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Effect of different chloride salts on chicken burger quality

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Abstract

The effect of using different chloride salts on the quality of chicken burgers was evaluated by physicochemical, textural, and sensorial analyses. Chicken burgers were prepared with five different chloride salt amounts (T1: 2% NaCl, T2: 1% NaCl, T3: 1% NaCl + 1% KCl, T4: 1% NaCl + 1% $CaCl_2$, and T5: 1% NaCl + 0.5% KCl + 0.5% $CaCl_2$). The pH, moisture content, water activity, TBARS, cooking yield, moisture retention, and colour values were measured to determine the physicochemical properties of the burgers. Additionally, texture profile analysis and sensory evaluation were performed on the cooked samples. Reducing or partially replacing NaCl with KCl increased the pH level compared with the control, whereas using $CaCl_2$ decreased the pH level. The highest moisture content and a_w values were determined in burgers containing 1% NaCl. Partial substitution of NaCl with KCl and/or $CaCl_2$ increased L* and b* values. A 50% reduction of NaCl or its replacement with 50% KCl did not affect the moisture retention and cooking yield compared with the control, but using $CaCl_2$ caused a decrease. Also, the cooking process significantly affected the pH, moisture, a_w, TBARS, and colour of the chicken burgers ($p < 0.01$). Reducing NaCl to 1% or partially replacing it with KCl and/or $CaCl_2$, decreased the hardness, resilience, and chewiness of the samples, whereas the use of $CaCl_2$ caused a greater decrease of these parameters. In the preparation of chicken burgers, a 50% substitution of NaCl with $CaCl_2$ reduced sensory scores for appearance, flavour, texture, and general acceptability, whereas a reduction of NaCl or 50% substitution with KCl had no effect.

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Introduction

Excessive sodium intake increases the risk of stroke and premature death due to cardiovascular diseases, by causing hypertension (Cook *et al*. 2016). Sodium intake exceeds dietary recommendations in many industrialised countries. Sodium chloride (NaCl) is the main source of sodium in the diet. The WHO recommends an intake of less than 5 g (approximately 2 g of sodium) per person per day of NaCl to prevent cardiovascular diseases, which are the leading cause of death worldwide (WHO, 2012). Therefore, decreasing the amount of sodium intake among the population is important for health with strategies such as reducing or effectively substituting the NaCl content in processed food products.

NaCl is one of the most commonly used ingredients in meat processing, and affects the flavour, texture, and shelf life of meat products. NaCl enhances the flavour by providing saltiness, has an important role in the texture, and improves the water and fat-binding properties of meat products (Desmond, 2006; Aprilia and Kim, 2023). Moreover, NaCl has a protective effect on the products by reducing water activity (Yotsuyanagi *et al*., 2016). However, in addition to these positive effects in meat products, excessive intake of NaCl into the human body through consumption also brings the health risks as mentioned earlier (Pateiro *et al.*, 2021; Aprilia and Kim 2023). One of such products are chicken burgers. Chicken burgers are processed meat product frequently consumed in fast-food restaurants, and prepared by mixing minced chicken and animal fat with different spices and additives including NaCl.

In many high-income countries, approximately 75% of NaCl intake comes from processed foods and meals prepared outside the home (WHO, 2012). Therefore, with the increasing demands of health-conscious consumers for foods with low sodium content, alternative methods are being explored to reduce sodium in processed products (Dötsch *et al*., 2009). Reducing the amount of NaCl or partial replacement of NaCl with other chloride salts such as potassium chloride (KCl) or calcium chloride ($CaCl_2$)

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are possible alternative (Desmond, 2006; Pateiro *et al.*, 2021; Aprilia and Kim, 2023). The replacement of NaCl with other chloride salts has been examined in hams (Armenteros *et al.*, 2009; Alino *et al.*, 2010; Lorenzo *et al.*, 2015; Cittadini *et al.*, 2020), sausages (Gimeno *et al.*, 1998; Guàrdia *et al.*, 2008; Zanardi *et al.*, 2010; Horita *et al.*, 2011; 2014; Campagnol *et al.*, 2012; Schmidt *et al.*, 2017; Araujo *et al.*, 2021), and beef or goat meat patties and burgers (Ketenoğlu and Candoğan, 2011; Barbosa *et al.*, 2017; Sousa *et al.*, 2020). However, there are no studies on reducing or replacing NaCl with KCl and/or $CaCl_2$ in chicken burgers that are widely consumed in fast-food restaurants. In the present work, the effects of reducing NaCl or partially replacing it with different chloride salts on the physicochemical, textural, and sensorial properties of chicken burgers were evaluated.

Materials and methods

Production of chicken burgers

Chicken breast meat and beef fat were used as the raw materials in burger production. After the chicken breast meat and beef fat were minced separately using a 3-mm plate with a grinder (AR 160, Arzum, Türkiye), five different groups of burgers were produced. The control group (T1) consisted of 70% chicken breast meat, 12% beef fat, 2% NaCI, 6% onion, 0.3% garlic, 0.7% red pepper, 0.2% black pepper, 0.3% cumin, 2.5% egg, and 6% breadcrumbs. In other groups, NaCl was decreased or partially replaced with other chloride salts: T2 (1% NaCl), T3 (1% NaCl + 1% KCl), T4 (1% NaCl + 1% $CaCl_2$), and T5 (1% NaCl + 0.5% KCl + 0.5% $CaCl_2$). All ingredients for each treatment were added simultaneously in a mixer (AR1129, Arzum, Türkiye), and kneaded for 2 min to obtain a homogeneous mixture. The burgers were shaped (7 cm diameter and 1 cm thickness) and then cooked on a hot plate (Elektro-mag, M4060, Türkiye) at 200°C for 8 min (4 min for each side). All samples were weighed using an analytical balance (SPB31, Scaltec, Germany), before and after cooking, to calculate the moisture retention and cooking yield.

