An-Najah University Journal for Research – A

Natural Sciences

Influence of the Partial Replacement of Sodium Chloride by Potassium Chloride, Monosodium Glutamate Salts and Their Combination on the Physiochemical Properties, Color, and Sensory Aspects of Beef Burger

Received: 26/12/2022, Accepted: 13/5/2023, DOI: 10.35552/anujr.a.37.2.2112

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Abstract: This study aimed to evaluate the effect of replacing NaCl with KCl and monosodium glutamate in beef burgers. The effect of this reformulation on physicochemical properties, salt content, color, sensory aspect, and consumers' acceptance was mainly examined. The findings of this study indicated that all treatments did not significantly differ in terms of moisture, color, and cooking loss. The presence of KCl induced little impact on pH. Furthermore, the replacement of NaCl with KCl did not affect the perceived saltiness and bitterness of the products. On the other hand, concerning overall acceptance, burgers with monosodium glutamate were mostly preferred by consumers. It was concluded that lowering sodium content by partially replacing NaCl with KCl and monosodium glutamate is possible even in beef burgers.

Keywords: Beef Burger, Low Sodium, Monosodium Glutamate, Potassium Chloride, Sensory Properties, Saltiness

Introduction

The beef burger is considered one of the most consumed meat products given that it requires little or no additional preparation at home (Angor and Al-Abdullah, 2010,p. 318). However, beef burgers might be unhealthy due to the additives and fats added during processing. In the majority of cases, the addition of salt in beef burgers contributes to an increase in sodium intake exceeding the recommended dietary level (Newson et al., 2013, p. 22).

Excessive sodium increases blood pressure. This is what may cause extra strain on the heart, possibly leading to a stroke (Pandya, 2017, p. 6). Also, in other cases, it can cause the body to retain water, resulting in puffiness, bloating, and weight gain (American Heart Association, 2016). The World Health Organization (WHO) recommends that daily salt intake to be less than 5g/day (=2gNa/day) (WHO, 2012, p. 2). In an attempt to overcome these health problems and encourage a healthy diet, many studies have partially replaced sodium chloride with other substitutes such

as magnesium, calcium, potassium chloride, and some flavor enhancers like monosodium glutamate (MSG) (Armenteros, Aristoy, Barat, & Toldra, 2009, p. 9699; Stanley, Bower, & Sullivan, 2017, p. 36; de Quadros, de Oliveira Rocha, Ferreira, &Bolini, 2015, p. 236). For example, Armenteros et al. (2009, p. 9699) used potassium, calcium, and magnesium to partially replace sodium in dry-cured loins. Stanley et al. (2017, p. 39) evaluated the influence of sodium chloride reduction and substitution with KCl-based salts on the physicochemical and sensory characteristics of pork sausage patties. Moreover, in an attempt to produce Low-sodium fish burgers, de Quadros et al. (2015, p. 236) added MSG to its formulations.

Monosodium glutamate is frequently used as a taste enhancer (Lateef, Siddiqui, Saleem, & Iqbal, 2012, p. 39). In developed countries, the average daily consumption of MSG is estimated to be 0.3–1.0 g (Hajihasani, Soheili, Zirak, Sa-hebkar, & Shakeri, 2020, p. 23). Monosodium glutamate has been classified as Generally Recognized As Safe (GRAS) by the Food and Drug Administration (FDA) (Geha et al., 2000, p. 1058). The European Food Safety Authority determined that 30 mg MSG/kg body weight per day is the acceptable daily intake (ADI) (EFSA, 2017). The objectives of this study were to evaluate the impact of partial replacement of sodium with potassium and MSG on physiochemical properties, salt content, and color in beef burgers, and to evaluate the sensory characteristics and consumers' acceptance of the reformulated product.

Materials and Methods

Samples Preparation

Beef burgers were prepared at a local Meat factory in Amman, Jordan. Grinding and mixing the beef forequarter pieces from a Jordanian local breed of two years old animal, of the same batch and of a homogenous composition with 12% fat (0.12g/1kg of beef meat; which was determined as a routine quality control test for the raw materials used in product manufacturing including the raw meat batches) in a mincer, using a plate with holes of 8 mm in diameter to ensure homogeneity. It was then divided into five separate batches of 5 kg. The raw meat used in burger manufacturing comes as batches of beef taken from the beef forequarter and beef flank mixed together.

