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Monosodium glutamate, disodium inosinate, disodium guanylate, lysine and taurine improve the sensory quality of fermented cooked sausages with 50% and 75% replacement of NaCl with KCl

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ABSTRACT

Fermented cooked sausages were produced by replacing 50% and 75% of NaCl with KCl and adding monosodium glutamate, disodium inosinate, disodium guanylate, lysine and taurine. The manufacturing process was monitored by pH and water activity measurements. The sodium and potassium contents of the resulting products were measured. The color values (L*, a* and b*), texture profiles and sensory profiles were also examined. Replacing 50% and 75% NaCl with KCl depreciated the sensory quality of the products. The reformulated sausages containing monosodium glutamate combined with lysine, taurine, disodium inosinate and disodium guanylate masked the undesirable sensory attributes associated with the replacement of 50% and 75% NaCl with KCl, allowing the production of fermented cooked sausages with good sensory acceptance and approximately 68% sodium reduction.

1. Introduction

Sodium chloride is the main source of sodium in human diet, and a higher salt intake is associated with high blood pressure (Desmond, 2006; He & Macgregor, 2010; World Health Organisation (WHO), 2010). During the last two decades, public health organizations and regulatory agencies have recommended reducing sodium intake (Food Standards Agency (FSA), 2009; World Health Organisation (WHO), 2010) to promote health benefits and reduce the risk of cardiovascular diseases (Matthews & Strong, 2005). Thus, the demand for low sodium foods, especially meat products, has increased considerably in recent years (Ruusunen & Puolanne, 2005).

After a regulation regarding *E. coli* 0157:H7 reduction/elimination in dry-fermented sausages was introduced in North America in the mid-1990s, some medium and large size processors added a heating step to the production of traditionally dried, non-cooked products. In addition to inactivating most vegetative forms of microbes and ensuring safety of these products, the heat treatment also decreases the processing time. Drying, which is the next stage after cooking, increases the stability and enhances the sensory properties of the product (Barbut, 2008). Therefore, the consumption of fermented cooked sausages has increased significantly in many countries. However, this type of product contains a large amount of sodium, which is a potential danger to the increase of hypertension incidence in the world.

The reduction of NaCl in fermented meat products is extremely important but is a major challenge for the meat industry. Several studies (Aliño, Grau, Fuentes, & Barat, 2010; Armenteros, Aristoy, Barat, & Toldrá, 2009; Campagnol, Santos, Wagner, Terra, & Pollonio, 2011; Gelabert, Gou, Guerrero, & Arnau, 2003; Zanardi, Ghidini, Conter, & Ianieri, 2010) have shown that the reduction of NaCl may change the quality of fermented, cooked and dried cured meat products because sodium chloride provides microbiological stability, reduces the water activity, contributes to the solubilization of myofibrillar proteins and develops flavor and texture characteristics (Lücke, 1998).

Some approaches to reducing the sodium content in meat products have been studied, including the use of other salts, such as KCl, $MgCl_2$ and $CaCl_2$ (Fulladosa, Serra, Gou, & Arnau, 2009). Among these salts, KCl is the most commonly used (Campagnol, Santos, Terra, & Pollonio, 2012; Gelabert et al., 2003; Gimeno, Astiasarán, & Bello, 2001; Gou, Guerrero, Gelabert, & Arnau, 1996; Guàrdia, Guerrero, Gelabert, Gou, & Arnau, 2008) for presenting functional properties similar to NaCl. However, high levels of KCl provide undesirable aftertastes such as bitter, metallic and astringent tastes (Askar, El-Samahy, & Tawfik, 1994; Guàrdia et al., 2008).

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Therefore, searching for ingredients that can reduce the adverse effects caused by KCl is one of the most important factors in developing low sodium meat products. Some of these ingredients, such as flavor enhancers (Campagnol et al., 2012; Campagnol, Santos, Wagner et al., 2011) and lactate (Gou et al., 1996; Guàrdia, Guerrero, Gelabert, Gou, & Arnau, 2006), are good candidates for salt substitutes and can minimize the undesirable effects of KCl in fermented meat products.

The effect of sodium reduction in fermented cooked sausages has been poorly studied. Campagnol, Santos, Morgano, Terra, and Pollonio (2011) demonstrated that the use of lysine, taurine, 5′-ribonucleotides (disodium guanylate and disodium inosinate) is efficient in reducing the sensory defects caused by replacing 50% of the NaCl content with KCl in fermented cooked sausages. These authors, however, did not report the synergistic effect between these compounds and did not evaluate monosodium glutamate, a compound that synergistically enhances the umami taste perception when used in combination with 5′-ribonucleotides (Halpern, 2000; Löliger, 2000). To date, the effect of replacing more than 50% NaCl with KCl on the quality of fermented cooked sausages has not been explored. Considering the recent increased consumption of processed meat, especially ready-to-eat products that contain processed meat as a filling or a topping, reducing high levels of NaCl could greatly benefit public health. Therefore, the present study evaluated the effect of monosodium glutamate, disodium inosinate, disodium guanylate, lysine and taurine on the physicochemical and sensory characteristics of fermented cooked sausages with 50% and 75% replacement of NaCl with KCl.

2. Materials and methods

2.1. Treatments

Treatments were prepared with two replacement levels of NaCl with KCl combined with monosodium glutamate, disodium inosinate, disodium guanylate and the amino acids lysine and taurine (Table 1).

