

Sodium reduction by hyposodic salt on quality and chemical composition of hamburgers

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ABSTRACT. This work evaluated the effect of NaCl reduction on the quality and sensorial attributes of hamburgers. Three treatments were tested: control (CON), 100% NaCl; reduction of 25% NaCl (T25), and one with 50% NaCl (T50). The pH, color, lipid oxidation, cooking losses, and texture were analyzed during 120 days of freezing storage. Chemical composition and sensory analyses were performed. The chemical composition was similar for all treatments. The pH value remained within acceptable limits throughout storage. The color, lipid oxidation, cooking losses, and texture were not influenced by the sodium replacement and freezing storage. Sensorial acceptability was also not influenced by sodium reduction. Thus, the results indicated that up to 50% replacement of NaCl by KCl could be carried out in hamburger production without altering the quality and sensorial acceptability.

Keywords: color; chemical composition; lipid oxidation; potassium chloride; sensorial evaluation.

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Introduction

In different countries around the world, sodium consumption exceeds the values recommended by the World Health Organization (WHO, 2012). However, excessive sodium intake can lead to hypertension and the incidence of cardiovascular diseases (Perry & Beevers, 1992; Desmond, 2006), hypertrophy of the heart's left chamber (Schmieder & Messerli, 2000), sodium retention in extracellular fluid, decrease in the elasticity of blood vessels, risk of stomach cancer (Tsugane, Sasazuki, Kobayashi, & Sasaki, 2004), proteinuria resulting in increased risk of kidney diseases (Du Cailar, Ribstein, & Mimran, 2002), increase of calcium in urinary excretion, risk of kidney stones (Cappuccio, Kalaitzidis, Duneclift, & Eastwood, 2000), and susceptibility to bone fractures (osteoporosis), especially for menopausal women (Devine, Criddle, Dick, Kerr, & Prince, 1995). Currently, sodium chloride consumption has been established at 5 to 6 g day⁻¹ person⁻¹, however the recommendation for consumption is 1 to 3 g day⁻¹ person⁻¹ (Yotsuyanagi et al., 2016).

Meat hamburgers are very popular products, particularly among the young generation, and are generally consumed in restaurants, small retail outlets, and as fast food. However, the average hamburger can contain high sodium content, of up to 540 mg 100 g⁻¹ product (Phillips, 2003). Thus, the food industry has been trying to reduce sodium in foods by replacing it with other substances (Carvalho, Madrona, Rydlewski, Corradini, & Prado, 2013b; Cestari et al., 2015; Lilic et al., 2015). NaCl replacement in food is complex, especially, in meat products, and thereby requires an understanding of the NaCl mechanism in meat. Several ingredients, such as potassium, ammonium, calcium, magnesium, and lithium, in chloride salt forms, and anions, such as phosphate and glutamate, might be used for sodium replacement (Carvalho et al., 2018). Notably, KCl is a common alternative and a possible substitute for sodium (Beck, Jekle, & Becker, 2012; Carvalho et al., 2013a; 2013b; 2018). Sensory analyses have shown that 25% of sodium can be replaced by potassium in meat foods (Carvalho et al., 2015; Carvalho et al., 2018). However, since the use of potassium provides a negative taste to the product (Beck et al., 2012), other natural ingredients, including herbs and spices, have been studied as potential flavor additives in meat and meat products (Aliño, Grau, Fernández-Sánchez, Arnold, & Barat, 2010; Carraro, Machado, Espindola, Campagnol, & Pollonio, 2012), to mask the bitter taste.

Thus, this study evaluated the effect of the partial substitution of NaCl by KCl, using a hyposodic salt and the inclusion of aromatic herbs and spices, on the chemical composition, pH, color, lipid oxidation, cooking losses, texture, and sensory evaluation of beef hamburgers.

Material and methods

Place, hamburger production and treatments

The experiment was undertaken in the Laboratory of Quality Analysis of Animal Products, Universidade Estadual de Maringá (UEM).

The selected meat came from the rib section of the *multifidus dorsi* muscle and was acquired from an abattoir in Maringá, from bulls finished in a feedlot at the Iguatemi Experimental Farm of the Universidade Estadual de Maringá. Herbs, spices, and texturized soy protein were acquired on the local market.

The beef was ground with an electric grinder (MCR10/NR12, G. Paniz Indústria de Equipamentos para Alimentação), and then manually mixed with the other ingredients (texturized soy protein, cold water, spices, and herbs), according to good manufacturing practices. The hamburgers were molded as 50 g unit⁻¹ with a thickness of 1 cm. After processing, the samples were identified, packed in a vacuum, and stored at -4°C for further analysis.