Physicochemical analysis

The pH values and the moisture contents of the samples were determined following AOAC International (AOAC, 2005) standards, and water activity (a_w) values of the samples were determined at 25°C using a water activity meter (Novasina TH-500, Switzerland) calibrated to six different standard salt solutions. The colour intensities were recorded following the criteria given by CIE (Commission Internationale de l'Eclairage) based on three-dimensional colour measurement. Colour values (L*, a*, and b*) of the samples were determined using a colorimeter (CR-200, Minolta Co, Osaka, Japan). Thiobarbituric acid reactive substances (TBARS) analysis was performed according to Lemon (1975). The absorbance values were determined using a spectrophotometer (Thermo Electron Corporation, Aquamate, England) at 532 nm wavelength, and the TBARS values were determined as μmol MDA/kg calibrated to a standard curve for TEP (1,1,3,3 tetraethoxypropane). To determine the amounts of moisture retained in the samples (Eq. 1) and the cooking yield (Eq. 2), the following equations were used:

$$\text{Moisture retention (\%)} = (cw \times mcb / rw \times mrb) \times 100 \quad \text{(Eq. 1)}$$

$$\text{Cooking yield (\%)} = (cw / rw) \times 100 \quad \text{(Eq. 2)}$$

where, cw = cooked weight (g), mcb = moisture in cooked burger (%), rw = raw weight (g), and mrb = moisture in raw burger (%).

Texture profile analysis

Texture profile analysis (TPA) was performed using a texture analyser (CT3 Texture Analyser, Brookfield Engineering, USA). Cylindrical samples (2 cm diameter and 1 cm thickness) extracted from chicken burgers were analysed at room temperature with two consecutive compression cycles, using a 50.8 mm diameter cylindrical probe (TA 25/1000, Brookfield Engineering Laboratories, USA). For the analysis, 1 mm/s pre-test speed, 2 mm/s test and post-test speed, 5 s recovery time, and 50% target strain were used. Texture profiles of the samples (hardness, adhesiveness, cohesiveness, springiness, chewiness, and resilience) were calculated from force-time curves.

Sensory analysis

The chicken burgers for each group were subjected to sensory analysis after cooking. Ten panellists from the food engineering department performed the sensory evaluation in two separate sessions with a 5-point hedonic scale (1 = very bad, 2

= bad, 3 = medium, 4 = good, or 5 = very good) for appearance, colour, flavour, texture, and general acceptability. Ten individual results per replication were recorded. The tests were initiated after the panellists were briefed about the scale, and conducted in a room with fluorescent lighting. The panellists were instructed to cleanse their mouths between samples using water and bread.

Statistical analysis

Treatments and production stages (before and after cooking) were considered as factors in the present work, and experiments were conducted following the randomised complete block design. Replicates were accepted as a random effect. For each treatment, chicken burgers were produced at two different times, and using two different raw material blocks. Nine chicken burgers were used for each treatment per replicate (block). Three measurements were performed for each replicate in the physicochemical analyses. However, six measurements were performed for each replication in the TPA analysis. The same statistical evaluation was also used for sensory analysis. Treatments and replicates were accepted as a fixed effect and random effect, respectively, while panellists were considered a repeated factor. The analysis of variance was applied to the obtained data (Two-way ANOVA with replication), and differences between means were compared by Duncan's multiple comparison test (IBM SPSS Statistics 20). All data were given as mean ± standard error in the tables and figures.

Results and discussion

Physicochemical properties

The physicochemical properties of chicken burgers produced with different chloride salts are given in Table 1. The pH values were significantly affected by the salt composition ($p < 0.01$). Chicken burgers containing 1% NaCl and 1% KCl (T3 group) yielded the highest mean pH value, whereas the lowest mean value was in the T4 group containing 1% NaCl and 1% $CaCl_2$ ($p < 0.05$). It was observed that reducing the NaCl used in chicken burgers (T2) or partially substituting NaCl with KCI (T3) increased the pH compared to the control group (T1). However, partial substitution of NaCl with $CaCl_2$ (T4) decreased the pH value of chicken burgers compared to the control group, even when KCl was used (T5). Similarly, Barbosa *et al*. (2017) found that partial replacement of NaCl with KCl in *kafta* prepared with goat meat caused higher pH values. Furthermore, Horita *et al*. (2011) reported that the presence of $CaCl_2$ in the salt mixture used in the production of reduced-fat mortadella decreased the pH value. Also, Cittadini *et al*. (2020) observed that partial replacement of NaCl with KCl in *cecina* production increased the pH value when using $CaCl_2$, whereas $MgCl_2$ decreased it. Despite these similar results, the mechanism of NaCl substitution with other chloride salts on the pH of meat products was not elucidated. In the present work, the pH value of the product was likely affected by whether the salts used were monovalent or divalent– cations (Na^+, K^+, or Ca^{+2}) in the chloride salts. Conversely, it was observed that the pH value did not change in beef patties that used commercial low-sodium salt (Ketenoğlu and Candoğan, 2011), in fermented sausages with KCl (Campagnol *et al*., 2011; 2012), and in salami produced by partial substitution of NaCl with other chloride salts (Zanardi *et al*., 2010). In the present work, the cooking process also significantly affected the pH values of chicken burger samples ($p < 0.01$), and a higher mean pH value was observed after cooking (Table 2). The increase in pH was possibly due to imidazolium (the basic R group of the amino acid histidine) being exposed due to protein denaturation during the cooking process (Choi *et al.*, 2015). It has also been reported that the cooking process caused an increase in the pH of meatballs (Choi *et al.*, 2016; Elbir *et al.*, 2023).