2.2. Manufacturing process

The raw materials used in this experiment were purchased from a Brazilian slaughterhouse under federal inspection. Processing was carried out in the Laboratory of Meat and Derivatives at the Faculty of Food Engineering, University of Campinas (São Paulo, Brazil). Two independent replicates of each treatment were made. The fermented sausages were produced using pork (650 g/kg), beef (200 g/kg) and pork fat (150 g/kg) as raw materials. The raw material was ground with a disk (8 mm) and mixed with NaCl and other ingredients according to each treatment (Table 1). Thereafter, the remaining ingredients were added: glucose (1 g/kg), sodium nitrite (0.15 g/kg), white pepper (2 g/kg), garlic (3 g/kg), nutmeg (0.02 g/kg), sodium erythorbate (0.25 g/kg) and a starter culture (0.25 g/kg; Bactoferm T-SPX Chr.Hansen) consisting of *Pediococcus pentosaceus* and *Staphylococcus xylosus*. After complete homogenization, the meat mixture was ground with a disk of 3 mm and stuffed into fibrous casings (50 mm diameter). The pieces of fermented sausage were placed in a ripening chamber at 28 ± 0.1 °C with a relative humidity between 85 and 90% until pH ≤ 5.2. Next, the pieces were cooked in a conventional oven until the core temperature of 62 °C was reached, according to the following cooking cycle: 50 °C for 1 h, then a 10 °C increase every 30 min until 70 °C was reached. After cooling, the sausages were ripened in a ripening chamber at 15 ± 0.1 °C and RH of 65 −75% until the water activity values were ≤0.92 for all treatments. Then, the casings were removed and the fermented cooked sausages were vacuum-packed and stored under refrigeration (4 ± 1 °C) until the time of analysis.

2.3. Physicochemical analysis

The pH was determined by direct measurement using a pH meter (MA 130 Mettler Toledo Industria e Comercio Ltda, SP, Brazil) at the beginning of the manufacturing process (before stuffing), after 24 h and at the end of processing. The water activity (Aw), sodium and potassium contents, color and texture profile analysis were determined at the end of processing. The water activity (Aw) was measured by an Aqualab water activity meter (Decagon Devices Inc., Pullman, USA). Three sausages per treatment were used to evaluate the pH and Aw, and each analysis was performed in triplicate. The sodium and potassium contents were determined in triplicate using three fermented cooked sausages per treatment (AOAC, 2005).

Color measurements were performed using a Hunter Lab colorimeter (Colorquest II, Hunter Associates Laboratory Inc., Virginia, USA) operating in reflectance mode, using illuminant D65 and 10° standard observer. CIElab values of L*, a* and b* were determined as indicators of lightness, redness and yellowness, respectively. Color variables were measured at four points on the central part of the cut surface of three slices of the five sausages per treatment.

The instrumental parameters (TPA) of the fermented sausages were measured using a TA-TX2 texture analyzer (Stable Micro Systems Ltd., Surrey, England) with a load cell of 10 kg. The parameters of hardness, cohesiveness and chewiness were measured in five fermented cooked sausages per treatment. Each sample was cut into cylinders of 3 cm and axially compressed into two consecutive cycles of 30% compression with a 30-mm diameter probe at a constant speed of 1 mm/s. Fifteen cylinders per treatment were used to evaluate the texture. Data

Table 1
Percentages of sodium chloride, potassium chloride, amino acids, monosodium glutamate and 5′-ribonucleotides used in the formulation of fermented cooked sausage treatments.

	Treatments (%)										
	FC	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Experiment 1 (50%NaCl/50%KCl)											
NaCl	2.5	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
KCl	–	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
MG	–	–	0.06	–	–	0.06	0.06	0.06	–	–	–
IMP/GMP	–	–	–	–	–	–	–	0.06	–	0.06	0.06
Lys	–	–	–	1.0	–	1.0	–	–	1.0	1.0	–
Tau	–	–	–	–	0.075	–	0.075	–	0.075	–	0.075
Experiment 2 (25% NaCl/75% KCl)											
NaCl	2.5	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625	0.625
KCl	–	1.875	1.875	1.875	1.875	1.875	1.875	1.875	1.875	1.875	1.875
MG	–	–	0.06	–	–	0.06	0.06	0.06	–	–	–
IMP/GMP	–	–	–	–	–	–	–	0.06	–	0.06	0.06
Lys	–	–	–	1.0	–	1.0	–	–	1.0	1.0	–
Tau	–	–	–	–	0.075	–	0.075	–	0.075	–	0.075

* NaCl- Sodium chloride; KCl- Potassium chloride; MG- Monosodium glutamate; IMP/GMP- Disodium inosinate/Disodium guanylate (50:50); Lys- Lysine e Tau- Taurine.

collection and construction of curves were performed by the Texture Expert, program version 1.11 (Stable Micro Systems Ltda.).

