Partial replacement of sodium chloride by potassium chloride and inclusion of oregano and thyme oils on consumer acceptability of beef hamburgers

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Abstract. This work replaces sodium chloride (NaCl) by potassium chloride (KCl) at increasing levels, with the addition of essential oils from oregano and thyme to mitigate the effect of potassium chloride on consumers' sensory evaluation of beef hamburgers. Three levels of replacement of sodium by potassium were tested (KC20, KC40 and KC60 with 20%, 40% and 60% of replacement respectively) and compared to the control (CONT, 100% sodium chloride) how much initial microbiological characteristics and sensory evaluation by 112 consumers. The replacement of NaCl by KCl did not change ($P > 0.05$) the initial microbial population. Likewise, the levels of replacement of NaCl by KCl did not change ($P > 0.05$) the color, odor and texture acceptability of the beef hamburgers. Substitutions of 20% and 40% of NaCl by KCl improved ($P < 0.05$) the flavor and overall acceptability of beef hamburgers. Still, for 60% replacement levels, no difference was observed ($P > 0.05$) when compared to the CONT group. Different clusters of consumers were observed for flavor and overall acceptability ($P < 0.05$). In conclusion, it is possible to replace up to 60% of NaCl by KCl in beef hamburgers, with the inclusion of essential oils of oregano and thyme, in the sensory evaluation by consumers being 20% the most recommended level of replacement.

Keywords: Essential oils, hypertension, meat products, potassium chloride, sensory evaluation, sodium replacement

Substituição parcial de cloreto de sódio pelo cloreto de potássio e inclusão de óleos de orégano e tomilho na aceitabilidade pelos consumidores de hambúrgueres bovinos

Resumo. Este trabalho substitui o cloreto de sódio (NaCl) por cloreto de potássio (KCl) em níveis crescentes, com a adição de óleos essenciais de orégano e tomilho para mitigar o efeito do cloreto de potássio na avaliação sensorial dos consumidores de hambúrgueres bovinos. Foram testados três níveis de substituição de sódio por potássio (KC20, KC40 e KC60 com 20%, 40% e 60% de substituição, respectivamente) e comparados com o controle (CONT, 100% cloreto de sódio), quanto às características microbiológicas iniciais e avaliação sensorial por 112 consumidores. A substituição de NaCl por KCl não alterou ($P > 0,05$) a população microbiana inicial. Da mesma forma, os níveis de substituição de NaCl por KCl não alteraram ($P > 0,05$) a aceitabilidade de cor, odor e textura dos hambúrgueres bovinos. As substituições de 20% e 40% de NaCl por KCl melhoraram ($P <$

0,05) o sabor e a aceitabilidade geral dos hambúrgueres bovinos. Ainda, para níveis de substituição de 60%, não foi observada diferença (P > 0,05) quando comparado ao grupo CONT. Diferentes grupos de consumidores foram observados para sabor e aceitabilidade geral (P < 0,050). Em conclusão, é possível substituir até 60% de NaCl por KCl em hambúrgueres bovinos, com inclusão de óleos essenciais de orégano e tomilho, na avaliação sensorial pelos consumidores, sendo 20% o nível de substituição mais recomendado.

Palavras-chave: Óleos essenciais, hipertensão, produtos cárneos, cloreto de potássio, avaliação sensorial, substituição de sódio

Introduction

The effects of high sodium consumption on blood pressure and, consequently, on the risk of cardiovascular disease, are well documented. High sodium intake occurs in several countries. However, the main consumption of sodium varies according to the country studied (Inguglia et al., 2017). In many countries, this consumption can go beyond industrialized products (Dötsch et al., 2009). Salt-based condiments is the principal source of sodium for the people (Doyle & Glass, 2010). Meat co-products foods are among those with the highest sodium content in the preparations of the typical meal (Carvalho et al., 2017). WHO (2010) recommends daily consumption of less than 5 g of chloride sodium or 2 g of sodium. Thus, different strategies are defined to achieve this objective: labeling, legislation, reformulation of products, tax incentives, and consumer education.