Formulations of the developed burger samples were detailed in Table I. The addition of water, salt (1.5 g/100 g), and spices to each batch was done separately as follows: Product 1 (i.e., control): 1.5% NaCl; Product 2: Only 0.75% NaCl; Product 3: 0.75% NaCl and 0.75% KCl; Product 4: 0.75% NaCl reduction with the addition of 0.3% MSG; Product 5: 0.75% NaCl reduction with 0.75% KCl and 0.3% MSG. After the additions, each batch of mince was mixed manually for 2 min. Then, the beef meat was minced and mixed for the second time for a more finely ground product used for burgers. The burgers were prepared with a weight of 120 g and were shaped between two sheets of paper (Wimpex, London, U.K.), using a meat patty-forming machine. The burgers were immediately frozen overnight at –20°C. Afterward, they were transferred in groups to polythene bags and stored at –20°C until taken for analysis.

The sodium chloride, potassium chloride, and monosodium glutamate used in the production of the beef burger were all food grade. The spices added to the product were black and white pepper. Analyses were carried out in triplicate.

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Table (1): Formulations of the developed sodium-reduced beef burgers made with the substitution of NaCl with KCl and monosodium glutamate.

Product No.	Water	Beef Meat	NaCl	Na	KCl	K	MSG	
	(ml/ 100g)	(g/100g)	(g/100g)	(mg/100g)	(g/100g)	(mg/100g)	g/100g	mg/100g
1	5	95.5	1.5	580	---	---	---	---
2	5.75	95.5	0.75	290	---	---	---	---
3	5	95.5	0.75	290	0.75	390	---	---
4	5.45	95.5	0.75	290	---	---	0.3	300
5	4.7	95.5	0.75	290	0.75	390	0.3	300

MSG: Monosodium Glutamate.

Moisture and ash Determination

Moisture and ash contents were determined by the oven drying method according to AOAC (2012).

These tests were conducted to investigate whether salt substitutions would influence the moisture content of beef burgers.

Salt Analyses

Analysis of sodium and potassium was conducted using a Flame photometer according to JENWAY Bibby scientific (2002).

Monosodium glutamate levels in the products were estimated by applying the modified HPLC Method according to Lateef et al. (2012, p. 39).

Determination of pH, Color Values, and Cooking Loss

Samples' pH was measured using a digital pH meter (Hanna, Italy) according to Pedro et al. (2021, p. 2).

A colorimeter was used to determine the color value in this situation (LAB values), L*, a*, and b* values were determined as indicators of lightness, redness, and yellowness (Al Assoly, Al Ismail, & Al-Abdullah, 2019, p. 153). These values (L, a, b) are usually used to compare meat product samples in terms of their color lightness, redness, and yellowness, which are important parameters in products like beef burgers.

The cooking loss was calculated by considering the initial (raw sample) and the final (cooked) sample weights and expressed as a percentage of the initial weight according to Pang, Bowker, Zhuang, Yang, & Zhang (2020, p. 6287) using the following formula:

$$cooking\ loss\ \% = \frac{raw\ burger - cooking\ burger}{raw\ burger} \times 100 \quad (1)$$

Sensory Evaluation

The sensory quality of beef burger samples was evaluated by a group of 30 untrained panelists from the teaching staff, graduate students, and technicians of the Department of Nutrition and Food Technology, the University of Jordan, Amman, Jordan. The panelists were of both sexes (majority i.e., 70% were females) with different ages (24-70 years old). The panelists were asked to taste each sample individually, where each panelist was able to take pieces of about 20-30 g from each sample.

This test was carried out to determine consumer acceptance, aroma, color, tenderness, saltiness, and bitterness using a 9-hedonic scale test, ranging from 9 (extremely like) to 1 (extremely dislike) (Artur et al., 2019, p. 5). Pieces of bread and water were served to neutralize the taste between the samples tested.

