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Original Scientific Paper

Salt reduction possibility in marinated chicken meat

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ABSTRACT

In this study, the possibility of NaCl reduction and its partial replacement with KCl in marinated, grilled chicken thighs was investigated. In the control group, 20 g of NaCl per kg of meat was added to the marinade, while in experimental group 1, that amount of NaCl was reduced by 25%. In experimental group 2, one-third of the NaCl was replaced with KCl; in group 3, one-half (both related to the control group); and in group 4, one-third of the NaCl was replaced with KCl, as related to group 1. Sensory properties, the sodium content and the sodium/potassium ratio were analysed for the grilled chicken thighs. Sensory evaluation was performed by ten trained assessors using numerical-descriptive scales. Sensory evaluation showed the mean intensity of saltiness score was statistically significantly lower ($p < 0.1$) in the chicken thighs from experimental group 4 compared with the control group and experimental groups 1 and 2. The mean overall acceptability score of the chicken thighs from experimental group 3 was lower than the scores of the control and groups 1 and 2 ($p < 0.01$), as well as lower than the score of group 4 ($p < 0.05$).

1. Introduction

Salt intake in modern human nutrition significantly exceeds physiological needs, which is why excessive sodium intake is now causing serious health problems. With the development of technology, salt no longer has a primary role in food preservation; instead, salt consumption has increased alongside the growth of industrial food production.

Salt has been identified as the most significant cause of essential hypertension, which is one of the main risk factors for the development of cardiovascular and kidney diseases (*O'Donnell et al.,* 2012; *Laranjo et al,* 2017*)*. Excessive salt intake leads to an increased risk of heart attack (*Perry & Beevers,* 1992), indirectly contributes to weight gain *(Feng et al.,* 2010), and increases the risk of *Helicobacter pylori* infection and the development of stomach cancer (*Tsugane et al.,* 2004).

The sodium requirement for basal metabolism in humans is 2,000 mg per day. However, the mean daily sodium intake is much higher, ranging from 3,500 to 5,000 mg per day, which corresponds to 9–12 g of table salt consumed. The American Heart Association recommends that individuals with high blood pressure limit their daily sodium intake to no more than 1,500 mg, and people with heart disease to no more than 1,000 mg per day. The intake of table salt depends not only on physiological needs but also on habits acquired in early childhood and dietary traditions. Approximately 20% of the total daily salt consumed through food originates from meat products (*Wirth,* 1991).

The salt content in meat products primarily depends on technologically justified amounts and their impact on perceived saltiness. Meat products' salt content can be reduced by lowering the amount of added sodium chloride (NaCl) (*Sofos,* 1983),

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by substituting part of the NaCl with other salts (*Sofos*, 1983; *Guàrdia et al.,* 2006), by using flavour enhancers and masking agents (*Desmond,* 2006), or through a combination of these approaches (*Sofos,* 1983). Potassium chloride (KCl) is the most commonly used substitute for NaCl; however, according to numerous studies, complete substitution is not possible, as it leads to an increase in bitter taste and a reduction in perceived saltiness (*Lilić et al.* 2012; *Soglia* 2014; *Lilić et al.* 2016; *Borović et al.* 2021).

In recent decades, production and consumption of chicken meat have been increasing, which can be attributed to several factors; rapid feed conversion compared to other animal species, favourable health characteristics (low fat content and high protein proportion), pleasant sensory qualities, affordable price, and a short rearing period, i.e., a fast reproductive cycle. To enhance its sensory properties, chicken meat is often marinated. Marinades are flavoured mixtures of spices, NaCl and other ingredients used to enhance the flavour, texture, colour, and tenderness of meat and meat products (*Lyon et al.* 2005; *Gómez et al.* 2019; *Latoch et al.* 2020; *Lopes et al.* 2022; *Rahman et al*. 2023).

The aim of this study was to investigate the possibility of reducing NaCl and substituting it with KCl in marinated chicken thighs, as well as the impact on the sensory properties of the grilled meat product.