Much recent research has focused on reformulating products using different techniques, such as replacing sodium chloride by potassium chloride, or other salts (Carvalho et al., 2017; Ramos et al., 2020). In addition, much of the research focuses on the isolated reduction of added salt, which can strongly affect the taste and acceptance of food. In contrast, the strategies that use the addition of herbs and spices can highlight the salty taste, improve the taste and nutritional characteristics of foods, favoring the acceptance of these foods (Alexandre et al., 2021; Kempinski et al., 2017; Sary et al., 2021; Vital et al., 2021). Several studies have already demonstrated the benefits of using herbs and spices in foods due to the effect of phenolic antioxidants on health, their synergisms and interactions that can enhance antioxidant activity in foods, in addition to basically adding flavor (Carvalho et al., 2017; Kempinski et al., 2017; Nascimento et al., 2020). Common herbs such as oregano, rosemary, and basil when used in the preparation of various foods, have an important effect in reducing lipid oxidation and antimicrobial activity, in addition to providing increased sources of antioxidant compounds in the diet (Carvalho et al., 2017; Kempinski et al., 2017; Nascimento et al., 2020).

The associated use of different herbs in various proportions, such as oregano, garlic, rosemary, and sage have great acceptability and is an effective proposal for reducing salt in foods, with results of up to 56% of acceptability among 60 evaluated tasters (Mitchell et al., 2013). Among the essential oils, oregano and thyme are the most used spices for culinary purposes (Vital et al., 2021; Vital et al., 2018). The essential oils of oregano and thymol are used in meat and its derivatives due to their antioxidant and antimicrobial activity, attributed to the presence of the phenolic compounds present in their composition (Emiroğlu et al., 2010). In addition to antioxidant and antimicrobial factors, these oils also have the flavoring factor, which could mitigate the effect of including potassium chloride in foods. Therefore, the sensory attributes of meat and its derivatives could be preserved or sharpened by the use of essential oils due to their flavoring characteristics (Monteschio et al., 2020; Ornaghi et al., 2020; Vital, 2021; Vital et al., 2018).

This study was carried out to evaluate the effect of partial replacement of sodium chloride by potassium chloride with the inclusion of essential oils (oregano and thymol) as flavoring products, on initial microbial count and sensory evaluation by consumers of beef burgers.

Material and methods

Meat samples

The meat used for this study was the *Biceps femuris* muscle from a Nellore steer, finished in *Brachiaria* pasture for 24 months, weighting 480.0 kg and slaughtered at 24 months old, obtained from the market of Maringá, Paraná, Brazil. The average weight of the *Biceps femuris* sample was 8.4 kg.

Beef hamburger preparation

Beef hamburgers were prepared so that the effect of gradual replacement of sodium chloride (NaCl) by potassium chloride (KCl) plus essential oils (oregano and thymol) could be evaluated. Chemical composition of essential oils added is described by Vital et al. (2021).

Four treatments were prepared: CONT (100% NaCl), KC20 (replacement of 20% NaCl by KCl), KC40 (replacement of 40% NaCl by KCl) and KC60 (replacement of 60% NaCl by KCl) (Table 1). The beef hamburger formulations were prepared according to Carvalho et al. (2013) and Carvalho et al. (2017). During preparation, the beef meat was weighed (60 grams for each hamburger) and molded with a hand cutter (1 cm thickness), water excess was removed and pork fat was incorporated into the process. Beef hamburgers were vacuum packed in polyethylene bags and frozen at -18º C for analysis.

Table 1. Beef hamburger composition.

Ingredients, %	Beef hamburgers			
	CONT[1]	KC20[2]	KC40[3]	KC60[4]
Beef meat	78.98	78.98	78.98	78.98
Pork fat	20.00	20.00	20.00	20.00
Sodium chloride	1.00	0.80	0.60	0.40
Potassium chloride	-	0.20	0.40	0.60
Essential oils[5]	0.02	0.02	0.02	0.02

[1]CONT = 100% sodium chloride; [2]KC20 = 80% sodium chloride + 20% potassium chloride; [3]KC40 = 60% sodium chloride + 40% potassium chloride; [4]KC60 = 40% sodium chloride + 60% potassium chloride; [5]Mix = 0.01% oregano essential oil + 0.01% thymol essential oil.

Microbiological analyses

Three hamburger samples at elaboration time were used to guarantee microbiological quality and acceptable safe levels according to Brazilian health authorities. Fecal coliforms at 35° C and coliforms at 45° C, coagulase-positive *Staphylococcus*, sulfate-reducing *Clostridium* at 46° C, and *Salmonella* sp. were evaluated, quantified, and detected according to methodology described by Silva et al. (2021).