The salt composition significantly affected the moisture content and a_w values of the chicken burgers ($p < 0.01$). The highest mean moisture content and a_w values were seen in the T2 group ($p < 0.05$). Although T4 and T5 groups had the lowest average moisture contents, T1 group (control) containing 2% NaCl had the lowest a_w value ($p < 0.05$). It was observed that reducing the NaCl amount from 2 to 1% in the production of chicken burgers caused increases in the moisture content and a_w. It was evident that the increase in a_w was due to the low salt concentration and high moisture content of T2 group. In addition, replacing NaCl with KCl and/or $CaCl_2$ also increased the a_w value, while decreasing the moisture content. This could be due to the lower molar concentration of KCl and $CaCl_2$ than NaCl in the solution phase of the product in accordance with Raoult's law, often cited to govern the dependence of a_w on water and solute

Table 1. Physicochemical properties of chicken burgers produced with different chloride salts.

		T1	T2	T3	T4	T5	Significance
pH		6.35 ± 0.08^{c}	6.38 ± 0.09^{b}	6.43 ± 0.07^{a}	5.61 ± 0.07^{e}	5.95 ± 0.07^{d}	**
Moisture content (%)		61.54 ± 0.62^{b}	62.27 ± 0.56^{a}	61.07 ± 0.67^{c}	60.82 ± 0.77^{cd}	60.63 ± 0.81^{d}	**
a_w		0.951 ± 0.001^{e}	0.961 ± 0.001^{a}	0.952 ± 0.001^{d}	0.955 ± 0.001^{b}	0.954 ± 0.001^{c}	**
TBARS (µmol MDA/kg)		22.04 ± 0.79^{ab}	22.99 ± 0.94^{a}	23.51 ± 1.22^{a}	20.54 ± 0.99^{b}	21.96 ± 0.74^{ab}	*
Cooking yield (%)		89.02 ± 0.27^{a}	88.53 ± 0.38^{a}	88.79 ± 0.56^{a}	86.53 ± 0.27^{b}	86.99 ± 0.49^{b}	**
Moisture retention (%)		82.18 ± 1.02^{a}	83.62 ± 0.45^{a}	83.21 ± 0.51^{a}	79.64 ± 0.34^{b}	79.91 ± 1.19^{b}	**
	L*	41.97 ± 1.28^{cd}	41.44 ± 1.55^{d}	42.78 ± 0.82^{c}	47.05 ± 0.50^{a}	45.00 ± 0.91^{b}	**
Colour	**a***	10.44 ± 0.47^{a}	10.74 ± 0.50^{a}	10.40 ± 0.46^{a}	10.68 ± 0.40^{a}	10.79 ± 0.50^{a}	ns
	b*	18.78 ± 0.53^{d}	18.48 ± 0.75^{d}	19.37 ± 0.26^{c}	21.58 ± 0.21^{a}	20.59 ± 0.26^{b}	**

Values are mean ± standard error; T1: 2% NaCl; T2: 1% NaCl; T3: 1% NaCl + 1% KCl; T4: 1% NaCl + 1% $CaCl_2$; T5: 1% NaCl + 0.5% KCl + 0.5% $CaCl_2$; $^{a-e}$: Means followed by different lowercase superscripts in the same row are significantly different ($p < 0.05$); *$p < 0.05$; **$p < 0.01$; ns: not significant.

Table 2. Physicochemical properties of chicken burgers before and after cooking.

		Before cooking	After cooking	Significance
pH		5.96 ± 0.06^{b}	6.32 ± 0.07^{a}	**
Moisture content (%)		63.49 ± 0.10^{a}	59.04 ± 0.18^{b}	**
a_w		0.957 ± 0.001^{a}	0.953 ± 0.001^{b}	**
TBARS (µmol MDA/kg)		21.00 ± 0.63^{b}	23.41 ± 0.50^{a}	**
	L*	46.75 ± 0.28^{a}	40.55 ± 0.66^{b}	**
Colour	**a***	9.22 ± 0.07^{b}	12.00 ± 0.18^{a}	**
	b*	20.71 ± 0.12^{a}	18.81 ± 0.42^{b}	**

Values are mean ± standard error. Means followed by different lowercase superscripts in the same row are significantly different ($p < 0.05$); **$p < 0.01$.

concentration in foods. Qualitatively, Raoult's law adequately explains the dependence of a_w on water and solute content in foods. Solutes with low molecular weights also provide a larger reduction of vapour pressure per unit weight of solute than solutes with high molecular weights (Toledo, 2007). However, it should be noted that the solution phase in most foods is not ideal. Guàrdia *et al*. (2008) reported that the lowest moisture content in fermented sausages was determined in the group containing the highest percentage of KCl as an alternative to NaCl, and the highest moisture content was in the control group using 100% NaCl. Conversely, it has been reported that the use of KCl instead of NaCl in *kafta* produced from goat meat (Barbosa *et al*., 2017), and the use of different chloride salts instead of NaCl in the production of reduced-fat mortadella (Horita *et al*., 2011) had no effect on the moisture content. Lorenzo *et al*. (2015) stated that while the use of NaCl and/or KCl in producing dry-cured bacon showed lower a_w values, the use of $CaCl_2$ and $MgCl_2$ increased a_w value. Barbosa *et al*. (2017) reported a higher mean a_w value in *kafta* produced from goat meat using 1.5% NaCl + 1.5% KCI compared with *kafta* samples containing 3% NaCl or 2.25% NaCl + 0.75% KCI. Also, Gimeno *et al*. (1998) found higher a_w values in dry fermented sausages using 1% NaCl + 0.55% KCl + 0.23% $MgCl_2$ + 0.46% $CaCl_2$ compared to the control group (2.6% NaCl).