2. Materials and Methods

Within the study, five experimental groups were formed—marinated boneless chicken thighs with different amounts of added NaCl, with the aim of reducing the total amount of NaCl, i.e., sodium. The marinade was prepared from the following ingredients: sunflower oil, garlic, lemon juice, mustard, acacia honey, NaCl, and KCl, in the amounts shown in Table 1. In the control group (C), only NaCl was added to the marinade, at 20 g per kilogram of thigh meat, while in group 1, 15 g of NaCl were added per kilogram of meat. In group 2, one-third of the NaCl was substituted with KCl relative to the control group; in group 3, half of the NaCl was substituted with KCl relative to the control group; and in group 4, one-third of the NaCl was substituted with KCl relative to group 1. Marination lasted for 24 hours, after which the marinated chicken thighs were thermally processed by grilling on an electric grill with non-stick ribbed plates and were evaluated immediately after heat treatment by 10 trained assessors.

2.1. Sensory evaluation

In a laboratory equipped in accordance with the SRPS EN ISO 8589:2015 (*Serbia*, 2015) standard, marinated, grilled chicken thighs from the experimental groups were sensory evaluated by ten trained assessors. The cooked chicken thighs were presented to the assessors in individual booths, while optimal working conditions were maintained in terms of temperature, air humidity, and lighting (*Baltić,* 1994). The following sensory attributes were evaluated: acceptability of colour on the surface and on the cut section, consistency, acceptability of saltiness, intensity of saltiness, intensity of bitter taste, and the overall acceptability of the product.

2.2. Determination of sodium and potassium content

Aliquots of approximately 0.5 g of homogenized chicken thigh were transferred into Teflon vessels, and 5 mL of nitric acid (p.a., Sigma) and 1.5 mL of hydrogen peroxide (30%, p.a., Merck) were added. The microwave digestion program consisted of three steps: 5 min from room temperature to 180 °C, 10 min hold at 180 °C, and 20 min venting. After cooling at

Table 1. Product composition (g)

Group	Chicken thighs, boneless	Sodium chloride	Potassium chloride	Lemon juice	Honey	Mustard	Garlic	Oil
C	1000	20		22	15	4.5	2	90
1	1000	15		22	15	4.5	2	90
2	1000	13.3	6.7	22	15	4.5	2	90
3	1000	10	10	22	15	4.5	2	90
4	1000	10	5	22	15	4.5	2	90

room temperature, the digested solutions were quantitatively transferred into disposable flasks and diluted to 100 mL with deionized water (Elga). The analysis was performed using inductively coupled plasma mass spectrometry (ICP-MS). Measurements were carried out using an iCap Q (Thermo Scientific, Bremen, Germany), equipped with a collision cell and operating in kinetic energy discrimination (KED) mode. The isotopes ^{23}Na and ^{39}K were measured. Torch position, ion optics, and detector settings were adjusted daily using a tuning solution (Thermo Scientific Tune B) to optimize measurements and minimize possible interferences. For quantitative analysis, a five-point calibration curve (including zero) was constructed for each isotope in the concentration range of 0.1–2.0 mg/L. An additional line of the peristaltic pump was used for online introduction of a multi-element internal standard (^{6}Li, ^{45}Sc – 10 ng/mL; ^{71}Ga, ^{89}Y, ^{209}Bi – 2 ng/mL), covering a wide mass range. Concentrations of each measured isotope were corrected for response factors of both higher and lower mass internal standards by interpolation. Mean scores and analytical results are presented below.

3. Results and Discussion

The results of the sensory evaluation of marinated chicken thighs are presented in Table 2. Samples from all examined groups were sensorially acceptable. Grilled chicken thighs from all groups had uniform colour acceptability and consistency, with no statistically significant differences between the scores ($p > 0.05$).

The presence of a bitter taste was detected only in group 3 chicken thighs. The intensity of the bitter taste differed significantly between the control and group 3, as well as between experimental groups 1 and 3 ($p < 0.01$). Bitter taste intensity also significantly differed between groups 2 and 3, as well as between groups 3 and 4 ($p < 0.05$). The obtained results are in agreement with the studies of many authors (*Desmond* 2006; *Ruuseunen & Puolanne* 2005*, Zanardi et al.* 2010), who stated that an increase in the KCl content in foods can result in bitter and metallic tastes.

The intensity of saltiness was directly influenced by the amount of added NaCl. The highest saltiness intensity (4.70 ± 0.90), observed in the control group, was statistically significantly higher ($p < 0.01$) that that of experimental groups 1, 3, and 4 (3.40 ± 0.66; 3.35 ± 0.10; and 2.80 ± 0.75, respectively). Statistically significant differences ($p < 0.01$) in saltiness intensity were also observed between experimental groups 2 and 4 (4.10 ± 0.70 and 2.80 ± 0.75).

