Acta Scientiarum

http://periodicos.uem.br/ojs/acta
ISSN on-line: 1807-8664
Doi: 10.4025/actascitechnol.v42i1.45632

SCIENCE, FOOD TECHNOLOGY AND FOOD ENGINEERING

Technological and sensory analysis of beef burger replacing NaCl with KCl and flavor enhancer

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ABSTRACT. High sodium consumption may increase the risk of hypertension. ANVISA has proposed reducing sodium levels in food, but this may reduce consumer acceptance. This study investigated the technological and sensory profile of samples of beef burger replacing NaCl with KCl added flavor enhancers, namely: CON (100% NaCl), F50 (50% NaCl and KCl + PuraQ®Arome NA4), and F60 (40% NaCl and 60% KCl + PuraQ®Arome NA4). Physicochemical, technological, microbiological and sensory parameters of the formulations were evaluated. There was no difference between formulations in microbiological, physicochemical and technological parameters. For color analysis, F60 reduced to the coordinate a* and raised b* compared to the CON. In sensory analysis, F60 reduced the flavor attribute compared to the CON. PuraQ® minimized the salty perception of the F50, however, but did not avoid the residual flavor in the F60. The principal component analysis associated the attributes with the formulations as follows: succulent and ideal seasoning (CON), soft and without salt (F50), and salty and residual flavor (F60). It was concluded that the reduction of 50% of NaCl added enhancer was better accepted by consumers, being a promising strategy in reducing sodium in burgers.

Keywords: meat products; salt; color; centesimal composition; CATA.

Received on December 3, 2018
Accepted on July 19, 2019

Introduction

Cardiovascular diseases are associated with high salt intake, which is considered the greatest risk factor for hypertension (Cobb, Appel, & Anderson, 2012). Studies have reported that 26.4% of the world's adult population is hypertensive, and that inadequate diet is the main cause of this pathology (Cruz et al., 2011; Inguglia, Zhang, Tiwari, Kerry, & Burgess, 2017; Jackson et al., 2016). Processed meat products are the most important source of salt (sodium chloride: NaCl) in the diet, contributing 20-30% of the daily intake of NaCl, which contains 39.3% sodium (Ruusunen & Puolanne, 2005). World consumption of salt *per capita* has been between 8 and 13 g day^{-1}, however, the World Health Organization (WHO) recommends a maximum intake of 5 g day^{-1}, equivalent to 2 g of sodium (Inguglia et al., 2017; Nilson, Jaime, & Resende, 2012; WHO, 2003).

In 2011, the Ministry of Health and the Brazilian Food Industry Association (ABIA) signed a commitment to gradually and voluntarily reduce sodium content in processed foods, considering the development of new technologies, formulations and adaptation of the consumer's taste (Brasil, 2013). Among the processed foods that agreed to reduce sodium, the burger stands out (Nilson et al., 2012). It is a processed meat product obtained from minced meat, with or without addition of fat and other ingredients, consumed by all social classes in restaurants and fast food outlets (Alves et al., 2017). However, it contains 43% of the daily sodium recommendation, raising the risk of cardiovascular diseases, since the excessive consumption of sodium can increase the risk of hypertension (Mitterer-Daltoé, Nogueira, Rodrigues, & Breda, 2017; Oliveira et al., 2014; WHO, 2003).

Sodium is an essential ingredient in the processing of meat products, and cannot be completely eliminated, since it plays a role in enhancing taste and has important technological properties (Alino et al., 2010; Choi et al., 2014; Grasso, Brunton, Lyng, Lalor, & Manahan, 2014). Reducing it in meat products may have a negative effect, such as increasing loss during cooking, in addition to reducing perceived salinity and flavor intensity (Choi, et al., 2014; Perisic, Afseth, Ofstad, Narum, & Kohler, 2013; Ruusunen & Puolanne, 2005).