Consumer acceptability and questionnaire

This experiment was approved by the Department of Animal Production and Research Ethics Committee at the State University of Maringá, under protocol CAAE: 66587222.0.0000.0104. In order to assess the acceptability of the hamburgers from the different treatments tested, the sensory evaluation of samples was performed in a private room (adequately adapted to perform a consumer test). Consumers were randomly selected at Universidade Estadual de Maringá (students, employers, and visitors) being the sample representative of college people and divided by gender and age interval (from 18 to 20 years, from 21 to 25 years, from 26 to 35 years, and over 36 years). Consumer acceptability test involve 120 participants, divided into 12 sessions, attending 10 people in each session.

Prior to consumer testing, a supplementary questionnaire was applied to gather more information about consumer habits. In this questionnaire, they were asked about sociodemographic variables, frequency of consumption and preferences on hamburger, salt and flavorings.

Each consumer evaluated four samples identified with a three-digit code, corresponding to the four different treatments tested (CONT, KC20, KC40 and KC60). Samples were provided to consumers one at a time, following a randomized design to avoid any order or carryover effects (Macfie et al., 1989). For culinary preparation, each hamburger was covered with aluminum foil and cooked on a pre-heated grill at 200° C (Philco Grill Jumbo Inox, PHILCO S.A., Brazil) until internal temperature reached 75° C. Each hamburger was then cut (2 × 2 cm cubes), wrapped in aluminum foil, and kept at 50° C until consumer evaluation (10 s after cooking). Consumers were asked to eat unsalted toasted bread and rinse their mouths with water before evaluating each sample, including the first one. Consumers were only informed that they would be evaluating beef hamburgers. All consumers were asked to taste the meat samples and evaluate the acceptability of five attributes: color, odor, flavor, tenderness, and overall acceptability; this was achieved using a structured hedonic nine-point scale ranging from 1 = dislike extremely to 9 = like extremely, where a medium level was not included according to methodologies described by Font-i-Furnols et al. (2008).

Statistical analyses

The field data were introduced into an Excel matrix after checking for missing data and outliers. Eight consumers were excluded from the study for presenting incomplete sample evaluations. Subsequent statistical analyses were performed with the SPSS v 27.0 software (IBM SPSS Statistics, SPSS Inc., Chicago, USA). For consumer analysis, treatment was considered as fixed factor, and consumers were considered as random factors, and session blocking effect. Statistical differences between factors were assessed using Tukey's test ($P \leq 0.05$). Subsequently, hierarchical cluster analysis was used to determine the different segments of consumers, using XLSTAT. The number of clusters was selected from the dendrogram, in an attempt to find a compromise between homogeneity within clusters and heterogeneity between clusters. Principal component analysis was used to identify the relationships between treatments and hamburger attributes. The results are presented graphically in a biplot that includes the attributes and the treatment.

Results and discussion

Microbiological analyses

The microbiological count data (Table 2) shows that the values are within the limits established by Brazilian legislation (Veiros et al., 2006), which allows up to 5×10^2 CFU/g for coagulase-positive *Staphylococcus*, 5×10^1 MPN/g for *Escherichia coli*, 5×10^5 CFU/g for mesophilic aerobic microorganisms and absence of *Salmonella* sp. in 25 g of the sample. Thus, the hamburgers of all treatments proved to be safe for consumption from a microbiological point of view, allowing their use in sensory evaluation, in accordance with Brazilian legislation (ANVISA, 2019).

Table 2. Microbiological analyses of beef hamburgers with partial replacement of sodium chloride by potassium chloride and addition of an oregano and thymol combination.

Microorganisms	Treatments			
	CONT[1]	KC20[2]	KC40[3]	KC60[4]
Staphylococcus coagulase positive, CFU/g	$<10^1$	$<10^1$	$<10^1$	$<10^1$
Escherichia coli, MPN/g	4.5×10^1	4.3×10^1	4.3×10^1	4.3×10^1
Mesophilic aerobic microorganism at 30º C, CFU/g	4.5×10^5	4.4×10^5	4.4×10^5	4.4×10^5
Salmonella, 25g	Absent	Absent	Absent	Absent

[1]CONT = 100% sodium chloride; [2]KC20 = 80% sodium chloride + 20% potassium chloride; [3]KC40 = 60% sodium chloride + 40% potassium chloride; [4]KC60 = 40% sodium chloride + 60% potassium chloride.