Statistical Analysis

Statistical analysis was carried out using a Statistical Package for the Social Sciences (SPSS). A scheffe post hoc test was used to elucidate significantly different means. Analysis of variance (ANOVA) was used with a completely randomized design (CRD) for continuous variables. Data were presented as mean and standard deviation (SD). Statistical significance was set at $p<0.05$.

Results and Discussion

Moisture and ash

Table II demonstrates the effects of the different formulations on the moisture and ash composition of beef burgers. The different formulations for the beef burgers had a statistically similar effect ($p>0.05$) on the moisture contents.

These results are in agreement with the findings of Horita, Morgano, Celeghini, & Pollonio (2011, p. 426) who reported that replacing NaCl with salt blends (NaCl, KCl, and $CaCl_2$) had no effect on moisture contents in reduced-fat mortadella product. Similar research by Stanley et al. (2017, p. 39) found that reducing NaCl and partially substituting KCl or modified KCl-based salts had no impact on the moisture content of pig sausage patties.

Regarding ash content, there were significant differences ($p<0.05$) among treatments, where the greatest percentages were found in sample 1 and sample 5 compared to other treatments which were similar ($p>0.05$). These findings corroborate Stanley et al. (2017, p.39) and Horita et al. (2011, p. 426) who found that the ash percentage changed depending on the salting treatment. Sample 3 had statistically different ash content than sample 1, this could be due to the addition of a higher quantity (by weight) of NaCl (1.5 g/100 g) in the formula of sample 1 in comparison with a lower addition of 0.75 g/100 g of NaCl in the case of sample 3, which at the end appeared quantitatively higher in sample 1. Although it was expected that sample 5 would be similar to sample 3 as they had the same added ingredients.

Table (2): moisture, ash (%), mineral, and MSG content (mg/100g) of the developed sodium-reduced beef burgers made with 5 different salting treatments by substituting NaCl with KCl and MSG.

Item	Product 1	Product 2	Product 3	Product 4	Product 5
Moisture (%)	$70.24^a \pm 1.07$	$71.52^a \pm 0.18$	$70.20^a \pm 0.59$	$70.43^a \pm 0.27$	$70.72^a \pm 0.32$
Ash (%)	$2.29^a \pm 0.06$	$1.60^b \pm 0.01$	$1.86^b \pm 0.03$	$1.90^b \pm 0.02$	$2.45^a \pm 0.21$
Sodium	$800^a \pm 0.004$	$400^c \pm 0.002$	$400^c \pm 0.00$	$430^b \pm 0.001$	$440^b \pm 0.0005$
Potassium	$350^c \pm 0.002$	$350^c \pm 0.0005$	$860^a \pm 0.0035$	$310^d \pm 0.0005$	$830^b \pm 0.0005$
MSG	N.D	N.D	N.D	$131^a \pm 3.2$	$141^a \pm 3.4$

Results are expressed as means of the three replicates ± SD.
N.D: not detected.
Means with different superscript letters in the same row are significantly different ($p<0.05$) according to the scheffe test.

product 1: control: 100% NaCl; Product 2: Only 50% NaCl reduction; Product 3: NaCl 50% reduction with KCl 50%; Product 4: 50% NaCl reduction with 0.3% MSG; Product 5: 50% NaCl reduction with 50% KCl and 0.3% MSG.

Mineral (Sodium, Potassium) and MSG Contents

The contents of sodium, potassium, and MSG in beef burgers are presented in Table II. Expectedly, the control sample exhibited the greatest ($P<0.05$) sodium content of 800mg/100g. However, the remaining samples showed numerically close values despite the significant difference ($P<0.05$) that existed between them, as illustrated in Table II. These differences were mainly due to the original sodium content of the meat.

With regards to potassium content, the results indicated that sample 3 and sample 5 contained relatively higher potassium content (P<0.05) of 860 and 830 mg/100g, respectively than other treatment. As expected, replacing NaCl with KCl lowered the sodium level significantly (P<0.05) resulting in a 50% sodium reduction in beef burgers. Using these measures will simplify the effort to achieve and maintain a daily salt intake reduction.

