally speaking, the results suggest that the addition of $CaCl_2$ to dry fermented sausages must be done with caution in order to not have a negative impact on the consumer's perception of salty taste. Interestingly, the penalty values for treatments with 50% reduced NaCl substituted with KCl were intermediate, with values between 0.692 and 0.926 for salty taste and 0.596 and 0.846 for texture. This suggests that KCl should be added to mixtures of substitute salts that are used in the dry fermented sausages. Our results generally reinforce the current challenge of reducing the NaCl content in meat products, indicating that further strategies are needed to minimize the sensory defects caused by using other chloride salts specifically those with calcium.

The internal preference map (Figure 1) explained 64.70% of the variation in consumer acceptance of dry fermented sausages, with 45.02% and 19.68% in the first and second dimensions, respectively. The first dimension separated the treatments into 2 groups: (1) control (100% NaCl) and F1 (50% NaCl) and (2) F2 (50% NaCl and 50% KCl). The second dimension separated the treatments into a third group composed of treatments with added $CaCl_2$ (F3 + F4). Most consumers were located to the right side (Figure 1) of the map providing evidence that the control, F1 (50% NaCl), and F2 (50% NaCl and 50% KCl) treatments were preferred. These treatments were characterized by the reduction in NaCl as well as the addition of KCl. On the other hand, treatments F3 (50% NaCl and 50% $CaCl_2$) and F4 (50% NaCl, 25% KCl, and 25% $CaCl_2$) were not well accepted by consumers.

The resulting dendogram of the hierarchical cluster analysis (HCA, Figure 2) resulted in 3 similarly distributed segments, according to the number of people, whereas Table 4 shows the means overall acceptance values among the 3 clusters. Both the first and second cluster grouped 34 individuals, whereas the third

Table 4–Consumer study of dry fermented sausages with 50% NaCl substituted with KCl and/or $CaCl_2$.

Sensory acceptance*	Control	F1	F2	F3	F4
Color	$7.00^a \pm 1.43$	$6.76^a \pm 1.44$	$6.93^a \pm 1.46$	$6.30^b \pm 1.62$	$6.89^a \pm 1.49$
Aroma	$5.91^a \pm 1.99$	$5.89^a \pm 1.91$	$5.68^{ab} \pm 1.85$	$5.21^b \pm 1.89$	$5.46^{ab} \pm 2.02$
Taste	$6.60^a \pm 1.82$	$6.06^b \pm 1.77$	$5.97^b \pm 1.85$	$4.57^d \pm 2.00$	$5.39^c \pm 1.99$
Texture	$6.80^a \pm 1.64$	$6.80^a \pm 1.55$	$6.33^b \pm 1.70$	$5.93^b \pm 1.81$	$6.26^b \pm 1.77$
JAR test*					
Salty taste (%)					
Too less	25.47^c	38.68^b	41.51^a	51.89^a	41.51^a
Just-about-right	46.23^a	44.34^a	23.58^b	23.58^b	33.02^a
Too more	28.30^a	16.98c	34.91^a	24.53^b	25.47^b
Texture (%)					
Too less	17.92^b	28.30^b	39.62^a	45.28^a	45.25^a
Just-about-right	52.89^a	48.11^a	39.62^a	32.08^b	42.45^a
Too more	29.35^a	23.58^b	20.75^b	22.64^b	12.26^c
Overall acceptability**					
Cluster 1 ($n = 34$)	6.35^b	4.85^b	5.29^b	3.09^b	3.47^c
Cluster 2 ($n = 34$)	6.65^b	7.09^a	5.94^b	5.32^a	5.59^b
Cluster 3 ($n = 38$)	8.03^a	6.74^a	7.32^a	5.27^a	7.05^a

Means ± standard deviation.
*Means in the same line with the same lower case letter are not significantly different according to a Tukey post-test ($P \geq 0.05$). 9-Point hedonic scale (1 = dislike extremely to 9 = like extremely). Just JAR values are displayed as percentages of consumer ratings from options: 1 to 4 for too less, 5 for just-about-right, and 6 to 9 for more. **Means in the same line with the same lower case letter are not significantly different according to LSD test ($P \geq 0.05$) between clusters. Control, 100% NaCl; F1, 50% NaCl; F2, 50% NaCl and 50% KCl; F3, 50% NaCl and 50% $CaCl_2$; F4, 50% NaCl, 25% KCl and 25% $CaCl_2$.

grouped 38 individuals. The control sample had the highest values with regard to the overall acceptance, varying from 8.03 to 6.35 in cluster 1 and 3. However, in segment 2, sample F1 (50% NaCl) had the highest value for overall acceptance, with 7.09 ($P < 0.05$). Generally speaking, the HCA results showed that there is commercialization potential for samples with 50% reduced sodium content in formulation F2 (50% NaCl and 50% KCl) and F4 (50% NaCl, 25% KCl, and 25% $CaCl_2$), showing that there is a consumer market for these treatments. These samples were assessed by a group of consumers (cluster 3). These results will be useful for the meat product industry, where it has been widely reported that the only product that is acceptable to consumers is with a 40% reduction in NaCl (Gou and others 1996). Future studies need to assess the development of the sensory profile of products using descriptive testing, such as quantitative descriptive analysis (Pimentel and others 2013, Morais and others 2014b) and consumer profiling techniques, as projective mapping and ultraflash profiling (Santos and others 2013). Finally, methodologies that involve increased consumption of special foods, such as repeated exposure (Costa and others 2014), should be equally evaluated.