The cooking process also significantly affected the moisture content and a_w values of chicken burger samples ($p < 0.01$), and lower mean moisture content and a_w values were seen after cooking (Table 2). This could be due to moisture loss during the cooking process. Moreover, treatment × production stage interaction showed a significant effect on the a_w values of chicken burgers ($p < 0.01$). While the highest a_w values were observed in the T2 group before and after cooking, the lowest a_w values after cooking were seen in the T1 group containing 2%

NaCl and the T3 group containing 1% NaCl + 1% KCl (Figure 1). This finding showed that it was possible to use 50% KCl instead of NaCl in the production of chicken burgers when taking into account the a_w.

An important factor affecting the quality of meat products is lipid oxidation, and the TBARS value is a good indicator for this. In the present work, the TBARS values of chicken burgers were affected by the salt composition ($p < 0.05$), and the lowest mean TBARS value was found in the T4 group containing 1% NaCl + 1% $CaCl_2$ (Table 1). Although the highest mean value was detected in the T3 group, no significant difference was observed among the T1, T2, T3, and T5 groups (Table 1). It has been reported that NaCl as an important prooxidant, accelerates lipid oxidation in meat products. However, the mechanism of this effect cannot be fully explained (Zanardi *et al*., 2010). Moreover, these results highlighted that $CaCl_2$ exhibited a lower pro-oxidative effect than NaCl and KCl in the samples. In contrast, it was reported that the limit value at which rancidity could be detected by consumers is 2 mg MDA/kg meat (approximately 27.753 μmol MDA/kg meat) for certain meat products (Greene and Cumze, 1982; Torres *et al*., 1994; Wood *et al*., 2003; Campo *et al*., 2006; Fraqueza and Barreto, 2009). In the present work, it was observed that this limit value was not exceeded in any of the chicken burger samples produced despite different salt compositions. The TBARS values of the samples were also significantly affected by the cooking process ($p < 0.01$) with a higher mean TBARS value seen after cooking (Table 2). In fact, it was reported that denatured myoglobin and the iron released from haemoglobin during the cooking of meat products catalyse lipid oxidation (Rojas and Brewer, 2007), and that the cooking process might cause pro-oxidant interactions by disrupting cell structure (Ramirez *et al*., 2005).

Colour is one of the most important features regarding consumer preference for meat products. The salt composition significantly affected the L* and b* values of the chicken burgers ($p < 0.01$). Although the highest mean L* and b* values were observed in the T4 group, the lowest mean values were found in the T1 and T2 groups (Table 1). Based on these results, reducing the amount of NaCl used in the production of chicken burgers to 1% did not have a significant effect on the L* value (which is an indicator of lightness) and the b* value (which indicates the yellow colour intensity). Conversely, it was observed that the substitution of NaCl with KCl and/or $CaCl_2$ at certain rates caused an increase in L* and b* values, with higher values obtained in groups containing $CaCl_2$. The difference in the colour parameters may be explained by the different physicochemical characteristics (pH, a_w, and moisture) of the meat products (Horita *et al.*, 2011). In the present work, lower pH and moisture contents and higher a_w values were determined in the groups containing $CaCl_2$. Cittadini *et al.* (2020) found the highest L* and b* values in dry-cured foal *cecina* manufactured with dichloride salts with the lowest values reported in the control samples. Similarly, Campagnol *et al.* (2012) reported that using 50% KCl instead of NaCl in fermented sausages increased the L* value. However, Barbosa *et al*. (2017) determined that the use of KCl in *kafta* produced from goat meat decreased the L* and a* values compared to the control. On the other hand, Horita *et al*. (2011) found that the use of different chloride salts instead of NaCl in the production of reduced-fat mortadella did not affect the colour characteristics. Also, a similar result was observed by Ketenoğlu and Candoğan (2011) for the use of commercial low-sodium salt in beef patties. The cooking process significantly affected the L*, a*, and b* values of chicken burger samples ($p < 0.01$), and it was observed that while L* and b* values decreased after cooking, the a* value increased (Table 2). This could have been due to the rise in pH and denaturation of proteins during the cooking process. These changes might have affected colour properties due to the formation of denatured metmyoglobin. The colour of cooked meat should be grey-brown, and is caused by protein (globin) denaturation during heat processing under aerobic conditions. The brown pigments of cooked meat are denatured metmyoglobin from the formation of denatured globin haemichrome (ferrihaemochrome). The pH is also important for the colour of cooked meat as the heat stability of the metmyoglobin increases with rising pH of the pigment solution (Nam, 2017). Also, the L* values of chicken burger samples were significantly affected by treatment × production stage interaction ($p < 0.01$). The highest L* values were obtained in the T4 group both before and after cooking, while the L* value decreased for all groups after cooking with the lowest values seen in the T1 and T2 groups (Figure 2). Therefore, the use of KCl and especially $CaCl_2$ in the production of chicken burgers, caused higher L* values after cooking.