2.4. Consumer study

This study was registered and approved by the Ethics in Research Committee of the University of Campinas (UNICAMP, SP, Brazil), under protocol n. 268/2010. The consumer study was performed in the Laboratory of Sensory Analysis at Faculty of Food Engineering, University of Campinas (São Paulo, Brazil). All participants signed a consent form agreeing to participate as volunteers in the sensory analysis. The acceptance tests were performed using a nine-point hedonic scale, with extremes ranging from "extremely dislike" to "extremely like". The attributes of color, aroma, flavor and texture were evaluated by 100 consumers (48 males and 52 females) recruited among the staff and students at UNICAMP, aged between 18 and 60 years (Meilgaard, Civille, & Carr, 2006). The samples were evaluated immediately after processing. Eleven formulations of each experiment were evaluated by the panelists in a monadic order in three sessions as described by Stone, Bleibaum, and Thomas (2012).

2.5. Statistical analysis

The results were assessed by analysis of variance (ANOVA), and the averages were compared by Tukey test at 5% significance level ($p \leq 0.05$) using the SPSS statistical package (SPSS, Chicago, IL, USA).

3. Results and discussion

3.1. Physicochemical analyses

The physicochemical characteristics of the fermented cooked sausages produced with low sodium content are shown in Table 2. The water activity values at the end of manufacturing ranged from 0.906 to 0.919 and 0.870 to 0.920 for Experiments I and II, respectively, with no statistically significant difference between the control and reformulated sausages. This demonstrates that replacing 50% and 75% NaCl with KCl in fermented cooked sausages did not affect the drying process. In agreement with these results, Campagnol, Santos, Morgano et al., (2011) found no changes in the Aw values in fermented cooked sausages with 50% replacement of NaCl with KCl and addition of inosinate and disodium guanylate, lysine and taurine.

During manufacturing, the pH development of the samples with 50 and 75% replacement of NaCl with KCl was similar. After 24 h of fermentation, the control and the other treatments presented pH values below 5.2. This rapid drop in pH is extremely important for fermented meat products because the lactic acid produced by the lactic acid bacteria inhibits a large number of pathogenic and spoilage microorganisms (Leroy, Verluyten, & Vuys, 2006; Urso, Comi, & Cocolin, 2006). At the end of the manufacturing process, the pH values ranged from 4.58 to 4.73 ($p > 0.05$—Experiment I) and 4.70 to 4.77 ($p < 0.05$—Experiment II), which is consistent with the results obtained by Campagnol, Santos, Morgano et al., (2011), and is typical for the meat product in question.

In the present study, replacing NaCl with KCl significantly decreased the sodium content and increased the potassium content of the products. The $\text{Control}_{50\%}$ presented a sodium content of 1378 mg/100 g, which is similar to that obtained by Campagnol, Santos, Wagner et al., (2011) using 2.5% NaCl (1345 mg/100 g) in the formulation of fermented sausages. Thus, replacing NaCl with KCl resulted in a 44.30% reduction of the sodium content and an approximate 127% increase of the potassium content (Table 2). In contrast, the treatments with 75% replacement of NaCl with KCl resulted in approximately 68% sodium reduction, while the potassium content increased more than 200%. These modifications provide healthier characteristics for the modified sausages and reduce sodium intake. This alternative reduces

Table 2
Physicochemical characteristics (± standard deviation) of fermented cooked sausages with reduced sodium content.