Three treatments were tested: control (CON) = 100% NaCl (common salt) with the addition of aromatic spices and herbs; T25 = reduction of 25% NaCl, substituted with 25% KCl (50 common salt and 50% hyposodic salt) with addition of spices and herbs; T50 = 50% NaCl reduction, replaced with 50% KCl (100% hyposodic salt) with the addition of spices and herbs. The hamburgers were formulated and prepared according to (Carvalho et al., 2015).

Herbs and spices, such as garlic powder (*Allium sativum*), oregano (*Oreganum vulgare*), urucum (*Bixa orellana*), and chili (*Capsicum baccatum*), were used to flavor the product and, also, mask the possible bitter taste of KCl. The sodium was reduced by replacing common salt (1 g contained 390 mg sodium and 25 mcg iodine) with hyposodic salt, containing 267 mg potassium, 191 mg sodium, and 25 mcg iodine per gram.

Hamburgers were produced with 88.67 ground beef, 4 texturized soy protein, 5 cold water, 0.20 garlic powder, 0.02 oregano powder, 0.10 annatto, and 0.01% chili. The NaCl and KCl percentages for each of the treatments were as follows: CON (2.00 NaCl and 0.00% KCl), T25 (1.50 NaCl and 0.50% KCl), T50 (1.00 NaCl and 1.00% KCl).

The hamburger quality was analyzed during frozen storage at 1, 60, and 120 days, except for chemical composition, microbiology, and consumers analyses, which were performed only on day 60.

Chemical composition

The chemical composition (moisture, ash, crude protein, total lipids, collagen) was determined by the principle of near-infrared transmittance, using a Food Scan Lab TM instrument (Foss NIR Systems, Inc., USA), which operates in transmittance mode from 850 to 1050 nm at 2 nm intervals. Samples (60 g) of minced meat were placed in a glass cup (90 × 90 × 15 mm) and scanned in duplicate. The spectrum of each sample was the average of five scan locations and was recorded as $\log 1 T^{-1}$ (T = transmittance). The duplicate scans of each sample were examined for consistency and then averaged. Carbohydrates were calculated by difference.

Hamburger preparation for analysis

Samples were taken from the freezer, maintained at ambient temperature (25°C) for 30 min. to thaw, removed from the vacuum package, and left to rest (30 min.) for oxygenation.

pH

The pH was determined by using a digital potentiometer (Hanna HI 99163) equipped with a penetration pH electrode.

Hamburger color determination

The color was measured by light reflectance in the CIELab space, using a Minolta CM-400 portable spectrophotometer, with integrating sphere, 10° angle, and illuminant D65. The L^* , a^* , and b^* coordinates

were recorded directly, representing luminosity (0: black to 100: white), greenness/redness ($-a^*$ to $+a^*$), and blueness/yellowness ($-b^*$ to $+b^*$), respectively.

Determination of lipid oxidation (thiobarbituric acid-reactive substances, TBARS)

The lipid oxidation was assessed by determining the 2-thiobarbituric acid reactive substances (TBARS), based on the method described by Tarladgis, Watts, and Younathan (1960). The samples were minced and weighed in a Falcon tube (10 g sample), and homogenized by using an Ultra-Turrax, following the addition of 20 mL trichloroacetic acid solution (10% in distilled water), then centrifuged (4000 rpm at 4°C) for 30 min. and filtered. The filtrate (2 mL) was mixed with the 2-thiobarbituric acid reagent (2 μ M in distilled water) and placed in a water bath at 97°C for 20 min. After cooling, the spectrophotometric absorbance was read at 532 nm (SP-220, Biospectro). The results were expressed as milligrams of malonaldehyde (MDA) per 1000 g sample. The calibration standard curve was prepared with suitable dilutions of 1,1,3,3-tetramethoxypropane, the precursor of MDA.

Cooking loss and texture

The water loss by cooking was analyzed as the difference in the weight of the sample thawed and after cooking on a preheated grill at 170°C until the hamburger reached an internal temperature of 72°C. The shear strength was measured after the samples reached room temperature, using the Stable Micro Systems TA.XT texturometer equipped with the Warner–Bratzler shear blade accessory, according to the procedure proposed by Wheeler et al. (1997).