The highest scores for saltiness acceptability were achieved by the control and experimental groups 1 and 2 (4.40 ± 0.92, 4.10 ± 0.54, and 4.30 ± 0.64, respectively), with no statistically significant differences between these groups ($p > 0.05$). However, compared with the control, in group 2, in which one-third of the NaCl was replaced by KCl, there was no significant change in saltiness, although a bitter taste was noted. Lower saltiness acceptability was determined in group 4 chicken thighs (mean of 3.15 ± 1.34), which was significantly lower than that observed in the control and experimental group 2 ($p < 0.05$). The least acceptable salty taste, due to the notable bitter taste, was observed in group 3 chicken thighs, in which one-half of the NaCl had been replaced with KCl—assessors scored this group as 2.70 ± 0.60, which was significantly lower ($p < 0.01$) than the scores for the control and experimental groups 1 and 2.

The scores for overall acceptability were very similar to those for saltiness acceptability, with no statistically significant differences ($p > 0.05$) between the mean scores of the control, and experimental groups 1, 2, and 4. The mean overall acceptability score only of the group 3 chicken thighs was significantly lower than those for the control and experimental groups 1 and 2 ($p < 0.01$), as well as lower than that for group 4 ($p < 0.05$).

Despite statistically significant differences in the intensity of saltiness, saltiness acceptability, and the appearance of a bitter taste, all evaluated chicken thighs were sensorially acceptable.

Similar studies were conducted by *Lee et al.* (2012), who used only NaCl and KCl in different ratios for marinating chicken breasts and found that substitution of up to 50% of the NaCl with KCl is possible without inducing significant changes in the sensory characteristics of the product. *Cavalho et al.* (2013) investigated the possibility of substituting NaCl with KCl at levels of 25% and 50% in marinated beef and chicken. For marination, in addition to sodium and potassium salts, they used a mixture of garlic, anise, turmeric, chili, ground pepper, oregano, and thyme. They also found that substitution of up to 50% of the NaCl with KCl was possible.

The results obtained in the current study were partially in accordance with the findings of *Lee et al.* (2012) and *Cavalho et al.* (2013), who showed that in marinated chicken fillet, up to 30% of the NaCl can be substituted with KCl without significant changes in sensory characteristics. In our research though, substituting 50% of the NaCl with KCl

Table 2. Sensory analyses of marinated, grilled chicken thighs, n=10

	Group				
	C	**1**	**2**	**3**	**4**
Saltiness acceptability					
X±SD	4.40±0.92^{x,a}	4.10±0.54^{x}	4.30±0.64^{x,a}	2.70±0.60^{y}	3.15±1.34^{b}
Coefficient of variation	20,83	13.13	14.89	22.22	42.62
Range of variation	2.00–5.00	3.00–5.00	3.00–5.00	2.00–3.50	1.00–5.00
Saltiness intensity					
X±SD	4.70±0.90^{x}	3.40±0.66^{y}	4.10±0.70^{x}	3.35±1.00^{y}	2.80±0.75^{y}
Coefficient of variation	19.15	19.51	17.07	29,89	26.73
Range of variation	2.00–5.00	2.00–4.00	3.00–5.00	2.00–5.00	2.00–4.00
Bitterness intensity					
X±SD	1.20±0.60^{x}	1.20±0.60^{x}	1.80±0.60^{a}	2.75±0.64 ^{y,b}	1.70±0.90^{a}
Coefficient of variation	50,00	50.00	33.33	23.35	52.94
Range of variation	1.00–3.00	1.00–3.00	1.00–3.00	2.00–3.50	1.00–4.00
Overall acceptability					
X±SD	4.40±0.92^{x}	4.55±0.47^{x}	4.20±0.40^{x}	3.20±0.33^{y,a}	4.15±0.55^{b}
Coefficient of variation	20.83	10.37	9.52	10.36	13.25
Range of variation	2.00–5.00	4.0–5.00	4.00–5.00	3.00–4.00	3.00–5.00

Legend: a, b Statistically significant difference ($p < 0.05$); x, y Statistically significant difference ($p < 0.01$)

led to changes in sensory characteristics, primarily in saltiness and the appearance of a bitter taste, that were in accordance with reports by *Ruusunen & Poulanne* (2005), *Desmond* (2006), and *Petracci et al.* (2013).