	Aw	pH $_{0h}$	pH $_{24h}$	pH $_{end}$	Sodium (mg/100 g)	Potassium (mg/100 g)
Experiment 1						
Control$_{50\%}$	0.910 ± 0.00^{a}	5.78 ± 0.02^{def}	4.95 ± 0.02^{bcd}	4.60 ± 0.02^{de}	1378.01 ± 2.87^{a}	547.16 ± 1.08^{f}
F1$_{50\%}$	0.906 ± 0.02^{a}	5.80 ± 0.03^{bcde}	4.92 ± 0.05^{cde}	4.58 ± 0.04^{e}	893.11 ± 3.54^{b}	1257.44 ± 1.74^{bc}
F2$_{50\%}$	0.911 ± 0.01^{a}	5.79 ± 0.00^{cdef}	4.97 ± 0.02^{abc}	4.73 ± 0.05^{a}	894.18 ± 3.05^{b}	1215.89 ± 3.88^{e}
F3$_{50\%}$	0.911 ± 0.01^{a}	5.79 ± 0.02^{cdef}	4.90 ± 0.02^{de}	4.70 ± 0.05^{ab}	849.08 ± 1.36^{e}	1223.78 ± 4.45^{de}
F4$_{50\%}$	0.907 ± 0.03^{a}	5.82 ± 0.01^{ab}	4.89 ± 0.02^{de}	4.60 ± 0.03^{cde}	863.33 ± 2.13^{cd}	1208.35 ± 9.96^{e}
F5$_{50\%}$	0.919 ± 0.01^{a}	5.80 ± 0.01^{bcde}	4.80 ± 0.04^{bcd}	$4.61 \pm 0.04\ ^{cde}$	867.78 ± 1.36^{cd}	1286.18 ± 1.74^{a}
F6$_{50\%}$	0.919 ± 0.01^{a}	5.78 ± 0.01^{def}	4.90 ± 0.03^{de}	4.67 ± 0.05^{bc}	772.26 ± 0.21^{g}	1254.53 ± 4.91^{bc}
F7$_{50\%}$	0.919 ± 0.01^{a}	5.85 ± 0.01^{a}	4.87 ± 0.07^{e}	4.58 ± 0.03^{e}	771.26 ± 1.88^{g}	1267.44 ± 3.01^{b}
F8$_{50\%}$	0.907 ± 0.00^{a}	5.77 ± 0.01^{ef}	5.01 ± 0.01^{ab}	4.67 ± 0.01^{bc}	806.74 ± 1.66^{f}	1255.58 ± 3.04^{bc}
F9$_{50\%}$	0.909 ± 0.00^{a}	5.82 ± 0.002^{ab}	5.02 ± 0.00^{a}	4.66 ± 0.03^{bc}	873.36 ± 1.96^{c}	1239.88 ± 13.29^{c}
F10$_{50\%}$	0.919 ± 0.01^{a}	5.76 ± 0.00^{f}	4.87 ± 0.02^{e}	4.60 ± 0.01^{cde}	857.11 ± 3.58^{de}	1249.78 ± 7.92^{bc}
Experiment 2						
Control$_{75\%}$	0.920 ± 0.00^{a}	5.78 ± 0.01^{bc}	4.75 ± 0.03^{e}	4.72 ± 0.00^{a}	1442.62 ± 2.29^{a}	516.01 ± 10.96^{e}
F1$_{75\%}$	0.919 ± 0.00^{a}	5.80 ± 0.01^{a}	4.78 ± 0.02^{cde}	4.73 ± 0.02^{a}	481.63 ± 2.69^{c}	1523.42 ± 5.02^{cd}
F2$_{75\%}$	0.909 ± 0.01^{a}	5.77 ± 0.00^{cd}	4.80 ± 0.02^{bcd}	4.76 ± 0.06^{a}	467.57 ± 2.25^{d}	1568.61 ± 7.45^{b}
F3$_{75\%}$	0.894 ± 0.01^{a}	5.76 ± 0.00^{de}	4.80 ± 0.01^{bcd}	4.71 ± 0.02^{a}	461.50 ± 1.66^{d}	1592.15 ± 5.96^{a}
F4$_{75\%}$	0.914 ± 0.04^{a}	5.80 ± 0.01^{a}	4.83 ± 0.02^{b}	$4.71^{a} \pm 0.03^{a}$	457.98 ± 1.17^{d}	1574.95 ± 8.24^{ab}
F5$_{75\%}$	0.895 ± 0.04^{a}	5.77 ± 0.00^{cd}	4.80 ± 0.04^{bcd}	4.73 ± 0.04^{a}	466.34 ± 2.44^{d}	1556.20 ± 5.10^{b}
F6$_{75\%}$	0.916 ± 0.01^{a}	5.79 ± 0.00^{ab}	4.77 ± 0.01^{de}	4.70 ± 0.02^{a}	495.55 ± 1.49^{b}	1535.28 ± 2.90^{c}
F7$_{75\%}$	0.870 ± 0.05^{a}	5.79 ± 0.00^{ab}	4.75 ± 0.02^{e}	4.74 ± 0.02^{a}	466.33 ± 3.38^{d}	1507.88 ± 6.01^{d}
F8$_{75\%}$	0.904 ± 0.00^{a}	5.78 ± 0.00^{bc}	4.81 ± 0.01^{bc}	4.74 ± 0.07^{a}	439.18 ± 2.02^{e}	1557.84 ± 7.23^{b}
F9$_{75\%}$	0.903 ± 0.01^{a}	5.76 ± 0.00^{de}	4.82 ± 0.02^{b}	4.75 ± 0.04^{a}	457.29 ± 1.01^{d}	1505.48 ± 3.43^{d}
F10$_{75\%}$	0.903 ± 0.00^{a}	5.75 ± 0.01^{e}	4.91 ± 0.01^{a}	4.77 ± 0.05^{a}	411.38 ± 2.95^{f}	1567.95 ± 5.42^{b}

*Values represent the average ± standard deviation ($n = 6$). Averages within the same column, in the same experiment, followed by the same letters did not show any significant difference ($p \geq 0.05$) by Tukey's test. The following treatments were used: **Experiment 1**: Control$_{50\%}$ (2.5% NaCl); F1$_{50\%}$ (1.25% NaCl and 1.25% KCl); F2$_{50\%}$ (1.25% NaCl, 1.25% KCl and 0.06% monosodium glutamate (MG)); F3$_{50\%}$ (1.25% NaCl, 1.25% KCl and 1.0% lysine (Lys)); F4$_{50\%}$ (1.25% NaCl, 1.25% KCl and 0.075% taurine (Tau)); F5$_{50\%}$ (1.25% NaCl, 1.25% KCl, 0.06% MG and 1.0% Lys); F6 (1.25% NaCl, 1.25% KCl, 0.06% MG and 0.075% Tau); F7 (1.25% NaCl, 1.25% KCl, 0.06% MG and disodium inosinate/disodium guanylate (IMP/GMP)); F8$_{50\%}$ (1.25% NaCl, 1.25% KCl,1.0% Lys and 0.075% Tau); F9$_{50\%}$ (1.25% NaCl, 1.25% KCl, 0.06% MG and IMP/GMP and 1.0% Lys) and F10$_{50\%}$ (1.25% NaCl, 1.25% KCl, 0.06% MG and IMP/GMP and 0.075% Tau). **Experiment 2:** Control$_{75\%}$ (2.5%NaCl); F1$_{75\%}$ (0.625% NaCl and 1.875% KCl); F2$_{75\%}$ (0.625% NaCl, 1.875% KCl and 0.06% MG); F3$_{75\%}$ (0.625% NaCl,1.875% KCl and 1.0% Lys); F4$_{75\%}$ (0.625% NaCl,1.875% KCl and 0.075% Tau); F5$_{75\%}$ (0.625% NaCl,1.875% KCl, 0.06% MG and 1.0% Lys); F6$_{75\%}$ (0.625% NaCl,1.875% KCl, 0.06% MG and 0.075% Tau); F7$_{75\%}$ (0.625% NaCl,1.875% KCl, 0.06% MG and IMP/GMP); F8$_{75\%}$ (0.625% NaCl,1.875% KCl,1.0% Lys and 0.075% Tau); F9$_{75\%}$ (0.625% NaCl,1.875% KCl, 0.06% MG and IMP/GMP and 1.0% Lys) and F10$_{75\%}$ (0.625% NaCl,1.875% KCl, 0.06% MG and IMP/GMP and 0.075% Tau).

