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Utilization of flavor enhancers in hamburgers with replacement of 70% NaCl by KCl

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Abstract

Hamburgers produced with replacement of 70% NaCl by KCl and addition of lysine, disodium inosinate, disodium guanylate, and monosodium glutamate were investigated. Physicochemical analyses (moisture, proteins, lipids, ash, pH, water activity, color, % yield, % shrinkage) and sensory evaluation were performed. Although the replacement of NaCl by KCl did not cause major changes in the physicochemical characteristics, negative effects on the sensory evaluation were detected. The use of lysine, disodium inosinate, disodium guanylate and monosodium glutamate reduced the sensory defects caused by the replacement of 70% NaCl by KCl, allowing the production of healthy burgers with acceptable sensory characteristics.

Introduction

Hamburger is a meat product that traditionally contains from 2.2 to 2.4% salt (Feiner, 2006), representing about 50% of the recommended daily amount of sodium in 100 g of product (WHO, 2003; 2012). Despite the high amount of sodium, hamburgers are widely consumed in countries around the world and therefore play an important nutritional impact on human's diet. Thus, from a public health perspective, studies on sodium reduction in burgers are required.

However, the sodium reduction in the manufacture of burgers is particularly difficult because it necessarily involves removing or partially replacing NaCl, which is the main source of sodium in the product (Weiss *et al*., 2010). This ingredient solubilizes the myofibrillar proteins improving slicing characteristics, and reduces the initial water activity contributing to conservation. Furthermore, besides conferring the characteristic salty taste of meat products, NaCl also enhances the taste and smell of other components and reduces the perception of other stimuli, such as the bitter taste of some compounds (Coultate, 2002).

Several strategies have been used to reduce the sodium content in meat products. Many studies have reported that the partial replacement of NaCl by KCl is one of the best alternatives to reduce sodium in meat products (Campagnol *et al*., 2011a; Campagnol *et al*., 2011b; Santos *et al*., 2014), once KCl has similar characteristics to NaCl and provides equivalent antimicrobial efficiency (Bidlas and Lamberd, 2008). Furthermore, the potassium intake has not been associated with the development of hypertension and cardiovascular diseases (Kimura *et al*., 2004; Geleijnse *et al*., 2007). However, the replacement of NaCl by KCl above 50% can confer bitter and astringent taste, and lower saltiness, compromising the sensory acceptance (Terrell, 1983; Pasin *et al*., 1989; Desmond, 2006; Mitchell, 2011).

Thus, the search for ingredients that are able to reduce or eliminate the sensory defects caused by the use of high levels of KCl may be a strategy to reduce sodium in meat products without depreciating the quality. Campagnol *et al*. (2011, 2012) and Santos *et al*. (2014) have reported that the use of lysine, disodium inosinate, disodium guanylate, and monosodium glutamate was effective to reduce the sensory defects caused by the replacement of 50% NaCl by KCl in dry fermented sausages. However, the potential application of these ingredients in burgers with NaCI substitution above 50% has not been studied. Based on this, this study aimed to evaluate the effect of addition of lysine, disodium inosinate, disodium guanylate, and monosodium glutamate on the physicochemical and sensory characteristics of burgers with a level of 70% replacement of NaCl by KCl.

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Material and Methods

Five treatments are designed to determine the effect of the 70% replacement of NaCl by KCl on the physicochemical and sensory characteristics of burgers. The compounds lysine, inosinate and disodium guanylate (IMP / GMP), and monosodium glutamate were also added to the treatments with the replacement of NaCl by KCl (Table 1).

Hamburger processing

The burgers were prepared using beef and pork back fat as raw materials. First, excess fat was removed from beef. The raw materials were separately ground in a conventional meat grinder with a 3-mm disk, and then mixed with the remaining ingredients. Hamburgers weighing approximately 80 grams were shaped using a machine for making hamburger patties (Hollymatic Super). The hamburgers were immediately frozen and stored at -18°C until the time of analysis.

Proximate composition

The moisture content was determined by oven drying at 105°C ± 2° C; Nitrogen was determined by the Kjeldahl method, and the protein content estimated by multiplying the nitrogen content by 6.25; The lipid content was determined by the Soxhlet method using petroleum ether, and ash was determined by incineration in a muffle at 550°C (Aoac, 2005). The proximate composition was determined in raw and cooked burgers using three pieces per treatment.

pH and water activity (A_w)

The pH values were determined by direct insertion of pH meter MA 130 (Mettler Toledo Industria e Comercio Ltda, SP, Brazil). The water activity (A_w) was measured in a Decagon Aqualab apparatus (Decagon Devices Inc., Pullman, Washington, USA). The pH and A_w were determined in raw and cooked burgers using three pieces per treatment.