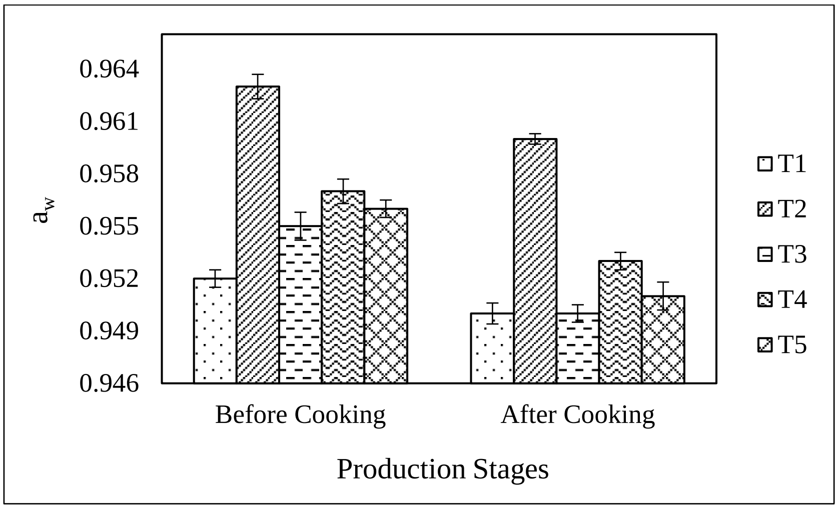

Figure 1. Changes in a_w values of chicken burgers before and after cooking (T1: 2% NaCl; T2: 1% NaCl; T3: 1% NaCl + 1% KCl; T4: 1% NaCl + 1% $CaCl_2$; T5: 1% NaCl + 0.5% KCl + 0.5% $CaCl_2$).

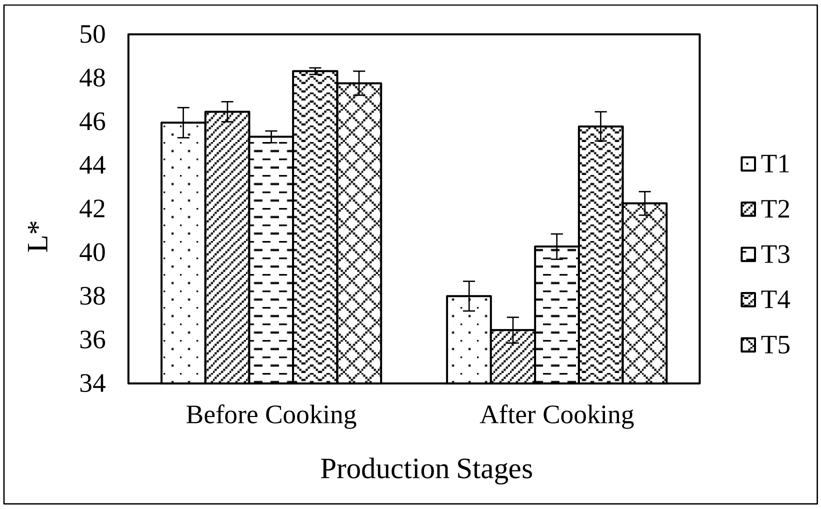

Figure 2. Changes in L* values of chicken burgers before and after cooking (T1: 2% NaCl; T2: 1% NaCl; T3: 1% NaCl + 1% KCl; T4: 1% NaCl + 1% $CaCl_2$; T5: 1% NaCl + 0.5% KCl + 0.5% $CaCl_2$).

The moisture retention and cooking yield of chicken burgers were significantly affected by the salt compositions used during preparation ($p < 0.01$). The lowest mean moisture retention and cooking yield values were obtained in T4 and T5 groups, while the highest mean values were in the T1, T2, and T3 groups (Table 1). Based on these results, a 50% reduction of NaCl used in the production of chicken burgers or its replacement with 50% KCl did not affect the moisture retention and cooking yield compared to the control, but the use of $CaCl_2$ in the production decreased both values. Similarly, Horita *et al*. (2011) reported that the use of $CaCl_2$ in the production of reduced-fat mortadella decreases the cooking yield. It has been reported that the presence of divalent calcium ions can contribute to reduced myofibrillar protein extraction, which is responsible for fat and water binding in meat batter, compared to monovalent chlorides. The inability of $CaCl_2$ to extract substantial amounts of myofibrillar proteins from meat might be due to its charge density or specific ion effects (Horita *et al.,* 2014). In contrast, Tobin *et al*. (2012) found that increasing salt (NaCl) levels in beef patties reduced cooking loss, and patties containing 0.75% salt had more cooking loss than patties containing 1.5%. In another study, it was stated that with increasing rate of replacement of NaCl with KCl in *kafta* produced from goat meat, the cooking loss also increased (Barbosa *et al*. 2017).

Texture properties

One of the most important parameters affecting the quality of meat products and consumer preference is texture (Chen and Opara, 2013; Bekhit *et al*., 2014).