Potassium chloride (KCl) is the most commonly used NaCl substitute for reducing sodium in meat products, because it does not affect pathologies such as hypertension and cardiovascular diseases (Alves et al., 2017; Lilic et al., 2015). However, when used in large quantities, it is necessary to associate with other ingredients, which reinforce the perception of salinity and mask the residual metallic taste of potassium (Grasso et al., 2014; Inguglia et al., 2017; Ruusunen & Puolanne, 2005). Flavor potentiator or enhancers are substances that do not have a salty taste in themselves, but may increase salinity perception when used with NaCl and compensate for salt reduction in meat products (Fellendorf, O'Sullivan, & Kerry, 2016).

In the literature, there are studies on the reduction of NaCl (Oliveira et al., 2014; Perisic et al., 2013), replacement with KCl (Alino et al., 2010; Carvalho et al., 2015; Fieira, Marchi, & Alfaro, 2015; Lilic et al., 2015), in meat products (Alves et al., 2017; Georgantelis, Blekas, Katikou, Ambrosiadis, & Fletouris, 2007; Jorge et al., 2015; Oliveira et al., 2016) and the use of flavor enhancers (Fellendorf et al., 2016). However, knowing that the burger is a very widely-consumed meat product with a high sodium content and a high risk of inducing hypertension, there has yet to investigation into developing the beef burger with replacement of 50 and 60% of NaCl with KCl and the addition of flavor enhancer to minimize the effect of sodium reduction and the residual taste of potassium.

Material and methods

The burgers were prepared at the Meat Product Processing Unit and the analyses carried out at the laboratories of the Physicochemical, Microbiological and Sensory Analysis at the Food Science and Technology Department of the Federal Institute of Education, Science and Technology of the Southeast of Minas Gerais State - Rio Pomba Campus, and at the Food Product Analysis laboratory of the Food Technology Department of the Federal University of Viçosa. The meat pork and beef used were acquired from a local business with the Federal Inspection Seal (SIF) and the condiments and additives from Pif Paf Alimentos.

Formulation and procedures

The three burger formulations were defined by reference to NaCl content and KCl substitute, with the addition of the flavor enhancer (Table 1): CON (100% NaCl); F50 (50% NaCl, 50% KCl and PuraQ®Arome NA4 flavor enhancer); F60 (40% NaCl, 60% KCl and PuraQ®Arome NA4 flavor enhancer). The PuraQ®Arome NA4 flavor enhancer is composed of substances derived from the fermentation, such as sugars, salts of organic acids and aromas (Fellendorf et al., 2016), and has been used in formulations F50 and F60 instead of sodium lactate because both ingredients have a microbiological stability function.

Table 1. Composition of burger formulations (%).

Ingredients	COM	F50	F60
Beef + Soy Protein (68.0 + 4.0)	72.00	72.00	72.00
Fat	8.0	8.0	8.0
Ice Water	11.89	11.93	11.93
Sodium Lactate	2.00	-	-
PuraQ®Arome NA4	-	2.00	2.00
Refined Salt (NaCl)	1.50	0.73	0.58
Potassium Cloride (KCl)	-	0.73	0.87
Refined Sugar	0.50	0.50	0.50
Sodium Tripolyphosphate	0.30	0.30	0.30
Monosodium Glutamate	0.30	0.30	0.30
Sodium Erythorbate	0.10	0.10	0.10
Caramel Pigment	0.05	0.05	0.05
Spice	3.36	3.36	3.36
Total	100.00	100.00	100.00

CON = 100% NaCl; F50 = 50% NaCl, 50% KCl + PuraQ®Arome NA4; F60 = 40% NaCl, 60% KCl + PuraQ®Arome NA4.

In the processing of the burgers, the beef was cleaned by removing the fat and apparent connective tissue, were ground separately in a semi-industrial grinder (CAF-model 22STB), mouth No. 20 and 5 mm disc. The other ingredients were then weighed, incorporated into the meat mass and hand mixed with according to Good Manufacturing Practices. After the homogenization of the ingredients, the burgers were shaped in stainless steel burger molds obtaining patties of 12 cm in diameter and 100 grams in weight. The burgers were packed in polyethylene bags and stored in a freezer at -18°C until analysis. When necessary, the steaks were grilled on the George Foreman anti-adherent grill (Super Jumgo - GBZ31SB) at 200°C for an average time of 4 minutes for cooking on both sides, time required to reach a temperature of 75°C in the center of the products (Oliveira et al., 2014).

