THE INFLUENCE OF POTASSIUM CHLORIDE AND MAGNESIUM CHLORIDE ON THE COLOR AND SENSORY PROPERTIES OF COOKED CHEESE

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ABSTRACT:

The aim of this paper is focused on reducing sodium chloride content by partial replacement with potassium chloride and magnesium chloride in cooked cheese samples. For the production of cheese, standardized cow's milk from a domestic market producer was used, and the cheese was produced by heating the milk to a temperature of 95°C and coagulation with acetic acid. The one salted only with NaCl was designated as the standard sample, and the other samples were salted with combinations of salts in which NaCl reduction was performed: sample A1 had a ratio of 15% KCl:85% NaCl, sample A2 30% KCl:70% NaCl, sample B1 15% $MgCl_2$:85% NaCl and sample B2 30% $MgCl_2$:70% NaCl. The cheese samples were stored at + 4°C and color parameters and sensory properties were analyzed on the 1st, 3rd and 5th days of storage. Based on the performed analyses, it was concluded that it is completely acceptable to replace sodium chloride with potassium chloride in the ratio of 15% KCl:85% NaCl. It is acceptable to replace sodium chloride with potassium chloride in the ratio of 30% KCl:70% NaCl, with the note that on the 5th day of storage there is a gradual deterioration of the sensory properties compared to the samples analyzed on the 1st day of storage. Replacement of sodium chloride with magnesium chloride in the ratios 15% MgCl2:85% NaCl and 30% MgCl2:70% NaCl is not acceptable. As such, it is not recommended in the production of cooked cheeses due to the appearance of a metallic and bitter taste that is present in cheese samples from the 1st to the 5th day of storage.

KEYWORDS: cooked cheese, sodium chloride, potassium chloride, magnesium chloride

INTRODUCTION

Nowadays, cheese is a premium dairy product consumed by all age groups around the world. The cheese market is one of the most dynamic within the dairy sector over 22,17 million megatons of cheese produced in 2022., which corresponds to one third of cow's milk production [1]. Cheese is a dairy product rich in nutrients such as proteins, peptides, fatty acids, vitamins and essential minerals such as calcium. Since it is very nutritious, it has a long history in human nutrition. The high content of fat and protein makes cheese an energy-rich and nutritious food for all age groups [2]. Homemade cooked cow's milk cheese is a representative of traditional cheesemaking and is widely represented in Bosnia and Herzegovina and has the characteristics of a traditional specialty due to the long-standing method of production and traditional composition [3]. It is produced by heating milk to a temperature of 90°C to 95°C, and by directly acidifying it with acid. The obtained curd is salted, placed in molds and pressed. This type of cheese can be consumed immediately after production or for a longer storage period [4]. The addition of salt to cheese is of great importance; in addition to the taste and smell, salt affects the ripening process, reduces the amount of water, increases the durability of the cheese and participates in the formation of the cheese rind [5].

Table salt is the most common ingredient responsible for the salty taste of food; it is the only substance that gives a clean, salty taste. The perception of salty taste is influenced by age, gender, genetics, weight or smoking habit, as well as taking medications. During the aging of the organism, there is a decrease in the response of receptors for salty taste [6]. Sodium is an essential mineral needed in human nutrition. The European Food Safety Agency (EFSA) has established a sodium intake of 2 g/day (corresponding to a salt intake of 5 g/day) for the adult population in Europe [7]. In practice, long-term salt consumption of more than 5 g/day for an adult has a negative effect because it affects the cardiovascular system and increases the risk of hypertension, heart