Sensorial analysis

Sensory analysis was done by 50 untrained testers and applied to verify the preference and acceptance of the samples based on a hedonic 9-point scale, varying from 1 = dislike very much to 9 = like very much. The samples were analyzed for the attributes of aroma, flavor, texture, and overall evaluation. For testing, the samples were grilled, cut into small cubes, wrapped in aluminum foil identified with random three-digit numbers, and served to the testers. Each tester received the samples, the analysis form, a cracker, and a glass of water to clean the palate. This study was approved by the Research Ethics Committee of the Universidade Estadual de Maringá, under protocol CAAE 21879413.9.0000.0104.

To perform the sensory analysis, analyses were done to guarantee the microbiological quality of the samples, including the coliforms at 45°C, *Staphylococcus* spp., clostridium sulfite-reducing spores at 46°C, and *Salmonella* spp. Twenty-five grams of the sample from each treatment was homogenized with 225 mL of peptone water for 1 min., to perform the initial dilution (10^{-1}) and then serial dilutions (up to 10^{-4}) were conducted (Silva, Neto, Junqueira, & Silveira, 2005). All treatments presented less than 10 MLN g^{-1} at 45°C of total coliforms. *Staphylococcus* spp., *Clostridium* spp., and *Salmonella* spp. were not detected. Thus, all results were in accordance with Brazilian legislation, certifying that the samples were adequate for human consumption (Mancini & Hunt, 2005).

Statistical analysis

Hamburger attributes and acceptability of the sensory qualities were assessed by analysis of variance using the general linear model of SPSS for Windows (version 15.0; IBM SPSS Statistics, SPSS Inc., Chicago, USA). Means and standard error were calculated for each variable, with three replicates per treatment for each analysis. The experiment was repeated twice. When differences were statistically significant, a Tukey test was deployed with statistical significance set at $p = 0.05$. In the consumer test, treatment was considered a fixed effect and the consumer was included as a random effect.

Results and discussion

Chemical composition of hamburgers

Data for the chemical composition of the hamburgers indicated all analyzed parameters were similar, irrespective of the treatments ($p > 0.05$) (Table 1). Moisture and crude protein percentages were around 70.53 and 20.01%, respectively. These percentages are within normal standards for hamburgers, as observed by Carvalho et al. (2015) and Torres, Rimoli, Olivo, Hatano, and Shimokomaki (1998). The ash percentage (1.95%) was lower than the values determined by Carvalho et al. (2018) for beef hamburgers prepared with NaCl reduction (2.41%).

The percentage of total lipids depends on the hamburger preparation (Carvalho et al., 2015; Gouvêa et al., 2016), the type of meat, and the ingredients used (fats). The lipids percentage was around 5.7%, which was not very high because of the type of meat used (*multifidus dorsi* muscle). Leonardi, Feres, Portari, and Jordao (2009) evaluated the composition of beef hamburger from supermarkets in Ribeirão Preto (São Paulo, Brazil) and found 9.23% lipid, assessed by the Soxhlet method, and 22.6% protein, based on the micro-Kjeldahl protocol. The carbohydrate content of the three types of beef hamburgers prepared in the current study was around 1.84% and corresponded mainly to the amount of soy protein added.

Partial replacement of NaCl by KCl did not affect ($p > 0.05$) on the collagen level (Table 1). The collagen content was low (1.40 mg g^{-1} protein) but very similar to that present in the meat used in the preparation of the hamburgers, as the meat retains its structure. The meat in this study came from young bulls (less than 18 months), finished in a feedlot, and fed a diet high in protein and energy. In general, these animals have a collagen content below 1.5 mg g^{-1} protein (Rivaroli et al., 2016).

pH

On day one, before the hamburgers were frozen, the pH was lower ($p < 0.027$) for CON relative to the sodium reduction treatments, with no difference between T25 and T50 (Table 2). After freezing for 60 and 120 days, the pH was similar ($p > 0.05$) for the three types of hamburgers.

The pH of CON did not change ($p > 0.05$) during the freezing period, whereas in treatments with partial replacement of NaCl, the pH was highest at 60 days of freezing (Table 2). In this study, the pH values ranged from 5.48 to 5.85, among the treatments and freezing days. Similar values were found previously in sodium-reduced hamburger (pH 5.42 to 5.86) after its preparation (Carvalho et al., 2015), and in hamburgers from buffalo and sheep, presenting pH values between 5.5 and 5.9 (Silva, Silva, Vargas, Franzolin, & Trindade, 2014; Gouvêa et al., 2016).