Cooking procedures

After thawing under refrigeration for 12 hours, the burgers were cooked in a hot plate until reaching 72°C at the center of the product. The plate contained a top and bottom heater, so that the turning of the burgers was not necessary. Analyses were performed in triplicate.

The yield percentage was calculated according to Murphy *et al*. (1975):

$$\% \text{ yield} = \frac{\text{Mass of the cooked sample X 100}}{\text{Mass of the raw sample}}$$

Table 1. Formulation of the low-sodium hamburgers

(%)	Control	KCl	R	GM	R+GM
Raw material					
Beef	85	85	85	85	85
Pork back fat	15	15	15	15	15
Ingredients					
Sodium chloride (NaCl)	2.5	0.75	0.75	0.75	0.75
Potassium chloride (KCl)	-	1.75	1.75	1.75	1.75
Lysine	-	-	0.5	0.5	0.5
IMP/GMP*			0.2	-	0.2
Monosodium glutamate	-	-	-	0.38	0.38

*IMP/GMP: Disodium inosinate and disodium guanylate (50:50)

The shrinkage percentage was calculated according to Berry (1992) using the following equation:

% shrinkage = (diameter of the raw sample - Diameter of the cooked sample) X 100

Determination of instrumental color

Color determination was performed using the Minolta CR-400 colorimeter (Konica Minolta Sensing Inc., Japan) with spectral reflectance included as a calibration mode, illuminant D65, and 10° observer angle, operating in the CIE system *(L^* a^* b^*)*. The color coordinates L^* (lightness), a^* (red color intensity) and b^* (yellow color intensity) were determined. Five pieces per treatment were used for color determination, and the color parameters were measured at four different points for each piece.

Sensory evaluation

A sensory acceptance test was performed using a nine-point hedonic scale, ranging from extremely disliked to extremely liked. The attributes color, aroma, flavor, texture, and overall acceptance were evaluated by 50 consumers (Meilgaard *et al*., 1999). The samples were evaluated in a monadic way in two sessions and the order of presentation followed a balanced design as described by Macfie *et al.* (1989). Prior to the tests, the burgers were cooked in a hot plate until reaching 72°C in the center of the product, and stored at 60°C in electric oven until it was served to consumers.

Statistical analysis

Data were evaluated by analysis of variance (ANOVA) and means compared by Tukey's test, at a

Table 2. Chemical composition, pH and Aw of the low-sodium hamburgers

RAW	Control	KCl	R	GM	R+GM
Moisture (%)	64.12±0.69^{a}	64.56±0.49^{a}	63.87±0.19^{a}	64.07±0.54^{a}	64.28±2.48^{a}
Protein (%)	19.86±0.24^{a}	20.44±1.72^{a}	19.32±1.05^{a}	19.30±2.86^{a}	19.05±1.10^{a}
Lipids (%)	13.39±2.51^{a}	11.64±0.89^{a}	13.04±4.62^{a}	13.47±1.83^{a}	15.36±0.90^{a}
Ash (%)	8.75±1.21^{a}	9.18±0.17^{a}	8.85±0.16^{a}	8.78±0.16^{a}	8.18±0.31^{a}
pH	5.57±0.00^{d}	5.68±0.01^{b}	5.71±0.00^{a}	5.62±0.00^{c}	5.67±0.00^{b}
Aw	0.980±0.00^{b}	0.988±0.00^{a}	0.981±0.00^{b}	0.978±0.00^{b}	0.975±0.00^{c}
COOKED	**Control**	**KCl**	**R**	**GM**	**R+GM**
Moisture (%)	54.67±1.72^{a}	52.33±0.19^{a}	55.52±0.44^{a}	53.89±0.36^{a}	51.09±7.61^{a}
Protein (%)	15.41±0.41^{a}	16.52±0.66^{a}	14.66±3.28^{a}	17.58±0.37^{a}	16.04±0.92^{a}
Lipids (%)	9.61±1.81^{a}	7.14±1.26^{a}	7.86±1.02^{a}	8.93±0.23^{a}	9.09±0.54^{a}
Ash (%)	4.12±0.44^{a}	3.25±0.88^{a}	3.30±0.63^{a}	4.45±0.01^{a}	3.95±0.04^{a}
pH	5.78±0.04^{ab}	5.97±0.01^{a}	5.87±0.07^{a}	5.64±0.21^{b}	5.89±0.05^{a}
Aw	0.946±0.00^{b}	0.948±0.00^{ab}	0.955±0.00^{a}	0.948±0.00^{ab}	0.949±0.00^{ab}