The WHO mentioned that the recommendation for sodium consumption was less than 5g/day salt (=2gNa/day) and the recommended amounts for potassium were 3400- 2600 mg/day (WHO, 2012, p. 2). In the present study, all beef burgers' that contained KCl have met these recommendations.

As demonstrated in Table II, MSG contents in sample 4 and sample 5 were 131 mg/100g and 141 mg/100g, respectively should be noted that the significant contents of MSG detected were half of the amount originally added to the samples, and this is possible due to the derivatization process being incomplete; where the samples could have reacted with the derivatization reagent (dinitrofluorobenzene) to form the glutamic acid derivative. The results of Rosa, Pinto-e-Silva, & Simoni (2021, p. 5320) confirm our finding that introducing MSG in meat can reduce their salt content.

Taking into account the daily ADI of MSG is 300–1000 mg as recommended by health authorities like the Joint FAO/WHO Expert Committee on Food Additives (JECFA), and the Food and Drug Administration (FDA).In this study, the amount of MSG detected in beef burgers was in compliance with these recommendations and our product is therefore considered safe.

pH

Table III presents the pH of the developed beef burgers. The lowest pH was found in the control sample, followed by sample 4 and sample 2. Consequently, the pH tended to lower as the sodium level increased. This might be due to salt ions (Cl–) attaching to positively charged protein side chains in the muscle matrix; causing the proteins' isoelectric point to shift to a lower pH (Hamm, 1986 p.175). These results are in accordance with Xiong, Deng, Warner, & Fang (2020, p. 2911).

Higher pH was measured in samples 5 and 3. This can be explained by the presence of potassium, which was validated in previous studies (Song, Ham, Noh, Chin, & Kim, 2020, p. 7; Keeton, 1984, p. 146) indicating that the use of KCl partially or completely to substitute NaCl increased the pH. It is suggested that this phenomenon may be due to a difference in sodium and potassium ion binding capacities to muscle protein and/or in cell membrane permeability (Aliño, Toldrá, Blesa, Pagán, & Barat, 2009, p. 428).

However, Rios-Mera, Saldaña, Patinho, Selani, & Contreras-Castillo (2021, p. 7) indicated that NaCl-reduced beef burgers in the presence of MSG with different concentrations of NaCl had no significant effect (P<0.05) on pH values. In conclusion, it is presumed that the partial substitution of NaCl by KCl and MSG has little effect on the pH values.

Weight Cooking Loss

The effect of NaCl substitution with KCl and MSG on beef burgers' weight cooking loss is illustrated in Table III. No significant differences (p<0.05) were detected after cooking among all treatments, indicating that the partial salt replacement did not affect the cooking loss. In fact, the results obtained from the cooking loss are confirmed by the finding in moisture. For instance, no significant differences in moisture were detected in the uncooked beef burgers which is evidence for the absence of any significant difference in the cooking loss. Stanley et al. (2017, p. 40) and Moon, Kim, Jin, & Kim (2008, p. 567) found that sodium and potassium have no effect on cooking loss. In agreement with our findings, Chun et al. (2014, p. 576) demonstrated that when MSG was added, there were no significant changes in the cooking loss.

Objective Color measures

Table III shows the values of L*, a*, and b* in the treated beef burgers. Significant differences (p<0.05) in L* values were detected in sample 2which had a lighter color than the remaining samples. However, there were no other significant variations in the lightness measurement related to the other treatments.

Similarly, NaCl replacements did not affect a* (redness) measure due to the lack of significant differences among the treatments evaluated. A similar observation occurred with the parameter b* (yellowness).

The pH value has a relationship with product lightness given that when the pH value decreases, the color becomes lighter (Fletcher, Qiao, & Smith, 2000, p. 784). However, the results presented in Table III indicate that salt has little impact on pH variations; resulting in the absence of differences in the color of the treatments.

Jankowiak, Cebulska, & Bocian (2021, p. 2813), in their study, confirmed that lower pH values showed higher lightness L* values in meat and meat products.