the risk of hypertension and consequently the incidence of cardiovascular diseases in some specific population groups.

Table 3 shows the values for the color parameters. Replacing 50% NaCl with KCl did not significantly change the L*, a* and b* values. Similar results were found by Campagnol, Santos, Morgano et al., (2011), who observed no difference in the color of fermented cooked sausages with NaCl replacement up to 50%. In contrast, Experiment II showed significant differences of L* and b* values compared with $Control_{75\%}$. However, despite the significant differences, the effect of replacing 75% NaCl with KCl and adding monosodium glutamate, disodium inosinate, disodium guanylate, lysine and taurine was not evident, most likely due the heterogeneous coloration of this meat product. There was no difference between the red color (a*) of the $Control_{75\%}$ and reformulated sausages, which may be important because the red color of fermented meat products is one of the major attributes for good sensory acceptance (Guàrdia et al., 2008; Purriños et al., 2011).

Results of the texture profile analysis (TPA) are presented in Table 3. As reported in the literature (Campagnol, Santos, Wagner et al., 2011; Gimeno et al., 2001; Gou et al., 1996), the replacement or reduction of NaCl could change the texture of fermented sausages. This could occur because sodium chloride is responsible for the solubilization and diffusion of muscle myofibrillar proteins that form a gel between the meat and fat particles, thus favoring slicing and improving the juiciness and texture of the product (Lücke, 1998). At 50% salt replacement, a significant reduction in the hardness and chewiness compared with $Control_{50\%}$ was observed only for treatments $F6_{50\%}$, $F7_{50\%}$ and $F8_{50\%}$. However, there was no observed effect of monosodium glutamate, disodium inosinate, disodium guanylate, lysine and taurine on the texture of the products.

In Experiment II, all treatments with 75% salt replacement presented a significant reduction in the hardness, chewiness and cohesiveness, which may depreciate the sensory quality of the product (Campagnol, Santos, Wagner et al., 2011). This result could be attributed to the high level of replacement of NaCl with KCl because the chloride ions are mainly responsible for the solubilization and extraction of proteins (primarily myosin and actin) from the myofibrils, and KCl demonstrates a non-chloride part of 48% compared with 39% in sodium chloride (Feiner, 2006).

3.2. Consumer study

The results of the sensory analysis are shown in Table 4. In Experiment I, only the formulation containing 50% NaCl and 50% KCl ($F1_{50\%}$) differed significantly from $Control_{50\%}$ for all of the studied attributes. Replacing 50% NaCl with KCl and adding of different combinations of monosodium glutamate, disodium inosinate, disodium guanylate, lysine and taurine were sufficient to remove all sensory defects caused by the replacement of sodium chloride. This result can be explained by the umami taste developed by the synergistic action between monosodium glutamate (GM) and disodium guanylate and inosinate (IMP/GMP) improve the quality and intensity of flavor in foods (Zhang et al., 2009) with reduced sodium content. Furthermore, the amino acids lysine (Turk, 1993) and taurine (Salemme & Barndt, 2006) have characteristics that provide increased saltiness and mask the metallic flavor of some metals, including potassium.

In Experiment II, replacing 75% NaCl with KCl ($F1_{75\%}$) depreciated the sensory quality of fermented cooked sausages. These results are similar to those found by Zanardi et al. (2010), Armenteros et al. (2009) and Gou et al. (1996) for fermented and dried cured meat products with low sodium content, who observed that replacing more than 50% NaCl with KCl impaired the sensory quality of the reformulated products. However, some combinations of monosodium glutamate, disodium inosinate, disodium guanylate and the amino acids lysine and taurine of the present study effectively suppressed the defects caused by the increased replacement of NaCl with KCl.

Table 3
Color characteristics and texture profile (± standard deviation) of the fermented cooked sausages with reduced sodium content.