Color

The substitution of common salt for hyposodic salt containing KCl had no influence ($p > 0.05$) on the color of beef hamburgers, as well as the freezing time (Table 3). The L^* values ranged from 37.27 to 39.69. García, Calvo, and Selgas (2009) found comparable L^* values for raw hamburgers (38.69), whereas, Carvalho et al. (2018) observed relatively higher L^* values when analyzing sodium-reduced beef burgers (40.75 to 47.52). These variations in L^* may be related to the type of muscle used, the breed of the animal, and processing. The a^* (between 9.80 and 12.42) and b^* (between 12.97 and 13.54) values were in agreement with Carvalho et al. (2018). The a^* value was due to the beef color, and the b^* value may be related to the texturized soy protein, which is yellow.

Table 1. Chemical composition of hamburgers with sodium chloride reduction.

Variables	Treatments			SEM*	p < value
	CON ¹	T25 ²	T50 ³		
Moisture, %	70.56	70.52	70.51	0.02	0.702
Ashes, %	1.95	1.95	1.95	0.002	0.124
Crude protein, %	20.09	19.98	19.96	0.08	0.089
Total lipids, %	5.64	5.68	5.78	0.13	0.439
Carbohydrate %	1.74	1.85	1.95	0.10	0.424
Collagen, mg g^{-1} protein	1.40	1.39	1.43	0.11	0.918

¹Control – With 100% sodium chloride, ²T25 – with 25% sodium reduction, ³T50 – with 50% sodium reduction. *Standard error.

Table 2. Effect of sodium chloride reduction and freezing time on pH of hamburgers.

Freezing time, days	Treatments			SEM*	p < value
	CON ¹	T25 ²	T50 ³		
1	5.48 ^{bb}	5.71 ^{ab}	5.66 ^{ab}	0.039	0.011
60	5.84 ^A	5.84 ^A	5.85 ^A	0.012	0.889
120	5.62 ^{AB}	5.76 ^{AB}	5.73 ^{AB}	0.028	0.141
SEM	0.068	0.023	0.033		
p < value	0.015	0.023	0.021		

¹Control – With 100% sodium chloride, ²T25 – with 25% sodium reduction, ³T50 – with 50% sodium reduction. The uppercase letters for statistical difference in the columns; The lowercase letters for statistics difference in the lines; *Standard error.

Table 3. Effect of sodium chloride reduction and freezing time on color of hamburgers.

Freezing time, days	Treatments			SEM*	p < Value	
	CON ¹	T25 ²	T50 ³			
L*						
1	38.36	37.88	37.27	0.445	0.639	
60	38.23	38.23	39.69	0.587	0.665	
120	37.27	38.11	38.05	0.452	0.782	
SEM*	0.540	0.470	0.628			
p < Value	0.775	0.963	0.424			
a*						
1	12.01	12.00	12.18	0.383	0.978	
60	10.31	10.17	12.42	0.810	0.518	
120	12.14	9.80	11.25	0.649	0.288	
SEM*	0.488	0.727	0.568			
p < Value	0.258	0.404	0.722			
b*						
1	12.97	13.25	13.46	0.388	0.616	
60	13.21	13.43	13.38	0.337	0.958	
120	13.24	13.54	13.52	0.254	0.862	
SEM*	0.198	0.311	0.454			
p < Value	0.867	0.926	0.880			

¹Control – With 100% sodium chloride, ²T25 – with 25% sodium reduction, ³T50 – with 50% sodium reduction. *Standard error.

Lipid oxidation (TBARS)

According to Campo et al. (2003), lipid oxidation in muscle systems is caused by the deterioration of fatty acids into products, such as aldehydes, ketones, alcohols, hydrocarbons, and low molecular weight fatty acids, changing the meat quality, especially the flavor. The current work failed to detect differences in the TBARS ($p > 0.05$) among the treatments and frozen storage times (Table 4). Likewise, Carvalho et al. (2018) did not observe any effect of NaCl reduction on lipid oxidation of beef hamburgers.

At 24 h after slaughter, the TBARS values in beef are below 0.100 mg MDA kg⁻¹ meat (Prado et al., 2015; Rivaroli et al., 2016). However, during hamburger processing, there is increased contact with the environment (oxygenation) and, consequently, an increase in MDA. The maximum values of MDA per kg of meat (0.194 mg MDA kg⁻¹ hamburger) were below the limits (2 mg MDA kg⁻¹ meat) for rancidity and its derivatives perceived by the consumer (Campo et al., 2003), demonstrating that even after frozen storage for 120 days, the product might be well accepted.