However, the impact of pH values was exhibited in sample 2. In accordance with these findings, Stanley et al. (2017, p. 40) demonstrated that lighter color (p<0.05) was observed in the NaCl-reduced control (50% sodium chloride), and no significant difference (p<0.05) among the other samples.

Table (3): pH value, weight cooking loss, and Objective color of the developed sodium-reduced beef burgers made with the replacement of NaCl with KCl and monosodium glutamate.

Item	Product 1	Product 2	Product 3	Product 4	Product 5
pH	$6.23^{c} \pm 0.03$	$6.36^{b} \pm 0.04$	$6.42^{b} \pm 0.0$	$6.35^{b} \pm 0.005$	$6.67^{a} \pm 0.01$
Cooking loss (%)	$36.99^{a} \pm 2.01$	$39.11^{a} \pm 1.35$	$41.94^{a} \pm 1.95$	$39.69^{a} \pm 1.53$	$36.79^{a} \pm 1.99$
L*	$34.10^{b} \pm 0.56$	$42.60^{a} \pm 0.97$	$37.79^{ab} \pm 0.95$	$35.37^{b} \pm 3.62$	$37.12^{ab} \pm 2.12$
a*	$13.80^{a} \pm 0.55$	$13.04^{a} \pm 3.17$	$16.53^{a} \pm 1.11$	$14.83^{a} \pm 4.04$	$14.41^{a} \pm 1.80$
b*	$11.33^{a} \pm 0.93$	$11.14^{a} \pm 1.62$	$12.19^{a} \pm 0.49$	$11.55^{a} \pm 2.91$	$12.74^{a} \pm 1.42$

Results are expressed as means of the three replicates ± SD. Means with different superscript letters in the same row are significantly different (p < 0.05) according to the scheffe test.

Product 1: control: 100% NaCl; **Product 2**: Only 50% NaCl reduction; **Product 3**: NaCl 50% reduction with KCl 50%; **Product 4**: 50% NaCl reduction with 0.3% MSG; **Product 5**: 50% NaCl reduction with 50% KCl and 0.3 MSG.

In another study, Moon et al. (2008, p. 567) and, Horita et al. (2011, p. 426) found no significant difference (p<0.05) in color measurements. Recently, Rios-Mera et al. (2021, p. 7) revealed that NaCl-reduced beef burgers –in the presence of MSG– did not affect the measurements of the objective color.

Sensory Evaluation

Table IV illustrates an overview of the mean sensory evaluation scores of beef burgers. Sample 4 and sample 5 had the highest acceptance scores, which were significantly higher (p < 0.05) than those without MSG (i.e., sample 1, sample 2, and sample 3). It is known that MSG is most likely related to taste improvement, which was probably attributed to the higher acceptability ratings of beef burgers. Interestingly, control beef burgers (1.5 % NaCl) exhibited the lowest overall acceptance scores.

In a previous study on the development of sodium-reduced fish burgers with MSG, de Quadros et al. (2015, p. 240) declared that MSG-containing samples were more acceptable than MSG-free ones.

In terms of color trait, results showed no significant difference (p<0.05) between treatments. This could be attributed to data found on the objective color measure. This suggests that partial replacement of NaCl with KCl and MSG has no effect on the color at the conducted concentrations. Similarly, Faralizadeh, ZakipourRahimabadi, & Khanipour (2016, p. 662) demonstrated that mean color scores were not significantly different across samples.

Similar results were found regarding the aroma attribute among all treatments. This might be attributed to the fact that all the samples were cooked consistently in the same way, and from the same meat batch.

The ratings by consumers for tenderness were significantly less ($p<0.05$) in control burgers with a mean hedonic score of 5.33 than in sample 3, sample 4, and sample 5 with scores of 6.59, 6.70, and 6.96, respectively, whereas sample 2 did not differ significantly from the other samples. Similarly, Rios-Mera et al. (2020, p.7) and Tobin, O'Sullivan, Hamill, & Kerry (2012, p. 464) revealed that NaCl increases the hardness level. However, substituting NaCl with MSG does not affect the tenderness of the beef burger. In agreement with that, Chun et al. (2014, p. 576) reported that the tenderness was not significantly affected.