The salt composition used in the production of chicken burgers significantly affected the hardness, resilience, cohesiveness, springiness, and chewiness of the samples ($p < 0.01$). However, it did not have a significant effect on adhesiveness ($p > 0.05$). The mean values of hardness, resilience, and chewiness determined for all groups differed from each other statistically ($p < 0.05$). The highest mean values for these parameters were seen in the T1 (control) group, while the lowest mean values seen in the T4 group (Table 3). Based on these results, reducing the amount of NaCl used in chicken burger production to 1% or replacing NaCl with certain ratios of KCl and/or $CaCl_2$ reduced the hardness, resilience, and chewiness values. Moreover, the use of $CaCl_2$ during production resulted in a greater decrease in these parameters. Sodium chloride improves the binding properties between water and fat in meat products, resulting in a strong gel formation during cooking that leads to firmer products with high hardness levels (Terrel, 1983). Reducing NaCl or substituting it with KCl or $CaCl_2$ was inadequate to provide this potential effect in the chicken burger samples. Since chewiness is markedly influenced by hardness, the interpretation of the results can be similar. No statistically significant difference was observed between the mean values of cohesiveness for the T1 and T3 groups. However, lower mean cohesiveness values were obtained for all other groups. In terms of springiness, the highest and the lowest mean values were in the T1 and T4 groups respectively. However, no statistically significant difference was found between the mean values for the T3 and T5 groups (Table 3). Therefore, reducing the amount of NaCl used in the production of chicken burgers to 1% decreased the cohesiveness and springiness compared to the control, the use of KCl did not affect the cohesiveness but decreased the springiness, and the use of $CaCl_2$ caused a greater decrease in both parameters. The decrease in cohesiveness and springiness when the sodium chloride content was reduced or replaced by other salts might have been due to the decreased amount of extracted muscle protein, consequently lowering the water-binding ability and gel strength. Campagnol *et al*. (2012) reported that a 50% replacement of NaCl used in fermented sausage production with KCl did not affect the springiness and cohesiveness, but significantly decreased the hardness. Horita *et al*. (2011) showed that the use of KCl in different ratios instead of NaCl in the production of reduced-fat mortadella decreased its hardness and cohesiveness, and the use of $CaCl_2$ increased the hardness and chewiness, but decreased the resilience and cohesiveness. Conversely, Alino *et al*. (2010) reported that the use of 50% NaCl + 50% KCl in dry-cured ham production did not affect its springiness, cohesiveness, and adhesiveness; however, it caused greater hardness and chewiness.

Table 3. Texture profile parameters of chicken burgers produced with different chloride salts.

	T1	T2	T3	T4	T5	Significance
Hardness (N)	98.32 ± 0.73^a	89.66 ± 1.65^c	92.78 ± 1.25^b	54.71 ± 1.09^e	63.63 ± 1.78^d	**
Adhesiveness (mJ)	0.05 ± 0.03^a	0.12 ± 0.03^a	0.17 ± 0.07^a	0.13 ± 0.04^a	0.19 ± 0.07^a	ns
Resilience	0.17 ± 0.00^a	0.14 ± 0.00^c	0.15 ± 0.01^b	0.08 ± 0.00^e	0.10 ± 0.00^d	**
Cohesiveness	0.40 ± 0.01^a	0.36 ± 0.01^b	0.39 ± 0.01^a	0.30 ± 0.01^d	0.32 ± 0.01^c	**
Springiness (mm)	5.65 ± 0.08^a	5.19 ± 0.07^c	5.48 ± 0.07^b	4.93 ± 0.07^d	5.34 ± 0.04^b	**
Chewiness (mJ)	218.75 ± 4.49^a	169.68 ± 5.87^c	196.00 ± 5.50^b	81.68 ± 3.44^e	109.01 ± 4.82^d	**

Values are mean ± standard error; T1: 2% NaCl; T2: 1% NaCl; T3: 1% NaCl + 1% KCl; T4: 1% NaCl + 1% $CaCl_2$; T5: 1% NaCl + 0.5% KCl + 0.5% $CaCl_2$; $^{a-e}$: Means followed by different lowercase superscripts in the same row are significantly different ($p < 0.05$); ** $p < 0.01$; ns: not significant.

Sensory evaluation

The results of the sensory analysis of the various chicken burger groups are shown in Table 4 with the corresponding ANOVA values. Among the sensory properties, appearance, flavour, texture, and general acceptability were significantly affected by the salt composition of chicken burgers ($p < 0.01$), but the colour was unaffected ($p > 0.05$). The lowest mean values for appearance, flavour, texture, and general acceptability were found in the T4 group ($p < 0.05$). However, there were no significant differences for these parameters between the other groups ($p > 0.05$). Based on these results, a 50% replacement of NaCl with $CaCl_2$ in the production of chicken burgers reduced the sensory scores for appearance, flavour, texture, and general acceptability. This was likely because $CaCl_2$ significantly affected the physicochemical and textural properties of the burgers, such as pH, cooking yield, moisture retention, hardness, and cohesiveness. However, reducing the amount of NaCl to 1 or a 50% substitution of NaCl with KCl did not affect the sensory properties. KCl is the most-used substitute in the preparation of low-sodium meat products, but it was reported that depending on the level of substitution, it resulted in sensory rejection since it produced a bitter and metallic taste (Horita *et al.*, 2011). However, in the present work, replacing NaCl with 50% KCl in the chicken burgers did not cause unfavourable sensory effects compared to the control. Tobin *et al*. (2012) found that low-fat beef patties with 50% reduced salt content were sensory acceptable. Ketenoğlu and Candoğan (2011) reported that the use of commercial low-sodium salt in beef patties did not have a significant effect on sensory properties. Also, Guàrdia *et al*. (2008) found that the substitution of NaCl with KCl in fermented sausages showed similar sensory properties to the control. In another study of dry-cured loin, the substitution of NaCl up to 50% with KCl provided similar results to the control (100% NaCl) in terms of aroma, texture, and taste, but higher scores for colour and general acceptability (Armenteros *et al*., 2009).

Table 4. Sensory properties of chicken patties produced with different chloride salts.