	L*	a*	b*	Hardness (N)	Cohesiveness	Chewiness (N)
Experiment 1						
$Control_{50\%}$	50.47 ± 0.83^{a}	14.29 ± 0.39^{a}	9.68 ± 0.38^{a}	66.01 ± 4.85^{a}	0.787 ± 0.01^{a}	35.97 ± 2.55^{a}
$F1_{50\%}$	49.21 ± 1.72^{a}	14.79 ± 0.82^{a}	9.56 ± 0.15^{a}	57.49 ± 4.17^{bcd}	0.774 ± 0.02^{ab}	31.42 ± 2.66^{abc}
$F2_{50\%}$	46.54 ± 0.71^{a}	15.67 ± 0.37^{a}	9.59 ± 0.29^{a}	59.89 ± 4.54^{ab}	0.809 ± 0.07^{a}	35.42 ± 3.20^{ab}
$F3_{50\%}$	49.31 ± 0.80^{a}	15.25 ± 0.57^{a}	10.24 ± 0.15^{a}	60.64 ± 5.88^{ab}	0.768 ± 0.02^{ab}	32.27 ± 3.60^{abc}
$F4_{50\%}$	48.32 ± 1.04^{a}	15.01 ± 0.43^{a}	9.34 ± 0.55^{a}	61.66 ± 5.22^{ab}	0.776 ± 0.01^{ab}	32.33 ± 2.46^{abc}
$F5_{50\%}$	46.76 ± 1.11^{a}	15.83 ± 0.27^{a}	9.37 ± 0.24^{a}	60.73 ± 3.78^{ab}	0.769 ± 0.02^{ab}	31.69 ± 3.30^{abc}
$F6_{50\%}$	50.78 ± 1.32^{a}	15.55 ± 0.47^{a}	10.78 ± 0.26^{a}	52.12 ± 5.24^{cd}	0.783 ± 0.01^{ab}	28.21 ± 1.93^{c}
$F7_{50\%}$	48.78 ± 1.31^{a}	15.56 ± 0.57^{a}	10.36 ± 0.21^{a}	56.64 ± 4.83^{bcd}	0.774 ± 0.00^{ab}	30.24 ± 2.38^{bc}
$F8_{50\%}$	47.31 ± 1.07^{a}	13.99 ± 4.04^{a}	9.00 ± 0.45^{a}	51.66 ± 2.57^{cd}	0.774 ± 0.00^{ab}	27.81 ± 2.68^{c}
$F9_{50\%}$	47.29 ± 1.61^{a}	15.34 ± 0.52^{a}	10.27 ± 1.60^{a}	59.55 ± 3.88^{ab}	0.782 ± 0.01^{ab}	32.07 ± 1.73^{abc}
$F10_{50\%}$	50.85 ± 1.18^{a}	14.86 ± 0.27^{a}	10.26 ± 0.35^{a}	62.58 ± 4.90^{ab}	0.769 ± 0.00^{ab}	32.56 ± 2.48^{abc}
Experiment 2						
$Control_{75\%}$	46.77 ± 3.78^{bc}	15.70 ± 0.68^{a}	9.86 ± 1.17^{cd}	66.02 ± 4.82^{a}	0.788 ± 0.01^{a}	35.97 ± 2.05^{a}
$F1_{75\%}$	51.03 ± 3.35^{ab}	14.35 ± 0.82^{a}	10.38 ± 0.52^{bcd}	31.68 ± 2.49^{b}	0.649 ± 0.04^{b}	13.33 ± 1.19^{d}
$F2_{75\%}$	52.27 ± 0.74^{a}	14.19 ± 1.69^{a}	10.42 ± 0.58^{bc}	35.73 ± 2.19^{cde}	0.635 ± 0.02^{b}	14.59 ± 1.22^{cd}
$F3_{75\%}$	50.85 ± 0.68^{ab}	14.72 ± 0.37^{a}	10.30 ± 0.26^{bcd}	38.27 ± 3.09^{bcd}	0.641 ± 0.01^{b}	15.36 ± 1.15^{bcd}
$F4_{75\%}$	46.25 ± 5.44^{bc}	14.78 ± 1.58^{a}	9.12 ± 1.05^{d}	39.28 ± 3.84^{bc}	0.646 ± 0.02^{b}	15.56 ± 1.55^{bcd}
$F5_{75\%}$	48.83 ± 1.22^{abc}	15.19 ± 1.37^{a}	10.64 ± 0.62^{abc}	36.40 ± 3.06^{bcde}	0.674 ± 0.05^{b}	15.71 ± 1.50^{bcd}
$F6_{75\%}$	51.24 ± 0.77^{ab}	15.41 ± 0.37^{a}	11.00 ± 0.30^{abc}	37.80 ± 6.33^{bcd}	0.639 ± 0.04^{b}	15.68 ± 3.11^{bcd}
$F7_{75\%}$	53.24 ± 2.52^{a}	13.80 ± 0.85^{a}	11.31 ± 1.0^{abc}	41.96 ± 3.19^{b}	0.660 ± 0.03^{b}	17.62 ± 1.55^{b}
$F8_{75\%}$	51.66 ± 1.07^{ab}	15.48 ± 0.46^{a}	11.77 ± 0.45^{a}	40.37 ± 1.98^{bc}	0.647 ± 0.03^{b}	16.88 ± 1.31^{bc}
$F9_{75\%}$	44.38 ± 6.52^{c}	15.53 ± 0.77^{a}	10.90 ± 0.14^{abc}	33.79 ± 2.09^{de}	0.666 ± 0.01^{b}	14.55 ± 1.19^{cd}
$F10_{75\%}$	46.68 ± 5.19^{bc}	15.43 ± 0.40^{a}	11.56 ± 0.60^{ab}	36.53 ± 3.08^{bcde}	0.647 ± 0.02^{b}	14.84 ± 1.38^{bcd}