One of the most important properties of NaCl is to inhibit microbial growth in food (Kim et al., 2021). However, this action is also attributed to KCl (Kahraman & Karaderi, 2019). In addition, the inhibition of microbial growth can also be attributed to the presence of carvacrol and thymol, the main components of the essential oils of oregano and thyme (Castilho et al., 2012; Gursul et al., 2019), which have strong antimicrobial activity due to their richness of phenolic compounds (Jafri et al., 2019). Both have antimicrobial activity against a broad spectrum of microorganisms (Khan et al., 2017; Wijesundara et al., 2021; Youssefi et al., 2019) and, when applied in combination, their antimicrobial effect is enhanced (Youssefi et al., 2019).

The obtained data corroborate the studies performed by Carvalho et al. (2015), Oliveira et al. (2021) and Silva et al. (2020), who also did not observe significant changes in the microbiological characteristics of beef hamburgers after replacing NaCl by KCl and adding flavoring.

Questionnaire

The profile of consumers in this study must be carefully analyzed, since the universe covered a certain population composed essentially of students and university agents, a class that characterizes the profile of hamburger consumers (Moreira Júnior, 2016; Ribeiro, 2016).

The consumer profile included 53.6% women and 46.4% men. In general, female participation has always been higher than male participation in studies evaluating innovations in meat consumption (Eiras et al., 2017; Matos et al., 2023; Passetti et al., 2020; Vital et al., 2018). However, participation between females and males was appropriately balanced.

In the general population, 32.1% were under 21 years of age, 37.5% were 21 to 25, 18.8% were 26 to 35 and only 11.6% were over 36 years of age. The sum of people aged 25 and under represents 70% of the population. These data demonstrate the large participation of younger people; the greater consumers of hamburgers (Moreira Júnior, 2016). In studies conducted with the population outside the university environment, the participation of consumers under the age of 25 represents less than 30% (Eiras et al., 2017; Guerrero et al., 2018; Monteschio et al., 2020; Passetti et al., 2020). On the other hand, in studies carried out at the university level, the participation of people aged 25 years or younger represents more than 55% (Matos et al., 2023; Vital et al., 2018).

Considering gender as the main effect, with regards to women, the highest representation is in the age group of less than 21 years of age (35.0%) against 28.8% of men (Table 3). These data are decurrent of the age of admission in the different sorts of under-graduate courses. In general, women start higher education at an earlier age (Barreto, 2015; Ribeiro, 2016).

The supplementary questionnaire distributed to the consumers provided information about socio demographic profile and consumption habits and preferences (Tables 3 and 4).

Regarding family income, measured by the minimum wage in effect in 2022 (R$1.212,00), it is observed that the highest percentage, both men and women, comes from families with up to two minimum wages (37.8%). This percentage decreases linearly with an increase in income. Families receiving over 10 minimum wages represented 12.9% of the population interviewed. Also, the women come from more humble families (46.7% come from families with up to 2 minimum wages) and men represent 28.8% in this class (Table 3). Among those who earn between 2 and 6 minimum wages, the percentages are more balanced (26.7%). Additionally, it is observed that who earn more than 10 minimum wages are represented in 19.2% of men, and only 6.7% of women, i.e., only 1/4 of individuals in this wage class.

Table 3. Sociodemographic characterization of consumers ($n = 112$)

Age	Hamburger Consumers		
	Total population	Male	Female
	%	%	%
< 21	32.14	28.85	35.00
21-25	37.50	44.23	31.67
26-35	18.75	19.23	18.33
> 36	11.61	7.69	15.00
Total, %	100.00	100.00	100.00
Family income, minimum wage			
Up to 2	37.76	28.85	46.67
From 2 to 6	26.67	25.00	28.33
From 6 to 10	22.62	26.92	18.33
Over 10	12.95	19.23	6.67
Total	100.00	100.00	100.00
Educational level			
Primary incomplete	0	0	0
Primary complete	0.84	0	1.67
Secondary incomplete	0	0	0
Secondary complete	15.19	15.38	15.00
Higher incomplete	55.38	55.77	55.00
Higher complete	28.59	28.85	28.33
Total	100.00	100.00	100.00

*Minimum wage (2022): 1.212,00 Brazilian Real =218 €/month, 240=$/month; 1 € = 5.56 Brazilian real 1 $ = 5.05 Brazilian real. (Exchange rates as 25 April.2023).