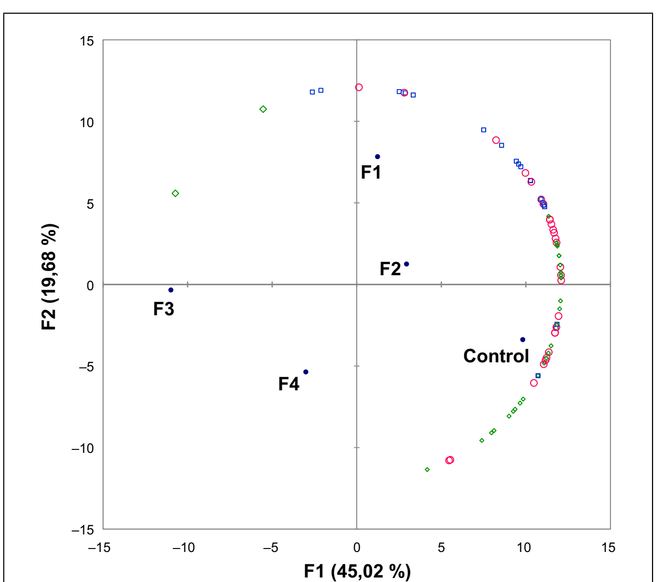

Figure 1–Internal preference map of consumers of dry fermented sausages with 50% NaCl substituted with KCl and/or $CaCl_2$ ($n = 106$). Control, 100% NaCl; F1, 50% NaCl; F2, 50% NaCl and 50% KCl; F3, 50% NaCl and 50% $CaCl_2$; F4, 50% NaCl, 25% KCl and 25% $CaCl_2$. ∘, Cluster 1 ($n = 34$); □, Cluster 2 ($n = 34$); and ♢, Cluster 3 ($n = 38$).

Conclusion

Reducing NaCl and substituting it with KCl and/or $CaCl_2$ makes reformulated dry fermented sausages healthier, reducing the sodium content by approximately 42%. Reducing NaCl by 50% and substituting that 50% with KCl caused small alterations in the technological dry fermented sausage manufacturing process. The 50% replacement of NaCl by $CaCl_2$ negatively affected

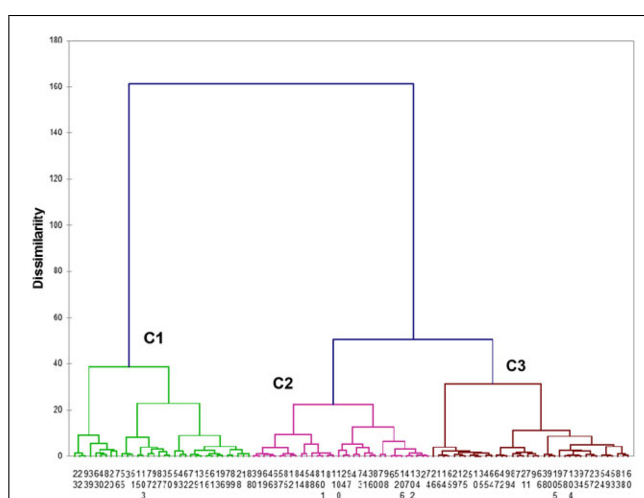

Figure 2–Dendogram of consumers of dry fermented sausages with 50% NaCl substituted with KCl and/or $CaCl_2$ ($n = 106$). Control, 100% NaCl; F1, 50% NaCl; F2, 50% NaCl and 50% KCl; F3, 50% NaCl and 50% $CaCl_2$; F4, 50% NaCl, 25% KCl, and 25% $CaCl_2$. Cluster 1 ($n = 34$), Cluster 2 ($n = 34$), and Cluster 3 ($n = 38$).

the manufacturing process of the dry fermented sausages, as the product presented high A_w, low pH, and lower micrococcaceae counts. Generally, dry fermented sausages manufactured with reduced NaCl were less accepted by the consumers. Cluster analysis and internal preference mapping identified a group of consumers that exists for dry fermented sausages with a 50% reduced NaCl content substituted with KCl or a blend of KCl and $CaCl_2$ (1:1). Thus, the present study suggests a potential consumer market for low-sodium fermented sausages, not an actual market. A marketing study is required to investigate the existence of this market.

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Author Contributions

B.A. Dos Santos collected the test data, drafted the manuscript, and interpreted the results; P.C.B. Campagnol drafted the manuscript and interpreted the results; A.G. da Cruz performed the statistic analysis and interpreted the results; M.A. Morgano performed the sodium, potassium, and calcium analysis in dry fermented sausages and interpreted the results; R. Wagner supervised performance of the experiments and assisted with design and writing; M.A.R. Pollonio designed the study, supervised performance of the experiments, interpreted the results, and assisted with design and writing.

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