Saltiness acceptability scores were greater in sample 4 than in the control sample which had less saltiness acceptability. Other experimental samples were not statistically ($P>0.05$) different from both the control and sample 4 (Table IV). Meaning that the panelists' preferences of samples 2, 3, and 5 varied since some thought their saltiness was desirable, while others thought it was less acceptable. According to Chun et al. (2014, p. 579), MSG enhanced the salty flavor, lowering the NaCl level without impairing the sensory qualities of meat products.

The degree of bitterness acceptability was highest in the control sample, sample 2, and sample 4 while sample 3 had a significantly ($p<0.05$) lower mean score. Ratings of sample 5 were not statistically different among samples. The feeling of bitterness in the samples containing KCl (sample 3 and sample 5) was very acceptable as the panelist, almost, did not recognize its existence. This suggests that 50% NaCl substitution with KCl is acceptable. In their work, Faralizadeh et al. (2016, p. 662) found that the replacement of NaCl with KCl did not affect bitterness.

Table (4): Mean sensory test scores of the developed sodium-reduced beef burgers made with the substitution of NaCl with KCl and monosodium glutamate.

Attribute	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Overall acceptability	6.33^{b} ±1.24	7.07^{ab} ±1.14	6.70^{b} ±1.26	7.74^{a} ±1.02	7.96^{a}±1.19
Color	7.03^{a} ±1.25	7.51^{a} ±1.08	7.25^{a} ±1.12	7.48^{a} ±0.93	7.18^{a} ±1.33
Aroma	7.00^{a}±1.3	7.18^{a} ±1.35	7.25^{a} ±1.45	7.59^{a} ±1.009	7.59^{a} ±1.18
Tenderness	5.33^{b}±1.51	6.40^{ab}±1.39	6.59^{a}±1.04	6.70^{a} ±1.46	6.96^{a}±1.22
Saltiness	5.48^{b} ±1.28	6.25^{ab} ±1.28	6.40^{ab} ±1.33	7.29^{a} ±1.10	6.22^{ab} ±1.64
Bitterness	8.29^{a} ±0.54	8.22^{a} ±0.84	7.03^{b} ±1.12	8.11^{a} ±0.75	7.48^{ab} ±1.42

Results are expressed as means of the three replicates ± SD.

Means with different superscript letters in the same row are significantly different ($p<0.05$) according to the scheffe test.

Product 1: control: 100% NaCl; **Product 2**: Only 50% NaCl reduction; **Product 3**: NaCl 50% reduction with KCl 50%; **Product 4**: 50% NaCl reduction with 0.3% MSG; Product 5: 50% NaCl reduction with 50% KCl and 0.3 MSG.

Conclusion

The findings of the present study suggest that the partial replacement of NaCl with KCl and MSG can be used as a substitution in beef burgers. The use of KCl can slightly affect the pH, although did not affect other physicochemical properties. On the side of sensory and consumer acceptance, the presence of MSG increased the overall acceptability of the products, and the substitution with KCl didn't affect the imparted bitterness and saltiness. From a health aspect, the substitution of NaCl with KCl and MSG can reduce sodium content and increase potassium content, providing a healthier product.

Ethics approval and consent to participate

The authors confirm that they respect the publication ethics and that they consent the publication of their work.

Consent for publication

The authors consent the publication of this work.

Availability of data and materials

Data is available upon the request

Funding

This work was funded by the Scientific Research Deanship, the University of Jordan.

Author's contribution

This research was initiated by the Ph.D student Siham Lebaini and supervised by Dr. Basem Al-Sawalha and Dr. Hadeel Ghazzawi at the department of Nutrition and Food Technology at the University of Jordan. The experimental work, design, analysis, and writing were carried by Siham and followed and supervised by both of her supervisors.

Conflicts of interest

All authors declare that they have no conflicts of inter-est

Acknowledgments

Authors would like to acknowl- edge the Scientific Research Deanship, the University of Jordan.

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