Regarding the educational level, the answers were consistent with the environment where the research was carried out (university environment). Only one person, among the 112 interviews, declared not having a complete secondary education (Table 3). Of the interviewees, 15.3% said that they have completed secondary education and, for the most part, answered that they have incomplete university education (55.4%). In addition, 28.5% answered that they have a complete university degree. This group, possibly, represents the university agents (administrative professors and technicians). In this regard, the participation of men and women was close (58.6%). The educational level of participants in studies related to meat or hamburger preference varies depending on the geographical location of the studies. When the universe is more comprehensive, the percentage of people with low educational level ranges

from 12 to 15% (Mottin et al., 2019; Passetti et al., 2020). On the other hand, when the studies are carried out in a university environment this same percentage is below 5% (Matos et al., 2023; Vital et al., 2018a). However, consumers who participate in the universe of meat consumption and its derivatives with a complete university level total between 45 and 50% (Matos et al., 2023; Mottin et al., 2019; Passetti et al., 2020; Vital et al., 2018b). In the present case, the participation of individuals with an incomplete university course was high (55.5%). However, these results are due to the place chosen for the sampling of consumers (university environment).

Table 4. Consumers' consumption habits ($n = 112$)

Questions	Hamburger Consumers		
	Total population	Male	Female
Where you purchase hamburger	%	%	%
Hamburgers dots	48.47	51.93	45.01
Supermarket	36.80	26.92	46.67
Butchery	9.49	17.29	1.68
Meat Boutique	5.24	3.86	6.64
Total, %	100.00	100.00	100.00
Where do you eat hamburgers			
At snack bars and burger joints	53.46	51.93	54.99
Prepares at home	22.89	30.72	16.01
Purchases frozen	15.77	11.54	19.99
Purchases ready and frozen at home	7.88	5.81	9.01
Total	100.00	100.00	100.00
Most important factor at time of purchase			
Appearance	47.23	46.13	48.33
Ease of purchase	20.58	21.15	20.01
Hygiene of the place of purchase	13.78	19.23	8.33
Price	12.31	9.61	15.01
Brand	5.13	1.94	8.32
Health Inspection	0.97	1.94	0
Total	100.00	100.00	100.00
Do you know that salt consumption is harmful			
Yes	100.00	100.00	100.00
No	0	0	0
Total	100.00	100.00	100.00
Do you prefer salty food			
Little salt	46.41	46.16	46.67
Yes	42.12	44.24	40.00
No	11.47	9.60	13.33
Total	100.00	100.00	100.00
Did you know NaCl can be replaced with KCl			
No	50.83	50.00	51.66
Yes	49.17	50.00	48.34
Total	100.00	100.00	100.00
You know what KCl is			
Yes	65.19	65.39	65.00
No	34.81	34.61	35.00
Total	100.00	100.00	100.00
Do you know the role of KCl			
No	66.60	61.53	71.66
Yes	33.40	38.47	28.34
Total	100.00	100.00	100.00
Would you eat a hamburger with KCl			
Yes	59.16	49.99	68.34
Maybe	38.20	48.07	28.34
No	2.64	1.94	3.32
Total	100.00	100.00	100.00

The preferred place of purchase of hamburger consumers is the hamburgers dots (48.5%) (Table 4). This habit is related to the place of consumption of the product. However, there is a consistent difference of the place of purchase between genders: for men, the place of purchase is butcheries (17.3%) compared to women (1.68%). The opposite is true with shopping in supermarkets (46.7%) for women compared to men (26.9%). It is curious to note that the preferred place of purchase of meat and its derivatives for men are butcheries; while for women it is supermarkets. However, the percentages of men and women

who prefer to buy burgers in hamburger joints are similar between genders (48.5%). This preference may possibly be related to the place of consumption.

The places of consumption of hamburgers are the hamburger dots (53.5%), without preferences between genders (Table 4). However, preparing the burger at home is preferred by men (30.7%) compared to women (22.9%). The purchase of frozen (15.7%) or cold (7.9%) hamburger has low preference.