disease and stroke [8, 9]. High daily salt intake in some countries, 12–16 g/day [10] or 6.8–10.7 g/100 g, which was determined on the basis of urinary excretion [11], causes kidney diseases, and indirectly affects the incidence of stomach cancer [12, 13]. There is strong evidence of a causal relationship between high salt intake and high blood pressure and stroke risk in humans and animals [14, 15]. In contrast, increased potassium intake protects against stroke, high blood pressure, heart problems and kidney failure. Additional use of potassium chloride with partial replacement with sodium chloride could help to reduce the sodium content [16].In blood pressure control, potassium plays an important role as well as sodium, and the balance of these two elements is important. However, the use of potassium chloride is generally limited due to its bitter taste [17, 15]. Magnesium lowers blood pressure because it causes a decrease in intracellular sodium and calcium content. As a natural calcium channel blocker, magnesium blocks sodium binding to vascular smooth muscle cells, increases prostaglandin vasodilation, cooperatively binds potassium, increases nitric oxide, causes vasodilation and lowers blood pressure [16, 15].

Health protection organizations driven by raised awareness of public change and consumer associations recognize a unique strategy for reducing salt in food as a preventive measure, which can be linked to initiatives on the consumption of saturated fat and sugar [18]. The World Health Organization (WHO) has set a global goal of reducing sodium chloride intake by 30% by 2025. [19, 20].

Over the past two decades, research dealing with the reduction of sodium content in cheese has intensified and now represents a multidisciplinary approach to reducing sodium content without compromising the quality and safety of cheeses [21]. In addition to reducing the mass fraction of sodium chloride that is added to the product, there are other approaches to reducing table salt, such as the use of substitutes for sodium chloride (potassium chloride, magnesium chloride, monosodium glutamate, potassium lactate, calcium lactate and monobasic potassium phosphate), the addition of improvers flavors or the use of microparticles of table salt crystals [22, 23].

MATERIAL AND METHODS

In this research work, a partial replacement of sodium chloride with potassium chloride and magnesium chloride was performed in samples of cooked cheese. After production, cheese samples were stored at +4°C for five days. On the first, third and fifth days of storage, sensory analysis and instrumental measurement of color parameters were performed on the samples.

For the production of cheese, cow's milk standardized on milk fat content from a domestic market producer was used, with the following composition that was printed on the declaration: fat 2.8%, proteins 3.4%, carbohydrates 4.6%, salt (from naturally occurring sodium) 0.1%, calcium 120 mg/100 ml. For the production of cheese, the milk was heated to a temperature of 95°C, and the coagulation of the milk was performed with 80% acetic acid in the amount of 0.2%. After forming the curds, the curds were left to rest for about 15 minutes and then transferred to a cheesecloth strainer to drain. After extracting the whey, the curd is salted with table salt or a combination of salts in the amount of 2%. The one salted only with NaCl was designated as the standard sample, and the other samples were salted with combinations of salts, whereby the reduction of NaCl with KCl and $MgCl_2$ was performed as followed: sample A1 15% KCl:85% NaCl, sample A2 30% KCl:70% NaCl, sample B1 15% $MgCl_2$:85% NaCl and sample B2 30% $MgCl_2$:70% NaCl.

Then each sample was transferred to a mold, where additional whey draining was performed under load for 6 hours, and then the cheese was removed from the mold and packed in plastic bags and stored at +4°C.

Instrumental color measurement was performed with a colorimeter LCC-A11 (LABTRON, United Kingdom). The spectrophotometer is equipped with a standard D65 light source and a standard 10° refraction shield. The instrument was calibrated using a white calibration plate. Instrumental color parameters were measured according to the CIE L*, a*, b* system. L* represents the light intensity and ranges from black (0) to white (100). a* indicates red (+ a*) when positive and green (-a*) when negative, while b* indicates yellow (+a*) when positive and blue (-a*) when negative.

Sensory analysis of cheeses was performed by a three-member Commission for Sensory Evaluation at the Biotechnical Faculty of the University of Bihać according to FIL-IDF Standard [24]. The following sensory properties were evaluated: external appearance (max. 2 points), color (max. 2 points), consistency (max. 2 points), cut surface (max. 2 points), smell (max. 2 points), taste (max. 10 points).