Centesimal composition, color and technological analyses

The centesimal composition analyses were performed on the raw burgers, obtaining the percentages of moisture, ash, proteins, fats and carbohydrates, in triplicate, according to the official methodology (Association of Official Analytical Chemists [AOAC], 2012). Determination of the sodium content was performed on the raw burgers using atomic spectrophotometry by the flame photometry method (AOAC., 2012). Color measurements were performed on the surface of cooked burgers using a color-measuring spectrophotometer (Model 4500L, HunterLab®) on the average of five readings at different points (Georgantelis et al., 2007). Technological analyses of yield, shrinkage and water retention capacity of the cooked product were also carried out (Oliveira et al., 2014).

Microbiological analyses

The burgers were subjected to microbiological analysis, aiming to identify the main bacteria in refrigerated and frozen raw meat products, according to ANVISA RDC Nº 12 of 02/01/01 (Brasil, 2001). Detection tests of coliforms at 45°C, *Staphylococcus* coagulase positive, *Salmonella* and *Clostridium* sulfite reductant were performed according to authors (Silva et al., 2010).

Sensory analyses

The sensory analyses were conducted following approval by the Research Ethics Committee for Research Involving Human Beings of the Federal Institute of Education, Science and Technology of the Sudeste of Minas Gerais State, approval number 1,826,821 (Plataforma Brasil), as well as after obtaining the results of the microbiological analyses and verifying that the formulations met the standards set.

Sensory evaluation was performed using the CATA ("Check all that apply") method, in which the descriptive attributes of the burgers were evaluated. In order to better understand how the formulations affect the sensory attributes, a map of external preferences (MPE, Figure 1) was produced by projecting the results obtained in the principal component analysis (PCA) of the burgers studied, based on the acceptance data and the descriptive attributes of the CATA methodology (Jorge et al., 2015). This test was performed in complete balanced and randomized blocks in two stages: First, 25 untrained consumers who had a habit of consuming beef burgers were recruited and instructed to identify the characteristics that best described the burger. The form contained 64 attributes, which characterized appearance, aroma, taste and texture to the product. The most cited terms in this test were selected to compose the CATA questionnaire, which was applied next.

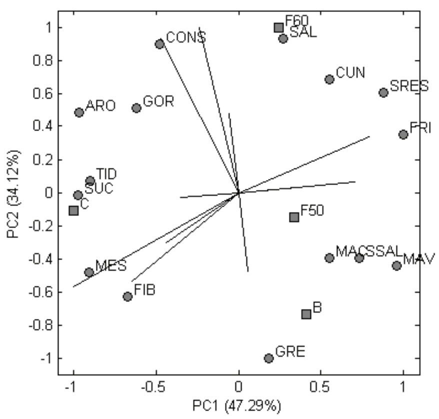

Figure 1. Graphic representation of the external preference map of the acceptance of the burger formulations.

ARO: aromatic, CONS: consistent, CUN: uniform color, FIB: fibrous, FRI: fried, GOR: fatty, GRE: grilled, MAC: soft, MAV: reddish brown, MES: dark brown, SAL: salty, SRES: residual flavor, SSAL: without salt, SUC: succulent, TID: ideal seasoning.

Statistical analysis

The experiment was conducted in a completely randomized design (CRD) with three repetitions using variance analysis (ANOVA) and, when it was significant ($p < 0.05$) performed Tukey's test in the Statistica

7.0 software. The CATA results were evaluated by the principal component analysis (PCA), using a vector model and the level of significance of 0.25 of probability, performed in the SensoMaker statistical software version 1.9 (MatLab®).

Results and discussion

Microbiological analyses

The results of the microbiological analyses (Table 2) show that the analyzed samples were within the limits established by Brazilian legislation (Brasil, 2001), allowing them to be used for sensory analysis.