When asked about the most important factor at the time of purchase of the hamburger, the answers were similar for men (46.3%) and women (48.3%) and identified with appearance, which includes the coloration of the product (Table 4). The second most important factor was ease of purchase for both men (21.1%) and women (20.0%). This reply must be related to life style. On the other hand, interestingly, men were more demanding when it came to the hygiene of the place of purchase. The majority of men said that, for them, this factor defines 19.2% of the choice of place of purchase and for women less than half that (8.3%). On average, between genders, this percentage was relatively high, as this requirement is little mentioned by meat buyers (Mottin et al., 2019). In this way, the hamburger consumer is more demanding with hygiene than buyers of other types of meat. The price factor is more important for women (15.0%) than for men (9.6%). However, it is curious to note that, for hamburger consumers, the price factor is low (12.3%). In general, price is always among the most important factors for meat consumers and their derivatives (Eiras et al., 2017; Matos et al., 2023; Mottin et al., 2019; Vital et al., 2018). In this way, hamburgers consumers show a slightly different profile from consumers of meat and fish. The factors brand and sanitary inspection have little importance, 5.1% and 1.0% respectively, for both genders.

Regarding the habit of consuming salty food or not, the responses between men and women were similar: 46.0% said they prefer little salt and 43.1% said they prefer salty food (Table 4). Although the sample surveyed by this research showed that salt consumption is harmful to health (100%), the percentage of people who prefer salty food (46.7%) and low salt (40.0%) is very high. Only 10.5% said they prefer unsalted food.

On the knowledge of the possibility of replacing sodium chloride with potassium chloride in an attempt to reduce sodium consumption, although most of the participants had higher education or were finishing college, results are divided with 50.8% not aware and 49.2% aware. These data show that the population, although of high educational level, is not concerned with or is unaware of the possibility of reducing sodium consumption.

When asked if the study's population was aware of potassium chloride, 65.0% said yes and 35% said no. These data are not surprising because it was a university population and, in addition, carried out at a college of life sciences.

Consumer acceptability

The results of the consumer sensory evaluation of the hamburgers are presented in table 5. No difference (P > 0.05) was observed for the attributes color, odor and texture among treatments of different seasonings. These results are satisfactory because color and appearance are the characteristics that most influence consumer decision making at the time of purchase (Eiras et al., 2017; Monteschio et al., 2020; Vital et al., 2018). Similarly, other authors found no changes in the sensory evaluation of color (Jin et al., 2018; Seganfredo et al., 2016; Silva et al., 2020), odor (Abbasi et al., 2019) and texture (Fellendorf et al., 2016; Ramos et al., 2020b; Silva et al., 2020) of meat products, as sausage, resoles, ham, with low NaCl content.

On the other hand, for the attributes of flavor and general acceptability, difference (P < 0.05) between treatments was observed (Table 5). The burgers with 20% and 40% replacement of NaCl (KC20 and KC40) by KCl obtained better results for the attributes of flavor and global acceptability, which remained in the acceptance zone of the hedonic scale, which includes values between 6.8 and 7.3. Thus, the use of a mixture of oregano and thyme essential oils in the formulations may have mitigated the reduction of NaCl in the sensory perception of hamburgers, in addition to masking the possible bitter and metallic residual taste characteristic of KCl. Different results were reported by other studies in which sensory acceptance decreased with the reduction of NaCl in the meat product. Pires et al. (2021)

observed a reduction in flavor acceptance when NaCl was reduced in beef hamburgers. Jin et al. (2018) observed lower overall acceptability in sausages when NaCl was replaced with a mixture of KCl and CaCl₂ or with a combination of KCl, CaCl₂ and MgCl₂. Carvalho et al. (2017) reported a reduction in flavor, texture and overall acceptability when NaCl was replaced by KCl in beef hamburgers.

Table 5. Sensory evaluation of beef hamburger with partial replacement of sodium chloride by potassium chloride and addition of mixture of oregano and thymol essential oils.

Attributes	Treatments/seasonings				SEM[5]	P < Value
	CONT[1]	KC20[2]	KC40[3]	KC60[4]		
Color	5.83	6.21	6.00	6.31	0.093	0.267
Flavor	6.91b	7.34a	7.08ab	6.83b	0.074	0.050
Odor	7.01	7.17	6.94	7.04	0.074	0.730
Tenderness	7.11	7.40	7.12	7.16	0.071	0.420
Overall acceptability	6.75b	7.28a	7.08a	6.91b	0.071	0.050

[1]CONT = 100% sodium chloride; [2]KC20 = 80% sodium chloride + 20% potassium chloride; [3]KC40 = 60% sodium chloride + 40% potassium chloride; [4]KC60 = 40% sodium chloride + 60% potassium chloride; [5]SEM = Standard error of the mean. The means, in the same line, followed by different letters, are different by Tukey's test (P < 0.05).