The obtained results were analyzed using appropriate mathematical and statistical methods, and the significance of the obtained differences was evaluated. All results are presented as mean of replicates ± standard deviation. In the analysis, the method of analysis of variance with two factors of variability

(ANOVA) with a significance level of 5% was applied, where factor A is the time interval of storage, and factor B is the type of sample.

RESULTS AND DISCUSSION

Table 1. shows the results of instrumental measurement of color parameters on the surface of cheeses.

Table 1. Results of instrumental color measurement (L*, a* and b*)

Day 1			
Sample	L*	a*	b*
Standard	93.52±0.513	0.21±0.415	10.12±0.248
A1	93.34±1.311	0.14±0.398	11.22±0.915
A2	93.44±1.418	0.06±0.916	11.57±0.547
B1	94.76±0.842	0.62±0.383	10.89±0.801
B2	90.08±0.962	-0.63±0.307	2.55±0.903
Day 3			
Sample	L*	a*	b*
Standard	99.87±0.894	4.72±1.715	7.07±0.428
A1	99.72±±0.835	4.93±0.994	6.70±01.934
A2	93.30±±0.486	-0.25±0.275	10.61±00.477
B1	94.23±0.368	0.23±0.305	10.35±00.185
B2	94.53±0.379	-0.45±0.186	9.64±0.346
Day 5			
Sample	L*	a*	b*
Standard	91.77±1.114	-0.30±0.516	12.14±0.577
A1	92.02±0.981	-0.12±0.439	12.47±0.511
A2	92.98±0.599	-0.85±0.268	11.85±0.486
B1	93.57±2.074	-0.60±0.715	10.62±0.544
B2	93.85±±0.768	-0.94±0.445	10.50±0.652
p	p_A=0.0807 p_B=0.695	p_A=0.07872 p_B=0.2615	p_A=0.2571 p_B=0.2571

A1- replacement of NaCl with KCl 15% , A2 – replacement of Na Cl with KCl 30%,
B1 – replacement of NaCl with $MgCl_2$ 15%, B2 – replacement of NaCl with $MgCl_2$ 30%,
results are shown as medium value ±standard deviation of five consecutive measurements

The surfaces of all samples are light in color (L*=100 completely light). The lowest L* value was recorded for sample B2 on the 1st day of storage 90.08, and the highest brightness value was determined for the standard sample on the 3rd day of storage 99.87. For the 3rd day of storage, the measured valuesof brightness L* were higher in all samples compared to the 1st and 5th days of storage, but the analysis of variance with two variability factors for the color parameter L* did not reveal a statistically significant difference ($p>0.05$) between samples for factor A and factor B.

The a* parameter indicates the range of colors from green (-a*) to red (+a*). On the 1st day of storage, all samples except sample B2 had positive valuesof the parameter a*, which means that the surface of sample B2 has a green tone, and the surfaces of the other cheeses have a red tone. For the 3rd day of storage, samples A2 and B2 had negative values, and the surfaces of the cheeses of these samples had a green tone, and the surfaces of the other samples had a red tone. On the 5th day of storage, all cheese samples had negative values for the parameter a*, which means that the surfaces of all cheese samples had a green tone. For the parameter a*, no statistically significant difference was found between the samples ($p>0.05$) in relation to factor A and factor B. Samples in which there were larger amounts of replacement salt yield cheeses with a more pronounced green tone, whereby the replacement of NaCl with 30% should be singled out $MgCl_2$ because the green tone of the surface in cheeses with this replacement amount of salt was present from the 1st to the 5th day of storage (the a* parameter was on the 1st day of storage -0.63; on the 3rd day -0.45 and on the 5th day of storage -0.94).