[*]Values represent the average ± standard deviation. Averages with the same letter on the same line are not significantly different ($p > 0.05$) according to Tukey's test. The following treatments were used: Control: 2.5% NaCl; KCl: 0.75% NaCl and 1.75% KCl; R: 0.75% NaCl, 1.75% KCl, 0,5% lysine and 0.2% disodium inosinate and disodium guanylate (50:50); GM: 0.75% NaCl, 1.75% KCl, 0.5% lysine and 0.38% monosodium glutamate; R+GM: 0,75% NaCl, 1.75% KCl, 0.5% lysine, 0.2% disodium inosinate and disodium guanylate (50:50) and 0.38% monosodium glutamate.

5% significance level ($p \leq 0.05$), using the statistical package SPSS for Windows (SPSS V 11.5, SPSS Inc., Chicago, IL).

Results and Discussion

The results of chemical composition, pH, and A_w of the low-sodium burgers are shown in Table 2. No significant differences were observed for moisture, proteins, lipids and ash levels of the raw and cooked burgers in all treatments. The proximate composition of the burgers was within the limits established by current legislation (Brasil, 2000).

The replacement of 70% NaCl by KCl and the addition of lysine, IMP / GMP, and MSG caused a significant increase in pH of the raw burgers. Despite the cooking process has increased the pH values, no significant differences were observed between treatments and the control sample. Significant differences were observed for the A_w values of the raw burgers from the treatments with KCl and R + GM when compared to the control, which was not observed for the treatments R and GM. With respect to the cooked burgers, although no significant differences were observed for the treatments KCl, GM, and R + GM, the treatment R presented higher A_w when compared to the control. Similarly, Campagnol *et al.* (2011a) investigated the substitution of 50% NaCl by KCl in cooked fermented sausages, and found no significant changes in the final water activity values.

The yield and shrinkage percentages of the burgers with reduced sodium is shown in Table 3. The replacement of 70% NaCl by KCl did not significantly affect the yield and shrinkage rate of the burgers. Ketenoglu and Candogan (2011) found that beef burger containing 2% sodium chloride showed higher yields and shrinkage rates when compared to the burgers made with 2% commercial salt (57% NaCl, 28% KCl, 12% magnesium sulfate, 2% L-lysine and 2% silicon dioxide).

The results of instrumental color are shown in Table 4. The treatments KCl, R, GM, and R + GM showed significant lower L^* values and higher a^* values when compared to the control, while b^* values were significantly lower in all treatments. This fact can be due to greater oxidative effect of NaCl, as compared to KCl. Similarly, some authors have reported color changes in low sodium meat products (Gou *et al.*, 1996; Gimeno *et al.*, 1999; Zanardi *et al.,* 2010). These coloring problems can occur due to pH differences arising of the substitution of NaCl by other salts (Gou *et al.*, 1996). However, Wirth (1991) found that a reduction of up to 50% NaCl has not significantly affected the color of the fermented sausages.

Table 5 shows the results of sensory evaluation of the low-sodium burgers. No significant differences were observed in the attributes color, aroma, and texture between treatments. The replacement of 70% NaCl by KCl adversely affected the sensory quality of the burgers, once significant lower scores were observed for the attributes flavor and overall

Table 3. % Yield and % shrinkage of the low-sodium hamburgers

	Yield (%)	Shrinkage (%)
Control	74.76±8.49^{a}	32.83±3.01^{a}
KCl	68.87±5.95^{a}	30.52±6.39^{a}
R	72.03±6.69^{a}	33.28±7.59^{a}
GM	72.34±6.52^{a}	26.07±4.58^{a}
R + GM	70.73±8.17^{a}	29.71±7.03^{a}

*Values represent the average ± standard deviation. Averages with the same column on the same line are not significantly different ($p > 0.05$) according to Tukey's test. The following treatments were used: Control: 2.5% NaCl; KCl: 0.75% NaCl and 1.75% KCl; R: 0.75% NaCl, 1.75% KCl, 0,5% lysine and 0.2% disodium inosinate and disodium guanylate (50:50); GM: 0.75% NaCl, 1.75% KCl, 0.5% lysine and 0.38% monosodium glutamate; R+GM: 0,75% NaCl, 1.75% KCl, 0.5% lysine, 0.2% disodium inosinate and disodium guanylate (50:50) and 0.38% monosodium glutamate.