Principal Component Analysis (PCA)

Information about seasonings preferences of the consumers is presented graphically in firure 1. The two main components of the axes explain 90% of the variation of the data. Principal Component Analysis let to know relation between the sensory attributes evaluated and the seasoning preferences as a function of their positioning in relation to the treatments within the quadrants in the graph. Thus, the closer they are within the same quadrant, and closer to the main axis, the better the effect of the treatment on the sensory attributes.

However, in the study of Carvalho et al. (2017), no flavoring was included, only black pepper Similarly, the impregnation of different essential oils in edible packaging improved the acceptability of fish (Vital et al., 2018). Thus, it is possible to hypothesize that the inclusion of oregano and thymol oils would have mitigated the negative effect of the inclusion of KCl replacing NaCl in hamburgers.
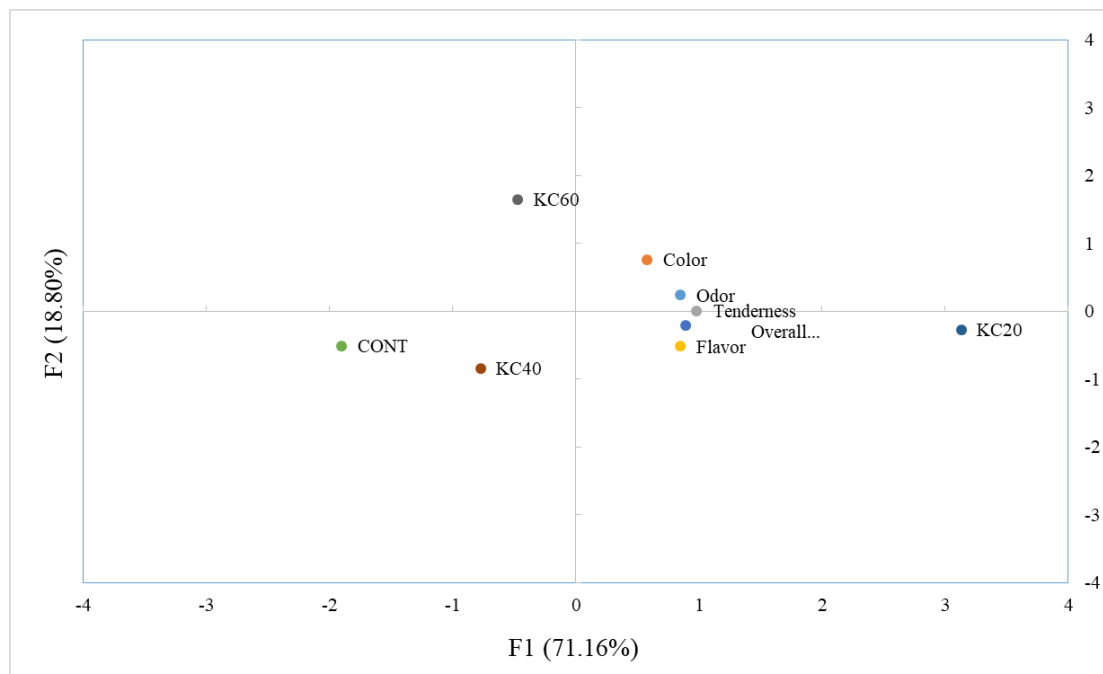

Figure 1: Principal component score for color, flavor, odor, texture and overall acceptability of bovine burgers with partial replacement of sodium chloride with potassium chloride and addition of oregano and thymol essential oils.

Cluster evaluation

Considering the acceptability of meat and its derivatives, different groups of consumers are characterized, which constitute different segments of the market that demand meat and its derivatives

with different characteristics. These segments may also occur as to consumer habit, preferences of burger choice and choice of certain attributes are considered (Realini et al., 2013). Therefore, it is important to know the order to identify different niche markets.