The b* parameter indicates the range of colors from yellow (+b*) to blue (-b*). The b* values are positive and all samples have a yellow tone, which is

one of the important characteristics of cooked cheeses. Sample A2 on the 1st day of storage had the highest b* value 11.57, and sample B2 had the lowest b* value 2.55. On the 3rd day of storage, sample A2 had the highest value for b* 10.61, and sample A1 had the lowest value 6.70. On the 5th day of storage, sample A1 had the highest b* value of 12.47, and sample B2 had the lowest value of 10.50. No statistically significant difference was found for the parameter b* ($p>0.05$) in relation to A and factor B. Sample A2, where NaCl was replaced by KCl 30%, should be singled out because it had the highest measured valuesof b* for the 1st and 3rd day of storage, and in these samples the surface had a more pronounced yellow tone. In sample B2, where NaCl was replaced by $MgCl_2$ 30%, smaller values were recorded for the parameter b*.

Table 2. Results of the cheese samples sensory analysis

Sample	External appearance	Color	Consistency	Cut surface	Smell	Taste	Total
Day 1							
Standard	1.87±0.06	1.93±0.12	1.87±0.06	1.93±0.12	1.90±0.10	9.63±0.55	19.30±0.44
A1	1.83±0.06	1.97±0.06	1.83±0.12	1.83±0.15	1.93±0.06	9.63±0.15	19.43±0.42
A2	1.83±0.06	1.83±0.15	1,80±0.17	1.77±0.21	1.97±0.06	9.63±0.21	18.83±0.40
B1	1.80±0.10	1.83±0.06	1.77±0.12	1.80±0.17	1.83±±0.12	9.47±0.49	18.50±0.70
B2	1.97±0.06	1.97±0.06	1.90±0.10	1.90±0.10	1.97±0.06	8.77±1.08	18.47±1.36
Day 3							
Standard	1.87±0.577	1.90±0.10	1.97±0.06	1.93±0.06	1.93±0.06	9.90±0.10	19.50±0.17
A1	1.93±0.06	1.97±0.06	1.87±0.15	1.83±0.06	1.97±0.06	9.83±0.06	19.40±0.20
A2	1.87±0.15	1.83±0.15	1,83±0.06	1.80±0.10	1.90±0.10	8.03±1.00	17.27±1.43
B1	1.83±0.15	1.83±0.12	1.70±0.10	1.77±0.12	1.83±±0.15	8.00±1.20	16.97±1.76
B2	1.93±0.12	1.83±0.06	1.80±0.10	1.87±0.15	1.80±0.10	8.40±0.36	17.70±0.56
Day 5							
Standard	1.87±0.06	1.87±0.06	1.83±0.06	1.83±0.06	1.87±0.05	9.80±0.10	19.07±0.25
A1	1.80±0.10	1.80±0.10	1.73±0.12	1.87±0.06	1.93±0.06	9.83±0.21	19.00±0.30
A2	1.70±0.10	1.70±0.10	1,90±0.10	1.63±0.12	1.70±0.10	7.40±1.02	16.07±1.20
B1	1.67±0.06	1.67±0.06	1.60±0.10	1.53±0.12	1.80±±0.17	7.70±1.25	16.03±1.32
B2	1.80±0.10	1.80±0.06	1.73±0.06	1.83±0.05	1.80±0.10	8.50±0.46	17.47±0.58
p	p_A=0.06558 p_B=0.5031	p_A=0.00214 p_B=0.01071	p_A=0.1803 p_B=0.05631	p_A=0.05186 p_B=0.02182	p_A=0.1155 p_B=0.2914	p_A=0.1649 p_B=0.03454	p_A=0.02131 p_B=0.00554

A1- replacement of NaCl with KCl 15%, A2 –replacement of Na Cl with KCl 30%, B1 – replacement of NaCl with $MgCl_2$ 15%, B2 –replacement of NaCl with $MgCl_2$ 30%, results were shown as medium value ± standard deviation for three ratings

In general, cooked cheeses have a homogeneous and pliable dough, without sticking to the blade of a knife, with a specific milky sweet-sour taste combination [25]. Cooked cheeses obtained by coagulation of milk with acetic acid have a good cutting ability, a characteristic pale yellow color, a moderately salty taste and a pleasant aroma [3].