Cooking loss and texture

Cooking losses ranged from 15.5 to 22.7% and were small compared to 26% for buffalo and beef hamburgers recorded by Silva et al. (2014), and 30% for beef hamburgers with a NaCl reduction (Carvalho et al., 2018). Cooking denatures muscle proteins, which directly influences the structural characteristics of the meat and meat products (Tornberg, 2005), and also the distribution of water³¹. These changes in structure cause a substantial loss of water (cooking loss) that can vary from 15 to 35% (Pearce, Rosenvold, Andersen, & Hopkins, 2011). The differences in cooking losses noted between the studies may be related to the method used, temperature, and cooking time (Aaslyng, Bejerholm, Ertbjerg, Bertram, & Andersen, 2003; Pearce et al., 2011).

The reduction of the NaCl content and the freezing period did not affect ($p > 0.05$) on the texture (shear force) (Table 5). The shear force ranged from 11.4 to 14.0 N. The texture of meat and meat derivatives is influenced by moisture, fat, and the presence of collagen. In addition, the shear force may vary, depending on the muscle used, preparation of the hamburger, ingredients, and animal species, with variations of 8 to 30 N recorded for bovine, buffalo, and sheep hamburgers (Carvalho et al., 2013a; Silva et al., 2014; Gouvêa et al., 2016).

Sensorial analysis

The partial substitution of NaCl did not change ($p > 0.05$) the color, aroma, flavor, texture, and general acceptance of beef burgers. The color and aroma attributes were assigned scores between 6.5 and 6.8 (Table 6), namely, between 'I liked it slightly' and 'I liked it moderately'. Similar results were noted by other researchers for sodium-reduced beef burgers (Carvalho et al., 2013a; 2015). Flavor, texture, and general acceptance received scores greater than 7, between 'I liked it moderately' and 'I liked it very much'. Thus, the hamburgers were well accepted by consumers (Dutcosky, 2011) According to other studies Carvalho

et al. (2015) and Tobin, 'O'Sullivan, Hamill, and Kerry (2012), the reduction of NaCl content up to 50% has not shown a significant effect on flavor, texture, and general acceptance, with scores >7 recorded.

Table 4. Effect of sodium chloride reduction and freezing time on lipid oxidation.

Freezing time, days	Treatments			SEM*	p < <i>Value</i>
	CON ¹	T25 ²	T50 ³		
Lipid oxidation					
1	0.167	0.168	0.186	0.005	0.224
60	0.173	0.169	0.173	0.004	0.88
120	0.186	0.194	0.180	0.002	0.101
SEM*	0.004	0.006	0.004		
p < <i>Value</i>	0.102	0.127	0.484		

¹Control – With 100% sodium chloride, ²T25 – with 25% sodium reduction, ³T50 – with 50% sodium reduction. *Standard error.

Table 5. Effect of sodium chloride reduction and freezing time on cooking losses and texture of hamburgers.

Freezing time, days	Treatments			SEM*	p < Value
	CON ¹	T25 ²	T50 ³		
Cooking losses					
1	19.57	15.51	20.15	0.993	0.055
60	20.62	18.08	17.74	0.679	0.134
120	22.76	21.43	18.75	0.953	0.235
SEM*	0.685	1.244	0.716		
p < Value	0.161	0.11	0.497		
Texture					
1	11.43	11.76	11.72	0.376	0.932
60	12.88	13.18	12.24	0.424	0.675
120	12.36	13.94	14	0.516	0.327
SEM*	0.399	0.477	0.509		
p < Value	0.359	0.233	0.183		

¹Control – With 100% sodium chloride, ²T25 – with 25% sodium reduction, ³T50 – with 50% sodium reduction. *Standard error.

Table 6. Sensorial analysis of hamburgers with sodium chloride reduction.

Attributes	Treatments			SEM*	p < Value Random consumer
	CON ¹	T25 ²	T50 ³		
Color	6.73	6.54	6.81	1.643	0.253
Aroma	6.76	6.81	6.68	1.662	0.846
Flavor	7.81	7.30	7.14	1.377	0.074
Texture	7.73	7.59	7.49	1.250	0.529
Overall acceptability	7.59	7.19	7.19	1.253	0.100

¹Control – With 100% sodium chloride, ²T25 – with 25% sodium reduction, ³T50 – with 50% sodium reduction. *Standard error.

Conclusion

The substitution of NaCl for KCl in hamburger incorporated with herbs and spices is an effective strategy for the acceptability of this product, enabling up to 50% NaCl substitution and thereby, sodium reduction, without altering the nutritional and sensorial qualities of the product. Substitution of 100% of common salt by hyposodic salt in these products maintained all characteristics, and may also improve consumers' health, due to the reduction of sodium consumption.

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