Regarding the color, odor and texture of beef burgers, there were three groups of consumers. The three clusters did not identify differences (P > 0.05) between treatments (data not shown).

For flavor acceptability, the first group (cluster 1) was the most significant group (41.96% of consumers) gave all treatments scores higher than 6.8 points, with the KC60 treatment being the least accepted (Table 6). The percentage of men and women was similar in this group (48.94% vs. 51.06%, respectively), being 68.1% of them under 24 years and 31.9% between 25 and 66 years. Cluster 2, which had the lowest share of consumers (25.0%), reported no differences based on taste acceptability between samples, with all treatments having high acceptability (between 8.3 and 8.6 points on a 9-point scale). Men and women in this cluster were not in similar proportions (42.86% vs. 57.14%, respectively), with 53.6% of them under 24 and 46.4% between 25 and 50 years old. Cluster 3, with 33.0% of consumers, gave the best scores to the samples of the KC20 treatment compared to the CONT, KC40 and KC60 treatments, which had scores lower than 6.0 points. This cluster contained 45.95% men and 54.05% women, 81.08% of whom were under 24 years old and 18.92% between 25 and 58 years old.

Three different groups of consumers (clusters) had been identified related to the global acceptability of hamburgers (Table 6). The main cluster (cluster 1) of consumers 44.6% observed a difference (P < 0.05) between the burgers, not preferring the burgers of the KC60 treatment. For the other treatments, global acceptability was similar (P > 0.05) with an average score of 7.06 on the scale from 1 to 9. The percentage of men and women was different in this group (44.0% vs. 56.0%, respectively), being 68.0% of them under 24 years of age and 32.0% between 25 and 53. The second largest cluster (cluster 2) had 32.1% consumers. This group did not identify differences (P > 0.05) between treatments, but had a high evaluation score (8.2). This group included different percentages of women (52.78%) and men (47.22%), being 61.1% of them under 24 years old and 38.9% between 25 and 56 years old. Cluster 3 was formed by a lower percentage of consumers (23.2%). However, this cluster showed differences across treatments (P < 0.05), although the score was low (5.43). Burgers with the addition of KCl and oregano and thymol essential oils were preferred (P > 0.05) by consumers, compared to the CONT. For the three groups by KCl and essential oils, the scores were similar (P > 0.05). This group included similar percentages of women (50.0%) and men (50.0%), being 61.1% of them under 24 years old and 38.9% between 25 and 58 years old.

Table 6. Acceptability score of beef hamburgers with partial replacement of sodium chloride with potassium chloride and addition of oregano and thymol essential oils.

Flavor acceptability	n	%	CONT[1]	KC20[2]	KC40[3]	KC60[4]	SEM[5]	P < Value
Cluster 1	47	41.96	7.34a	7.47a	7.40a	6.91b	0.174	0.038
Cluster 2	28	25.00	8.54	8.64	8.39	8.25	0.148	0.589
Cluster 3	37	33.04	5.14b	6.19a	5.68ab	5.65ab	0.123	0.031
Overall acceptability								
Cluster 1	50	44.64	7.02a	7.02a	7.14a	6.62b	0.070	0.053
Cluster 2	36	32.14	8.17	8.47	8.11	8.14	0.126	0.437
Cluster 3	26	23.22	4.27b	6.12a	5.54a	5.77a	0.150	0.001

[1]CONT = 100% sodium chloride; [2]KC20 = 80% sodium chloride + 20% potassium chloride; [3]KC40 = 60% sodium chloride + 40% potassium chloride; [4]KC60 = 40% sodium chloride + 60% potassium chloride; [5]SEM = Standard error of the mean. Means, on the same line, followed by different letters, are different by Tukey's test (P < 0.05).

Conclusion

The substitution of sodium for potassium by up to 60% did not produce considerable changes in the initial microbiological characteristics of beef hamburgers. In the sensory analysis of consumers, the replacement of up to 20% sodium with potassium and the addition of a mix of oregano and thymol essential oils improved the flavor of hamburgers which, consequently, may have influenced the general acceptability by consumers. Replacing up to 60% NaCl by KCl does not change the sensory attributes of burgers for consumers. Thus, it is possible to replace up to 60% NaCl by KCl with the inclusion of the combination of oregano and thymol essential oils in hamburgers without generating negative effects being 20% the most recommended replacement.

Declaration of competing interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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