	T1	T2	T3	T4	T5	Significance
Appearance	4.10 ± 0.14^{ab}	4.20 ± 0.12^{a}	4.30 ± 0.13^{a}	3.75 ± 0.18^{b}	4.15 ± 0.13^{a}	**
Colour	4.15 ± 0.13^{a}	4.10 ± 0.10^{a}	4.25 ± 0.10^{a}	3.95 ± 0.15^{a}	4.05 ± 0.15^{a}	ns
Flavour	4.05 ± 0.14^{a}	3.95 ± 0.18^{a}	3.95 ± 0.15^{a}	2.75 ± 0.14^{b}	3.85 ± 0.18^{a}	**
Texture	3.70 ± 0.15^{ab}	3.85 ± 0.21^{a}	4.15 ± 0.17^{a}	3.25 ± 0.16^{b}	3.85 ± 0.15^{a}	**
General acceptability	3.95 ± 0.14^{a}	3.85 ± 0.15^{a}	4.10 ± 0.12^{a}	3.00 ± 0.13^{b}	3.95 ± 0.17^{a}	**

Values are mean ± standard error; T1: 2% NaCl; T2: 1% NaCl; T3: 1% NaCl + 1% KCl; T4: 1% NaCl + 1% $CaCl_2$; T5: 1% NaCl + 0.5% KCl + 0.5% $CaCl_2$; $^{a-e}$: Means followed by different lowercase superscripts in the same row are significantly different ($p < 0.05$); $**p < 0.01$; ns: not significant.

Conclusion

In terms of physicochemical properties, instead of reducing the amount of NaCl used in the production of chicken burgers, partially substituting it with KCI could be a good solution to attain a low sodium product. Furthermore, the closest TPA results to the control (100% NaCl) were obtained in chicken burgers containing 1% NaCl and 1% KCl (T3 group). On the other hand, the sensory properties of the chicken burgers were negatively affected by the partial use of $CaCl_2$ instead of NaCl. Therefore, it was concluded that it could be possible to use 50% KCl instead of NaCl in the production of chicken burgers, while the use of $CaCl_2$ would be appropriate at a lower amount, and in the presence of KCl.

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References

Alino, M., Grau, R., Toldra, F. and Barat, J. M. 2010. Physicochemical changes in dry-cured hams salted with potassium, calcium and magnesium chloride as a partial replacement for sodium chloride. Meat Science 86(2): 331-336.

Aprilia, G. H. S. and Kim, H. S. 2023. Development of strategies to manufacture low-salt meat products - A review. Journal of Animal Science and Technology 64(2): 218-234.

Araujo, D. H. S., Rodrigues, R. T. S., Costa, M. M., Miranda, J. O., Lira-Alencar, N. R. C., Queiroz, M. A. A., … and Gois, G. C. 2021. Reduction of sodium content in frozen goat sausage using different types of salt. LWT - Food Science and Technology 135: 110272.

Armenteros, M., Aristoy, M. C., Barat, J. M. and Toldra, F. 2009. Biochemical changes in dry-cured loins salted with partial replacements of NaCl by KCl. Food Chemistry 117(4): 627-633.

Association of Official Analytical Chemists (AOAC). 2005. Official methods of analysis of AOAC International - Meat and meat products. 18th ed. United States: AOAC.

Barbosa, P. T., Santos, I. C. V., Ferreira, V. C. S., Fragoso, S. P., Araujo, I. B. S., Costa, A. C. V., … and Silva, F.A.P. 2017. Physicochemical properties of low sodium goat kafta. LWT - Food Science and Technology 76: 314-319.

Bekhit, A. E. A., Carne, A., Ha, M. and Franks, P. 2014. Physical interventions to manipulate texture and tenderness of fresh meat: A review. International Journal of Food Properties 17(2): 433-453.

Campagnol, P. C. B., Santos, B. A., Terra, N. N. and Pollonio, M. A. R. 2012. Lysine, disodium guanylate and disodium inosinate as flavor enhancers in low-sodium fermented sausages. Meat Science 91: 334-338.

Campagnol, P. C. B., Santos, B. A., Wagner, R., Terra, N. N. and Pollonio, M. A. R. 2011. The effect yeast extract addition on quality of fermented sausages at low NaCl content. Meat Science 87: 290-298.

Campo, M. M., Nute, G. R., Hughes, S. I., Enser, M., Wood, J. D. and Richardson, R. I. 2006. Flavor perception of oxidation in beef. Meat Science 72: 303-311.

Chen, L. and Opara, U. L. 2013. Approaches to analysis and modeling texture in fresh and processed foods - A review. Journal of Food Engineering 119(1): 497-507.

Choi, Y. S., Kim, H. W., Hwang, K. E., Song, D. H., Jeong, T. J., Kim, Y. B., … and Kim, C. J. 2015. Effects of fat levels and rice bran fiber on the chemical, textural, and sensory properties of frankfurters. Food Science and Biotechnology 24: 489-495.

Choi, Y. S., Sung, J. M., Park, J. D., Hwang, K. E., Lee, C. W., Kim, T. K., … and Kim, Y. B. 2016. Quality and sensory characteristics of reduced fat chicken patties with pork back fat replaced by dietary fiber from wheat sprout. Korean Journal for Food Science of Animal Resources 36(6): 799-806.

Cittadini, A., Dominguez, R., Gomez, B., Pateiro, M., Perez-Santaescolastica, C., Lopez-Fernandez, O., … and Lorenzo, J. M. 2020. Effect of NaCl replacement by other chloride salts on physicochemical parameters, proteolysis and lipolysis of dry-cured foal ‘‘cecina’’. Journal of Food Science and Technology 57(5): 1628-1635.

Cook, N. R., Appel, L. J. and Whelton, P. K. 2016. Sodium intake and all-cause mortality over 20 years in the trials of hypertension prevention. Journal of the American College of Cardiology 68(15): 1609-1617.

Desmond, E. 2006. Reducing salt: A challenge for the meat industry. Meat Science 74: 188-196.

Dötsch, M., Busch, J., Batenburg, M., Liem, G., Tareilus, E., Mueller, R. and Meijer, G. 2009. Strategies to reduce sodium consumption: A food industry perspective. Critical Reviews in Food Science and Nutrition 49(10): 841-851.