According to the results of the sensory analysis shown in Table 2., on the 1st day of storage, sample A2 had the highest total number of points 19.43, and sample B2 had the lowest number of points 18.47. The evaluators noted that sample A1 had a fairly uniform structure compared to other cheese samples. For the property external appearance, sample B2 was rated best 1.97, and sample B achieved the lowest number of points 1.80. For the color property, samples A1 and B2 had equal numbers of points 1.97, while the lowest number of points was recorded for samples A2 and B1 1.83. On the first day of storage, sample B2 had the best consistency 1.90, and sample B1 achieved the lowest number of points for consistency 1.77. The evaluators noted that sample B2 has a compact dough and does not crumble when cut. For the property of cut surface, the standard sample achieved the highest number of points 1.93, and sample A2 the lowest number of points 1.77. Samples A2 and B2 had the highest number of points for the smell on the first day of storage 1.97, and sample B had the lowest number of points 1.83. On the first day of storage, the highest number of points for taste was recorded for samples standard, A1 and A2 9.63, and the lowest number of points for taste was achieved by sample B2 8.77. The evaluators found that the standard sample had a more pronounced salty taste compared to the other samples.

For sample B2 (replacement of NaCl with $MgCl_2$ 30%), the evaluators found a metallic taste that became more intense during chewing of the sample.

By sensory analysis of the samples on the 3rd day of storage, the highest total number of points was recorded for the standard sample 19.50, and the lowest for B1 16.97. For the standard sample, a slightly higher feeling of saltiness was found compared to the other samples. For the property external appearance, samples A1 and B2 were rated best 1.93 points, and sample B1 achieved the lowest number of points 1.83 . For the color property, sample A1 was the best rated 1.97, and samples A2, B1 and B2 had the lowest number of points 1.83. The standard sample had the best consistency 1.97, and sample B1 achieved the lowest number of points for consistency 1.70. The standard sample had the best cut surface 1.93, and sample B1 had the lowest score 1.77, because the evaluators noticed that the cheese dough crumbles when cutting this sample. The highest number of points for smell was achieved by sample A1 1.97, while the evaluators noted that the standard and A1 retained a fresh smell, and sample B2 had the lowest number of points 1.80. The standard achieved the highest number of points for taste 9.90, while sample B1 had the lowest number of points 8.00. Samples of cheeses where NaCl was replaced with $MgCl_2$ had a more pronounced bitterness and metallic taste compared to the standard.

By sensory analysis of samples on the 5th day of storage, the highest total number of points was recorded for the standard 19.07, followed by sample A1 19.00. Comparing the total number of points on the 5th day of storage in relation to the total number of points recorded for the 1st and 3rd day of storage, the standard and sample A1 were uniformly rated high by the evaluators. In the case of other samples, a trend of reduction in the total number of points was observed for the 5th day of storage compared to the 1st and 3rd days. For the attribute external appearance, the standard was rated best 1.87, and sample B1 achieved the lowest number of points 1.67. The standard had the best score for color 1.87, and sample B1 had the lowest number of points 1.67. Sample A2 had the highest number of points for consistency 1.90, and B1 had the lowest number of points 1.60. For the property of cut surface, sample A1 had the highest number of points 1.87, and sample B1 had the lowest number of points 1.53. Sample A1 had the best score for smell 1.93 points, and sample A2 had the worst score 1.70) Sample A1 and standard had the best taste scores 9.83 and 9.80, and sample A2 scored the lowest number of points 7.40. According to the results of the analysis of variance, no statistically significant difference was found between the samples ($p>0.05$) for external appearance, consistency and smell in relation to factor A and factor B. For cut surface and taste, in relation to factor A (storage time interval) no statistically significant difference ($p>0.05$) was found between the samples, while a statistically significant difference ($p<0.05$) was found for factor B (type of sample). A statistically significant difference ($p<0.05$) was found between the samples in relation to factor A and factor B for color variations, as well as for the overall impression.