One of the most important properties of NaCl is providing microbiological stability to products. This action is also attributed to KCl for pathogenic bacteria (Bidlas & Lambert, 2008). The results of this study demonstrate that the partial replacement of NaCl with KCl in beef burgers did not affect microbial growth. These data corroborate those of Carvalho et al. (2015) and Oliveira et al. (2014), who also did not observe significant alterations in the microbiological characteristics in beef burger with reduced sodium content and in burger with replacement of NaCl with KCl and addition of flaxseed flour, respectively.

Table 2. Microbiological analyses of the burgers.

Formulation	CON	F50	F60	PM
Coliform at 45°C (UFC g^{-1})	<10^1	1.6 x 10^2	<10^1	5 x 10^3
Salmonella (in 25g)	Absent	Absent	Absent	Absent
Staphylococcus coagulase positive (UFC g^{-1})	<10^2	<10^2	<10^2	5 x 10^3
Clostridium sulfite reductant at 46°C (UFC g^{-1})	<10^1	<10^1	<10^1	3 x 10^3

CON = 100% NaCl; F50 = 50% NaCl, 50% KCl + PuraQ®Arome NA4; F60 = 40% NaCl, 60% KCl + PuraQ®Arome NA4. PM: microbiological standards of RDC No. 12 of January 2001 (Brasil, 2001).

Centesimal composition analyses

Table 3 shows the results of the physicochemical, sensory and sodium content analyses of the burgers.

In this study, it was found that the reduction of NaCl did not affect ($p > 0.05$) any of the parameters of the centesimal composition of the burgers. Considering that the formulations studied differed only in the contents of NaCl, KCl and ice water, such results were expected. These data corroborate those of Carvalho et al. (2015) and Oliveira et al. (2014), which, in replacing 50% NaCl with KCl in burger also did not observe difference for ash, proteins, lipids and carbohydrates between the treatments.

Table 3. Physicochemical, color, technological and sensory analyses of burgers.

Parameters	CON	F50	F60
Physicochemical analysis (%)			
Moisture	66.0 ± 1.1 a	66.6 ± 0.7 a	67.0 ± 0.8 a
Ash	3.2 ± 0.3 a	3.4 ± 0.1 a	3.4 ± 0.1 a
Protein	20.0 ± 1.7 a	19.4 ± 2.5 a	18.9 ± 3.0 a
Fat	3.1 ± 1.1 a	4.5 ± 1.8 a	4.6 ± 1.7 a
Carbohydrate	7.7 ± 1.1 a	6.1 ± 1.7 a	6.1 ± 1.9 a
Sodium (mg 100 g^{-1})	1,393.0 ± 100.4 a	950.0 ± 40.5 b	895.0 ± 36.5 b
Color analysis			
L*	36.0 ± 3.8 a	37.5 ± 1.6 a	37.9 ± 2.0 a
a*	9.6 ± 1.1 a	8.4 ± 0.4 b	8.6 ± 0.1 b
b*	16.8 ± 0.7 a	17.04 ± 0.53 ab	17.9 ± 0.4 b
Technological analysis (%)			
Yield	82.8 ± 5.1 a	78.8 ± 6.9 a	78.4 ± 6.6 a
Shrinkage	18.2 ± 6.5 a	19.8 ± 4.8 a	20.0 ± 7.0 a
WRC	73.9 ± 7.6 a	67.9 ± 10.1 a	67.6 ± 10.4 a
Sensory analysis			
Appearance	7.7 ± 0.2 a	7.6 ± 0.2 a	7.4 ± 0.2 a
Aroma	7.6 ± 0.2 a	7.6 ± 0.2 a	7.3 ± 0.2 a
Flavor	8.0 ± 0.2 a	7.8 ± 0.2 ab	7.3 ± 0.2 b
Texture	7.7 ± 0.2 a	7.8 ± 0.2 a	7.5 ± 0.2 a
Overall Acceptance	7.9 ± 0.2 a	7.7 ± 0.2 a	7.6 ± 0.2 a

CON = 100% NaCl; F50 = 50% NaCl, 50% KCl + PuraQ®Arome NA4; F60 = 40% NaCl, 60% KCl + PuraQ®Arome NA4. WRC: water retention capacity. Averages on the same line followed by the same letters do not differ from each other by *Tukey's* test at the 5% probability level. L* (change from light to dark, with 100 being white and zero being black); +a (indicates red), -a (indicates green); +b (indicates yellow) and -b (indicates blue).