* Values represent the average ± standard deviation ($n = 10$). Averages within the same column, in the same experiment, followed by the same letters did not show any significant difference ($p \geq 0.05$) by Tukey's test. The following treatments were used: **Experiment 1**: $Control_{50\%}$ (2.5% NaCl); $F1_{50\%}$ (1.25% NaCl and 1.25% KCl); $F2_{50\%}$ (1.25% NaCl, 1.25% KCl and 0.06% monosodium glutamate (MG)); $F3_{50\%}$ (1.25% NaCl, 1.25% KCl and 1.0% lysine (Lys)); $F4_{50\%}$ (1.25% NaCl, 1.25% KCl and 0.075% taurine (Tau)); $F5_{50\%}$ (1.25% NaCl, 1.25% KCl, 0.06% MG and 1.0% Lys); F6 (1.25% NaCl, 1.25% KCl, 0.06% MG and 0.075% Tau); F7 (1.25% NaCl, 1.25% KCl, 0.06% MG and disodium inosinate/disodium guanylate (IMP/GMP)); $F8_{50\%}$ (1.25% NaCl, 1.25% KCl,1.0% Lys and 0.075% Tau); $F9_{50\%}$ (1.25% NaCl, 1.25% KCl, 0.06% MG and IMP/GMP and 1.0% Lys) and $F10_{50\%}$ (1.25% NaCl, 1.25% KCl, 0.06% MG and IMP/GMP and 0.075% Tau). **Experiment 2:** $Control_{75\%}$ (2.5% NaCl); $F1_{75\%}$ (0.625% NaCl and 1.875% KCl); $F2_{75\%}$ (0.625% NaCl, 1.875% KCl and 0.06% MG); $F3_{75\%}$ (0.625% NaCl, 1.875% KCl and 1.0% Lys); $F4_{75\%}$ (0.625% NaCl, 1.875% KCl and 0.075% Tau); $F5_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and 1.0% Lys); $F6_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and 0.075% Tau); $F7_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and IMP/GMP); $F8_{75\%}$ (0.625% NaCl, 1.875% KCl,1.0% Lys and 0.075% Tau); $F9_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and IMP/GMP and 1.0% Lys) and $F10_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and IMP/GMP and 0.075% Tau).

Table 4
Consumer acceptability (± standard deviation) of the color, aroma, flavor and texture of fermented cooked sausages with reduced sodium content.

	Color	Aroma	Flavor	Texture
Experiment 1				
Control$_{50\%}$	7.16 ± 1.10^{a}	6.30 ± 1.32^{ab}	6.51 ± 1.32^{a}	6.71 ± 1.45^{ab}
F1$_{50\%}$	6.37 ± 1.27^{b}	5.91 ± 1.29^{b}	4.66 ± 1.69^{b}	5.96 ± 1.39^{b}
F2$_{50\%}$	6.77 ± 2.20^{ab}	6.24 ± 2.44^{ab}	6.52 ± 3.92^{a}	6.92 ± 2.46^{a}
F3$_{50\%}$	7.18 ± 1.24^{a}	6.65 ± 1.46^{ab}	6.80 ± 1.44^{a}	7.17 ± 1.37^{a}
F4$_{50\%}$	6.87 ± 1.36^{ab}	6.40 ± 1.54^{ab}	6.41 ± 1.30^{a}	6.76 ± 1.38^{ab}
F5$_{50\%}$	6.93 ± 1.41^{ab}	6.61 ± 1.46^{ab}	6.64 ± 1.48^{a}	7.02 ± 1.42^{a}
F6$_{50\%}$	6.86 ± 1.56^{ab}	6.85 ± 1.31^{a}	6.58 ± 1.47^{a}	6.83 ± 1.43^{a}
F7$_{50\%}$	6.60 ± 1.47^{ab}	6.68 ± 1.34^{ab}	6.71 ± 1.34^{a}	7.03 ± 1.16^{a}
F8$_{50\%}$	6.55 ± 1.36^{ab}	6.42 ± 1.53^{ab}	6.29 ± 1.56^{a}	6.88 ± 1.22^{a}
F9$_{50\%}$	7.03 ± 1.26^{ab}	6.54 ± 1.41^{ab}	6.86 ± 1.42^{a}	7.01 ± 1.40^{a}
F10$_{50\%}$	6.71 ± 1.40^{ab}	6.31 ± 1.46^{ab}	6.42 ± 1.39^{a}	$6.75 \pm 1.38^{a.}$
Experiment 2				
Control$_{75\%}$	6.94 ± 1.37^{a}	6.94 ± 1.31^{a}	7.21 ± 1.18^{a}	7.05 ± 1.38^{a}
F1$_{75\%}$	5.94 ± 1.35^{bc}	5.87 ± 1.55^{b}	5.92 ± 1.35^{b}	5.92 ± 1.53^{b}
F2$_{75\%}$	5.85 ± 1.50^{c}	5.98 ± 1.65^{ab}	6.05 ± 1.47^{b}	5.96 ± 1.59^{b}
F3$_{75\%}$	6.22 ± 1.48^{abc}	6.18 ± 1.71^{ab}	6.03 ± 1.90^{b}	6.11 ± 1.71^{ab}
F4$_{75\%}$	6.54 ± 1.72^{abc}	6.24 ± 1.68^{ab}	6.19 ± 1.65^{b}	5.85 ± 1.80^{b}
F5$_{75\%}$	6.45 ± 1.53^{abc}	6.28 ± 1.63^{ab}	6.30 ± 1.56^{ab}	6.52 ± 1.73^{ab}
F6$_{75\%}$	6.78 ± 1.41^{ab}	6.42 ± 1.58^{ab}	6.35 ± 1.61^{ab}	6.41 ± 1.56^{ab}
F7$_{75\%}$	6.93 ± 2.81^{a}	6.30 ± 3.19^{ab}	6.33 ± 2.80^{ab}	6.10 ± 3.10^{ab}
F8$_{75\%}$	6.65 ± 1.27^{abc}	5.90 ± 1.68^{b}	6.06 ± 1.71^{b}	6.31 ± 1.69^{ab}
F9$_{75\%}$	6.39 ± 1.76^{abc}	6.11 ± 1.64^{ab}	6.29 ± 1.80^{ab}	6.08 ± 1.95^{ab}
F10$_{75\%}$	6.32 ± 1.43^{abc}	5.81 ± 1.37^{b}	5.95 ± 1.59^{b}	6.51 ± 1.66^{ab}