The sodium and potassium contents and their ratios in the grilled chicken thighs are presented in Table 3. The highest sodium content was determined in the control group, corresponding to the highest amount of added NaCl, while the lowest was found in experimental groups 2 and 4, in which the amount of NaCl was half that of the control.

The highest potassium content was found in group 3, in which 50% of the NaCl was replaced with KCl, followed by group 2, in which one-third of the NaCl was replaced with KCl. The sodium-to-potassium ratio was the highest in the control chicken thighs and the lowest in group 2 chicken thighs.

The recommended daily intake of sodium (*Dietary Guidelines for Americans*, 2005) is 2,300 mg. The recommended dietary intake of potassium is 4,700 mg per day for adolescents, 3,000 mg per day for children aged 1–3 years, 3,800 mg per day for children aged 4–8 years, and 4,500 mg per day

Table 3. Sodium and potassium content and the sodium/potassium ratio in grilled chicken thighs after marination

Group	Sodium, mg/100 g	Potassium, mg/100 g	Sodium/Potassium Ratio
C	1820	440	4.14
1	1190	430	2.77
2	1067	800	1.33
3	960	1150	0.83
4	960	890	1.07

for children aged 9–13 years. The optimal sodium-to-potassium ratio for healthy adults is 0.49, along with a recommendation to consume fruits and vegetables rich in potassium. In this study, the best sodium-to-potassium ratio was achieved in the chicken thighs in which 50% of the NaCl was replaced with KCl, but even this ratio was still considerably higher than the recommended ratio. A slightly higher ratio was observed in the chicken thighs from the other experimental groups, corresponding to the amount of added NaCl.

4. Conclusion

Reducing the salt content in the marinade by replacing NaCl with KCl did not affect the colour or consistency of marinated, grilled chicken thighs. Although differences were observed among the examined groups in terms of saltiness intensity, saltiness acceptability, and the occurrence of a bitter taste, all chicken thighs were nevertheless considered acceptable with regard to their sensory properties. The sensory evaluation scores for overall acceptability were very similar to those for saltiness acceptability, and no statistically significant differences were observed among the mean scores of the control and experimental groups 1, 2, and 4. In contrast, the mean overall acceptability score of the group 3 chicken thighs was significantly lower than those of the control and experimental groups 1 and 2, as well as lower than that of experimental group 4.

The production of marinated chicken thighs with reduced NaCl/sodium content, and without significant sensory changes, is possible by reducing the amount of NaCl added as well as by partially replacing some of the NaCl with KCl, achieving more favourable sodium-potassium ratios according to health recommendations.

Mogućnost redukcije sadržaja soli u mariniranom pilećem mesu

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INFORMACIJE O RADU

Ključne reči:
Pileći batak
Marinada
Redukcija sadržaja soli

APSTRAKT

U ovoj studiji ispitivana je mogućnost smanjenja sadržaja natrijum-hlorida (NaCl) i njegove delimične zamene kalijum-hloridom (KCl) u mariniranim pilećim batacima sa karabatakom. Analizirane su senzorne osobine, kao i sadržaj natrijuma i odnos natrijuma i kalijuma. Senzorna ocena izvršena je od strane deset obučenih ocenjivača primenom numeričko-deskriptivnih skala. U kontrolnoj grupi u marinadu je dodato 20 g NaCl po kilogramu mesa, dok je u prvoj eksperimentalnoj grupi količina NaCl smanjena za 25%. U drugoj grupi jedna trećina natrijum-hlorida zamenjena je kalijum-hloridom, a u trećoj grupi jedna polovina (u oba slučaja u odnosu na kontrolnu grupu). U četvrtoj grupi jedna trećina natrijum-hlorida zamenjena je kalijum-hloridom u odnosu na prvu grupu. Intenzitet slanosti bio je statistički značajno niži ($p < 0,1$) kod uzoraka četvrte eksperimentalne grupe u odnosu na kontrolnu, prvu i drugu grupu. Ocena ukupne prihvatljivosti uzoraka iz treće eksperimentalne grupe bila je niža od ocena kontrolne, prve i druge grupe ($p < 0,01$), kao i od ocene četvrte grupe ($p < 0,05$).

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