Table 4. L^*, a^* and b^* values of the low-sodium hamburgers

	L*	a*	b*
Control	51.32±1.63^{a}	11.82±0.95c	13.17±1.04^{a}
KCl	45.13±2.49b^{c}	16.23±2.39^{ab}	9.44±1.44^{b}
R	44.09±2.91c	17.64±2.45^{ab}	10.43±1.54^{b}
GM	46.65±3.35^{b}	15.63±2.34^{b}	9.77±1.41^{b}
R + GM	46.63±2.07^{bc}	17.87±1.50^{a}	10.68±1.00^{b}

*Values represent the average ± standard deviation. Averages with the same column on the same line are not significantly different ($p > 0.05$) according to Tukey's test. The following treatments were used: Control: 2.5% NaCl; KCl: 0.75% NaCl and 1.75% KCl; R: 0.75% NaCl, 1.75% KCl, 0,5% lysine and 0.2% disodium inosinate and disodium guanylate (50:50); GM: 0.75% NaCl, 1.75% KCl, 0.5% lysine and 0.38% monosodium glutamate; R+GM: 0,75% NaCl, 1.75% KCl, 0.5% lysine, 0.2% disodium inosinate and disodium guanylate (50:50) and 0.38% monosodium glutamate.

acceptance when compared to the control. These results can be mainly due to the bitter taste conferred by KCl when used at levels above 50% NaCl substitution as reported by other authors (Campagnol *et al.*, 2011a; Campagnol *et al.*, 2011b; Campagnol *et al.*, 2012; Santos *et al.*, 2014). The addition of lysine and IMP / GMP was not sufficient to suppress the sensory defects caused by KCl. In contrast, the treatments containing monosodium glutamate did not differ significantly from the control for all sensory attributes. This behavior may be due to the umami taste conferred by monosodium glutamate (GM), which improves the quality and intensity of flavor in

Table 5. Consumer acceptability of the low-sodium hamburgers

	Color	Aroma	Flavor	Texture	Overall Aceptance
Control	7.4±1.4^{a}	7.3±1.6^{a}	7.7±1.5^{a}	7.5±1.3^{a}	7.5±1.2^{a}
KCl	7.1±1.6^{a}	7.2±1.5^{a}	6.9±1.7^{b}	6.9±1.6^{a}	6.2±1.4^{b}
R	7.5±1.4^{a}	7.2±1.2^{a}	6.8±1.5^{b}	7.1±1.7^{a}	6.1±1.4^{b}
GM	7.3±1.4^{a}	7.3±1.5^{a}	7.4±1.4^{ab}	7.3±1.4^{a}	7.6±1.1^{a}
R + GM	7.3±1.3^{a}	7.0±1.2^{a}	7.2±1.3^{ab}	7.1±1.4^{a}	7.3±1.3^{a}

*Values represent the average ± standard deviation. Averages with the same column on the same line are not significantly different ($p > 0.05$) according to Tukey's test. The following treatments were used: Control: 2.5% NaCl; KCl: 0.75% NaCl and 1.75% KCl; R: 0.75% NaCl, 1.75% KCl, 0,5% lysine and 0.2% disodium inosinate and disodium guanylate (50:50); GM: 0.75% NaCl, 1.75% KCl, 0.5% lysine and 0.38% monosodium glutamate; R+GM: 0,75% NaCl, 1.75% KCl, 0.5% lysine, 0.2% disodium inosinate and disodium guanylate (50:50) and 0.38% monosodium glutamate.

low sodium foods (Zhang *et al.*, 2009).

Conclusions

The results showed that the replacement of 70% NaCl by KCl did not cause major changes in the physicochemical characteristics of the burgers; however, it adversely affected the sensory properties. The use of monosodium glutamate alone or combined with lysine, disodium inosinate, and disodium guanylate suppressed the sensory defects caused by the replacement of 70% NaCl by KCl, allowing the production of healthy burgers with acceptable sensory characteristics.

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