Protein and lipid analyses did not present statistical difference ($p > 0.05$) between treatments and met the requirements of the Technical Regulation of Identity and Quality of Hamburger (Brasil, 2000), which establishes a minimum protein content of 15% and a maximum of 23% for lipids.

On the other hand, a significant difference was found in the sodium contents between the control group and the other formulations. Due to the reduction of 50 and 60% of NaCl content in the F50 and F60 formulations, a reduction in sodium content of 32.0 and 36.0% was observed in the burgers, respectively. The reduction obtained (F50: 443 mg and F60: 498 mg) enabled the experimental formulations to come under the "light" classification of Brazilian legislation, according to Technical Report No. 50/2012. This regulates that a product is classified in the "light" category when one of its ingredients is reduced by at least 25%, which would represent a reduction of 348 mg of sodium.

Color analyses

The color of a meat product can be altered by sodium reduction and decisively affect overall consumer acceptance (Jorge et al., 2015; Zanardi, Ghidini, Conter, & Ianieri, 2010). In this study it was verified that Luminosity (L*) did not differ significantly between the treatments ($p > 0.05$) indicating that the sodium replacement did not negatively influence the color of the cooked burgers. Similar results were found by Alves et al. (2017) who analyzed the replacement of 50% NaCl with KCl in sausage and did not observe change in the L* parameter, as well as by Fellendorf et al. (2016) when studying NaCl replacement with KCl or PuraQ®Arome NA4 in black puddings.

The a* coordinate showed a significant reduction ($p < 0.05$) for the treatments with NaCl replacement, tending to a less red coloration. When comparing the data of this study, papers on burger and PuraQ®Arome NA4 were not found in the literature, although Fellendorf et al. (2016) verified in black puddings, that in replacing 40 and 60% of NaCl, KCl significantly reduced the values of a*, however, PuraQ®Arome NA4 did not interfere. On the other hand, Alves et al. (2017) did not observe difference in the value of a* for the replacement of 50% of NaCl with KCl in sausage.

The observed values for b* were like those found by Georgantelis et al. (2007), who studied beef burger with 1.5% NaCl. In the present study it was also observed that the replacement of 60% NaCl with KCl plus PuraQ®Arome NA4 significantly increased the yellow coloration when compared to the control. Such behavior was not identified by Fellendorf et al. (2016) when analyzing 60% NaCl replacement with KCl or PuraQ®Arome NA4 separately in black puddings, however, they did not evaluate the association of the two substitutes, suggesting that further studies with burger be performed to confirm the data for the a* and b* coordinates.

Technological analyses

The analyses of yield, shrinkage and water retention capacity did not show a significant difference ($p > 0.05$) between the treatments analyzed after cooking, concluding that the sodium replacements did not significantly influence these characteristics. The data of the present experiment were like those of Oliveira et al. (2014), which in the evaluation of beef burger substituted 66.0% NaCl with KCl, also do not find statistical difference between the formulations for these technological parameters. On the other hand, although the variation was insufficient to differ statistically, formulations with lower sodium content (F50 and F60) showed a lower capacity to maintain moisture in the burger matrix, resulting in a slight decrease in yield and in water retention capacity % after cooking. This is explained by the role of salt in meat products, which has vital importance in the solubilization and extraction of myofibrillar proteins, in the reduction of its isoelectric point, solubilizing actin and myosin proteins, and raising water retention capacity % (Alves et al., 2017; Mitterer-Daltoé et al., 2017).