*Values represent the average ± standard deviation ($n = 100$). Averages within the same column, in the same experiment, followed by the same letters did not show any significant difference ($p \geq 0.05$) by Tukey's test. The following treatments were used: **Experiment 1**: Control$_{50\%}$ (2.5% NaCl); F1$_{50\%}$ (1.25% NaCl and 1.25% KCl); F2$_{50\%}$ (1.25% NaCl, 1.25% KCl and 0.06% monosodium glutamate (MG)); F3$_{50\%}$ (1.25% NaCl, 1.25% KCl and 1.0% lysine (Lys)); F4$_{50\%}$ (1.25% NaCl, 1.25% KCl and 0.075% taurine (Tau)); F5$_{50\%}$ (1.25% NaCl, 1.25% KCl, 0.06% MG and 1.0% Lys); F6 (1.25% NaCl, 1.25% KCl, 0.06% MG and 0.075% Tau); F7 (1.25% NaCl, 1.25% KCl, 0.06% MG and disodium inosinate/disodium guanylate (IMP/GMP)); F8$_{50\%}$ (1.25% NaCl, 1.25% KCl,1.0% Lys and 0.075% Tau); F9$_{50\%}$ (1.25% NaCl, 1.25% KCl, 0.06% MG and IMP/GMP and 1.0% Lys) and F10$_{50\%}$ (1.25% NaCl, 1.25% KCl, 0.06% MG and IMP/GMP and 0.075% Tau). **Experiment 2:** Control$_{75\%}$ (2.5% NaCl); F1$_{75\%}$ (0.625% NaCl and 1.875% KCl); F2$_{75\%}$ (0.625% NaCl, 1.875% KCl and 0.06% MG); F3$_{75\%}$ (0.625% NaCl, 1.875% KCl and 1.0% Lys); F4$_{75\%}$ (0.625% NaCl, 1.875% KCl and 0.075% Tau); F5$_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and 1.0% Lys); F6$_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and 0.075% Tau); F7$_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and IMP/GMP); F8$_{75\%}$ (0.625% NaCl, 1.875% KCl,1.0% Lys and 0.075% Tau); F9$_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and IMP/GMP and 1.0% Lys) and F10$_{75\%}$ (0.625% NaCl, 1.875% KCl, 0.06% MG and IMP/GMP and 0.075% Tau).

The color values were significantly lower for F2$_{75\%}$ compared with the Control$_{75\%}$. The treatments F8$_{75\%}$ and F10$_{75\%}$ were significantly different from the Control $_{75\%}$ because these treatments received lower scores for the aroma and flavor attributes. Regarding the flavor, treatments containing monosodium glutamate combined with lysine (F5$_{75\%}$), taurine (F6$_{75\%}$), disodium inosinate and disodium guanylate (F7$_{75\%}$) and disodium inosinate, disodium guanylate and lysine (F9$_{75\%}$) did not differ from Control$_{75\%}$, which demonstrates a significant improvement in the sensory quality of the products with 75% replacement of NaCl with KCl. The texture attributes were significantly lower for the treatments F1$_{75\%}$ (KCl), F2$_{75\%}$ (MG) and F4$_{75\%}$ (Tau) compared with Control$_{75\%}$. These results demonstrate that consumers under the trial conditions did not notice the different texture of the modified products, disagreeing with the results of the texture profile analysis (Table 3).

4. Conclusion

The results suggest that the 50% replacement of NaCl with KCl and the addition of monosodium glutamate, disodium inosinate, disodium guanylate, lysine and taurine produced fermented cooked sausages with suitable physicochemical and sensory qualities. The addition of monosodium glutamate with lysine (F5$_{75\%}$), taurine (F6$_{75\%}$), disodium inosinate and disodium guanylate (F7$_{75\%}$) and disodium inosinate, disodium guanylate and lysine (F9$_{75\%}$) was sufficient for removing the defects caused by 75% replacement of NaCl with KCl, resulting in safe and quality fermented cooked sausages with a sodium reduction of 68%.

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