Elbir, Z., Ekiz, E., Aoudeh, E., Oz, E., Savaş, A., Brennan, C., … and Oz, F. 2023. Enhancing effect of chia seeds on heterocyclic amine generation in meatball. International Journal of Food Science and Technology 58: 2560-2572.

Fraqueza, M. J. and Barreto, A. S. 2009. The effect on turkey meat shelf life of modified-atmosphere packaging with an argon mixture. Poultry Science 88: 1991-1998.

Gimeno, O., Astiasaran, I. and Bello, J. 1998. A mixture of potassium, magnesium and calcium chlorides as a partial replacement of sodium chloride in dry fermented sausages. Journal of Agricultural and Food Chemistry 46: 4372-4375.

Greene, B. A. and Cumuze, T. H. 1982. Relationship between TBA numbers and inexperienced panelist's assessments of oxidised flavor in cooked beef. Journal of Food Science 47: 52-58.

Guàrdia, M. D., Guerrero, L., Gelabert, J., Gou, P. and Arnau, J. 2008. Sensory characterization and consumer acceptability of small calibre fermented sausages with 50% substitution of NaCl by mixtures of KCl and potassium lactate. Meat Science 80(4): 1225-1230.

Horita, C. N., Messias, V. C., Morganob, M. A., Hayakawa, F. M. and Pollonioa, M. A. R. 2014. Textural, microstructural and sensory properties of reduced sodium frankfurter sausages containing mechanically deboned poultry meat and blends of chloride salts. Food Research International 66: 29-35.

Horita, C. N., Morgano, M. A., Celeghini, R. M. S. and Pollonio, M. A. R. 2011. Physico-chemical and sensory properties of reduced-fat mortadella prepared with blends of calcium, magnesium and potassium chloride as partial substitutes for sodium chloride. Meat Science, 89(4): 426-433.

Ketenoğlu, O. and Candoğan, K. 2011. Effect of low-sodium salt utilization on some characteristics of ground beef patties. Gıda 36(2): 63-69.

Lemon, D. W. 1975. An improved TBA test for rancidity new series circular., Nova Scotia: Halifax-Laboratory.

Lorenzo, J. M., Bermudez, R., Domínguez, R., Guiotto, A., Franco, D. and Purriños, L. 2015. Physicochemical and microbial changes during the manufacturing process of dry-cured lacón salted with potassium, calcium and magnesium chloride as a partial replacement for sodium chloride. Food Control 50: 763-769.

Nam, K. C. 2017. The colour of poultry meat: understanding, measuring and maintaining product quality. In Ricke, S. (ed). Book Achieving Sustainable Production of Poultry Meat, p. 273-290. London: Burleigh Dodds Science Publishing.

Pateiro, M., Munekata, P. E. S., Cittadini, A., Dominguez, A. and Lorenzo, J. M. 2021. Metallic-based salt substitutes to reduce sodium content in meat products. Current Opinion in Food Science 38: 21-31.

Ramirez, M. R., Morcuende, D., Estevez, M. and Lopez, R. C. 2005. Fatty acid profiles of intramuscular fat from pork loin chops fried in different culinary fats following refrigerated storage. Food Chemistry 92: 159-167.

Rojas, M. C. and Brewer, M. S. 2007. Effect of natural antioxidants on oxidative stability of cooked, refrigerated beef and pork. Journal of Food Science 72: 282-288.

Schmidt, M. M., Dornelles, R. C. P., Vidal, A. R., Fontoura, A., Kubota, E. H., Mello, R. O., … and Demiate, I. M. 2017. Development of cooked and smoked chicken sausage with reduced sodium and fat. The Journal of Applied Poultry Research 26(1): 130-144.

Sousa, A. M. B., Alves, R. A., Madeira, D. S. S., Santos, R. M., Pereira, A. L. F., Lemos, T. O. and Abreu, V. K. G. 2020. Storage of beef burgers containing fructooligosaccharides as fat replacer and potassium chloride as replacing sodium chloride. Journal of Food Science and Technology 57(9): 3232-3243.

Terrell, R. N. 1983. Reducing the sodium content of processed meats. Food Technology 37(6): 66-71.

Tobin, B. D., O'Sullivan, M. G., Hamill, R. M. and Kerry, J. P. 2012. Effect of varying salt and fat levels on the sensory quality of beef patties. Meat Science 91(4): 460-465.

Toledo, R. T. 2007. Fundamentals of food process engineering. 3rd ed. New York: Springer Science.

Torres, E. A. F. S., Shimokomaki, M., Franco, B. D. G. M., Landgraf, M., Carvalho, J. B.C. and Santos, J. C. 1994. Parameters determining the quality of charqui, an intermediate moisture meat product. Meat Science 38: 229-234.

Wood, J. D., Richardson, R. I., Nute, G. R., Fisher, A. V., Campo, M. M., Kasapidou, E., … and Enser, M. 2003. Effects of fatty acids on meat quality: A review. Meat Science 66: 21-32.

World Health Organization (WHO). 2012. Guideline - Sodium intake for adults and children. United States: WHO.

Yotsuyanagi, S. E., Contreras-Castillo, C. J., Haguiwara, M. M. H., Cipolli, K. M. V. A. B., Lemos, A. L. S. C., Morgano, M. A. and Yamada, E. A. 2016. Technological, sensory and microbiological impacts of sodium reduction in frankfurters. Meat Science 115: 50-59.

Zanardi, E., Ghidini, S., Conter, M. and Lanieri, A. 2010. Mineral composition of Italian salami and effect of NaCl partial replacement on compositional, physico-chemical and sensory parameters. Meat Science 86 (3): 742-747.