Sensory analyses

For sensory analysis of burgers, the attributes of appearance, aroma, texture and overall acceptability did not present significant difference ($p > 0.05$) between treatments. When studying the replacement of 60% NaCl with KCl or PuraQ®Arome NA4 in black puddings, Fellendorf et al. (2016) also did not observe significant alteration in the sensory evaluation of these attributes. Fieira et al. (2015) also did not identify alteration in these parameters when replacing NaCl with KCl in Italian salami. On the other hand, Carvalho et al. (2015) studying burger with a reduction of 50% of NaCl, identified that the reduction of sodium elevated the scores for the attributes appearance, aroma and texture. It did not find burger studies to compare to the present study; however, this variation in sensory results in diversified products between studies suggests the need for further studies with burgers to confirm such findings.

For the flavor attribute, a significant difference ($p < 0.05$) was identified between the CON and F60 formulations, showing that the replacement of 60% NaCl with KCl decreased acceptance by consumers. For the substituted 50% of NaCl (F50) no change in flavor attribute was observed when compared to the other formulations. Carvalho et al. (2015) verified a significant reduction in the flavor attribute (salty, fatty, and meaty) in the burger with reduction of 50% of NaCl compared to the control. This difference between the results of the studies for the formulations with 50% NaCl can be explained by the addition of the flavor enhancer in the present study, suggesting that PuraQ®Arome NA4 improved taste perception and did not negatively affect acceptance by consumers.

In the sensory evaluation of the hedonic scale, the replacement of NaCl with KCl did not negatively affect consumer acceptance of the burgers. The formulation with 50% replacement of NaCl showed no statistical change in the evaluated attributes. However, the formulation with 60% replacement with KCl, despite showing a slight reduction in the flavor attribute score, maintained all attributes with scores above 7.3 ("moderately liked"), showing a good acceptance of the formulation.

CATA methodology

The two principal components of the external preference map (MPE) together explained 81.4% of the variance of the acceptance data after adjustment with a vector model (r^2 = 0.9858), being considered sufficient to represent the dispersion of the samples, as it explains more than 70% of the data variation (Minim, 2013).

In the principal component analysis (PCA), the dispersion of the formulations studied identifies the formation of three distinct groups located in different quadrants. The terms "salty" and "residual flavor" of the flavor attribute and "uniform color" of the appearance attribute were the most correlated with the F60 formulation burger, showing that the use of PuraQ®Arome NA4 was efficient in enhancing the salty taste of burgers with sodium reduction, however, it did not sufficiently minimize the bitter taste from KCl. The term "residual flavor" also showed an approximation tendency for the F50 formulation, which is explained by the replacement of NaCl with KCl in the proportion of 50%.

The terms "succulent" of the texture attribute and "ideal seasoning" of the flavor attribute were more correlated with the control sample. In the data of Carvalho et al. (2015) studying the reduction of 25 and 50% of NaCl, consumers identified the "salty" flavor attribute most associated with the control treatment. In the present study, results like those of Carvalho et al. (2015) were expected due to the higher levels of NaCl and the presence of sodium lactate in the control treatment. This difference can be attributed to the action of the flavor enhancer in stimulating the perception of salty taste in the F60 formulation.

The F50 treatment showed the terms "soft" of the texture attribute and "without salt" of the flavor attribute as the most related to the replacement with 50% KCl, suggesting that although it was not statistically significant, sodium reduction was also perceived in this formulation. This result is like that presented by Carvalho et al. (2015), which showed greater adherence to "soft" texture attributes in burgers with 50% reduction of NaCl.

Conclusion

Replacing 50% NaCl with KCl added flavor enhancer proved to be the most viable alternative in the development of reduced-sodium beef burger, and a promising alternative to meet Anvisa's goals.

Flavor enhancer has been used by the food industry to emphasize salt perception in NaCl reduction. PuraQ®Arome NA4 has proven viable to replace 50% NaCl, but for bolder reductions and to mask the residual taste of KCl, it is suggested to associate it with herbs and spices or new ingredients.

Acknowledgements

The authors thank CNPq for the Scientific Initiation (PIBITI) scholarship, the FAPEMIG for financial support while developing the project, the Rio Pomba Campus and the Pro-Rector of Research and Innovation of IF Sudeste MG for the laboratory infrastructure and resources for development of research.

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