Replacement of sodium chloride with compounds of high molecular weight gives sour taste and less saltiness of cheeses [26]. If the replacement of sodium chloride with potassium chloride is more than 50%, then it negatively affects the sensory properties of cheeses, but it is still the best alternative for the substitution of sodium chloride due to the similarity in the chemical structure of KCl and NaCl [27].

Like potassium chloride, salts such as magnesium chloride in combination with sodium chloride cause less salty taste, and increased bitterness of food products to which they are added, creating a metallic taste. In a cheddar cheese production experiment with complete or partial replacement (1:1) of NaCl with $MgCl_2$, $CaCl_2$ and KCl, and after 4 months of ripening at 4°C cheeses in which NaCl was completely replaced with alternative salts were extremely bitter and completely unacceptable, and cheeses with $MgCl_2$ and $CaCl_2$ had the worst firmness, hardness and extensibility. Cheese salted with a combination of NaCl and KCl salts was the only acceptable one and did not differ much from the control cheese sample [28].

Grummer et al. [29] used sodium chloride and sea salt in combination with potassium chloride, modified potassium chloride, magnesium chloride or calcium chloride in the production of cheddar cheeses. Cheeses with calcium chloride and magnesium correlated positively with bitter, metallic, earthy, soapy, impure taste, and negatively with cooked and milky taste. Cheeses that were salted with combinations of NaCl:$MgCl_2$ (1:1) or NaCl:$CaCl_2$ (1:1) had a bitter and metallic taste, and the conclusion is that the use of calcium chloride and magnesium chloride for salted cheeses results in differences in taste that are unacceptable for quality cheese. For cream cheese in which during production sodium chloride was replaced with potassium chloride and magnesium chloride [22], during the sensory evaluation it was determined that in the standard sample (cheese salted only with sodium chloride) the dominant taste is saltiness. In samples where sodium chloride was replaced with magnesium chloride, a significant salty

taste lasted approximately nine seconds. After that, the bitter taste prevailed until the end of the analysis; the taste is also characterized as undesirable and more intense than the bitter taste of potassium chloride.

During the production of Minas fresh cheese [30], sodium chloride was replaced with potassium chloride in the following concentrations: 0, 25, 50 and 75%. The control sample with 0% KCl achieved the highest number of points for all evaluated sensory parameters. Samples with 50% and 75% KCl achieved a lower number of points for taste and texture, which is related to the concentration of potassium chloride, because the perception of bitter taste occurs. Sodium chloride can mask the resulting unpleasant aroma as long as potassium chloride is present in smaller concentrations. The conclusion is that potassium chloride can be a successful replacement for sodium chloride in the production of cheeses with a reduced level of taste and smell, such as fresh cheese that has a shelf life of up to 20 days.

CONCLUSION

According to the results of measuring the color parameter L*, the surfaces of the cheese samples are light in color. By measuring the color parameter a*, samples in which higher concentrations of substitute salts were used result in the color of cheeses with a more pronounced green surface tone, while the sample in which sodium chloride was replaced with magnesium chloride in the amount of 30% should be singled out. The replacement of sodium chloride with potassium chloride in the amount of 30% results in the color of cheeses with a more intense yellow tone of the surface, as shown by the results for the color parameter b*. If sodium chloride is replaced with magnesium chloride in the amount of 30%, the color of the surface of the cheese is lighter, pale yellow.

Samples of cheeses in which sodium chloride is partially replaced by magnesium chloride have generally worse sensory properties compared to the standard sample and samples in which sodium chloride is partially replaced by potassium chloride, especially in terms of taste. It is completely acceptable to replace sodium chloride with potassium chloride in the amount of 15%, because the quality of the samples is uniform during the observed storage period. It is also acceptable to replace sodium chloride with potassium chloride in the amount of 30%, with a note that during storage, the quality of the cheese gradually decreases, which is indicated by a decrease in the total number of points. If there is a greater replacement amount of magnesium chloride salt present in the cheese, the metallic taste and bitterness are more pronounced, which become more pronounced starting from the 1st to the 5th day of storage.

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