Effects of Partial Replacement of Sodium Chloride by Potassium Chloride on Rheological, Sensory, Qualitative and Microbial Characteristics of Baguettes

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ABSTRACT: *The current study aimed to investigate the effects of partial replacement of sodium chloride by potassium chloride on the rheological, sensory, qualitative, and microbial characteristics of baguettes. Replacement of sodium chloride by potassium chloride in null flour at 0% potassium chloride (control group, 100% sodium chloride), Treatment 1 (75% sodium chloride and 25% potassium chloride), Treatment 2 (50% sodium chloride and 50% potassium chloride), Treatment 3 (75% sodium chloride and 25% potassium chloride) and Treatment 4 (100% potassium chloride) was studied in baguettes. Results of the microbial count of flour showed that Treatment 2 included the highest yeast number of Saccharomyces cerevisiae. Investigation of rheological characteristics of dough using farinograph and extensograph devices showed significant differences in experimental treatments ($p \leq 0.05$) that Treatment 2 showed better conditions than other experimental treatments. Assessment of the sensory characteristics of baguettes demonstrated the efficacy of Treatment 2 in treatments and significant differences were observed in porosity, texture, and taste of bread ($p \leq 0.05$). Therefore, it seems possible to produce bread with fewer levels of sodium chloride and partly substitute them with potassium chloride with no significant effects on the quality of bread. In conclusion, a replacement level of 50% potassium chloride with 50% sodium chloride is suggested to produce baguettes of good quality.*

KEYWORDS: *Baguette; potassium chloride; sodium chloride; rheological characteristics; flour microbial test; sensory evaluation*

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INTRODUCTION

Urban spread and fast-growing industries have led to the shifting of traditional diets to diet patterns, including meats, eggs, cheeses, bread, salts, oils, and sweets [1]. Typically, such changes in nutritional patterns lead to increases in the consumption of fats, animal proteins, sugars, and salts and decreases in the consumption of plant proteins, fibers, and complex carbohydrates [2]. Accordingly, these changes in diets lead to changes in disease patterns and death [3]. Consumption of table salt (sodium chloride) has increased significantly over the past few decades due to dietary changes [3]. Bread is one of the major sources of salt, which is responsible for 30% of the daily intake of salt [4–6]. Studies on the consumption of salt, using bread in various countries, have shown that in Ireland, 25.9% [7]; in Turkey, 25.5% [4]; in Belgium, 24.8% [8]; in France, 24.2% [9]; in England, 19% [10] and in Argentina, 25% [11] of necessary salt are received through bread consumption.

Sodium plays a vital role in the body as well as its important role in regulating fluid and blood pressure as high salt consumption can cause water retention, edema, and hypertension [12]. Intake of high quantities of salt (high sodium) increases urinary calcium excretion, which consequently increases the body's need for calcium [13]. Recently, studies have been carried out on the effects of partial replacement of bread sodium chloride by various salts on the rheological, physical, sensory, and microbial characteristics of bread as well as their storage time, consumer acceptance, and health promotion [5, 14–16]. In foods, particularly bread, one of the major substitutes for salt is potassium chloride (KCl). Potassium chloride in fermented products not only prevents the growth of harmful microorganisms but also affects the product's taste since the chemical produces flavors similar to those of sodium chloride at low concentrations [3, 16]. Low concentrations of potassium are associated with high blood pressure and in most people, sodium restriction does not merely improve blood pressure control but should be accompanied by high levels of potassium. Medical experts in the United States have shown that the consumption of potassium-rich foods decreases the risks of stroke and heart disease [17]. Industrial bulk bread includes a little waste, compared to other bread. Because of the high quality of baking, a wide variety of products, and the perfect fermentation stage including proper food situations. Furthermore, the baguette is one of the most important widely-used industrial bread in the world [18].

Table1 - Features of null flour used in this study

Features of Null Flour	amount
Moisture (%)	87±2
Ash (%)	0.6±0.1
Falling Number (s)	300-350
Zeleny (mm)	19±0.5
pH	5.6±0.1

This study aimed to investigate the partial replacement of potassium chloride with sodium chloride in baguettes to decrease sodium and increase potassium by preserving and improving the qualitative characteristics of these high-consumption industrial bread.

EXPERIMENTAL SECTION

Physical and chemical tests of flour

Null flour was purchased from Zar Industrial Flour Company, Karaj, Iran. Iodized sodium chloride was purchased from Hadie, Iran. Before the production of baguettes, characteristics of moisture, ash, Zeleny, falling number, and pH of the flour were assessed (Table 1) [19].

Effects of replacing sodium chloride with potassium chloride in null flour of baguette were studied at 0% level (control group, 100% sodium chloride), Treatment 1 (25% potassium chloride and 75% sodium chloride), Treatment 2 (50% potassium chloride and 50% sodium chloride), Treatment 3 (75% potassium chloride and 25% sodium chloride) and Treatment 4 (100% potassium chloride). After treatments, the characteristics of wet gluten, gluten index, and particle size index of null flour were assessed [19].

Flour microbial test

Cell Count of Saccharomyces cerevisiae

Briefly, 10 g of the flour sample was added to YGC agar media (Merck, Germany) in plates and then peptone water diluent solution was added to the plates. Plates were stored at 25 °C for five days under aerobic conditions. Then, a number of *Saccharomyces cerevisiae* yeast was counted using a light microscope (E100, Nikon, Japan) and reported as the cell count in 1 g (AACC, 2000).

Dough Preparation and Bulk Bread Production

The bread was produced using the direct dough method. First, all bread ingredients, including null flour, *S. cerevisiae*, water, and sodium chloride, or a mixture of sodium chloride and potassium chloride, were mixed in a dough mixer based on the highlighted treatments. The mixing step was carried out at two speeds a slow speed of 90 rpm for 5 min and a fast speed of 180 rpm for 5 min. Water and dough temperatures were 10 and 28 °C, respectively. The dough was divided into several sections and molded into special molds. Then, the initial fermentation was carried out at 32 °C for 8 h at relative humidity of 80%. After this time, the volume of the dough reached twice its initial volume. Before molding, the dough rested for 20 min. After fermentation, the dough surface was cut and baking was carried out using a baking oven with a steam injection system at 220 °C for 10 min. Then, the baked bread was cooled down at room temperature [16].

Dough rheology tests

Dough rheology tests were carried out using farinograph and extensograph devices (Brabender, Duisburg, Germany), demonstrating the characteristics and durability of dough against mixing and tension stresses and clarifying the technological characteristics of dough. Farinograph device was used to study dough characteristics such as water absorption, resistance, stability, and consistency. In addition, extensograph device was used to assess the ability of dough extension due to the force of tearing, resistance to extension, the ratio of these two parameters against each other, and fermentation effects on these parameters. The assessments were carried out using AACC method [19].

Bread sensory tests

Sensory evaluation of bread was carried out based on AACC standard no. A50-33 [19]. Physical bread characteristics such as shape, volume, crust color, cooking attributes, crust attributes, cracking, and fracture were assessed as well as bread internal characteristics such as (crumb) color, aroma, texture, and porosity [14]. The quality of fresh bread was assessed by ten experienced panelists (five males and five females with an average age of 35–45) using a 5-point hedonic scale method (max score: 5; min score: 0) for the shape, upper and lower surface characteristics, porosity, chewiness, stiffness, and softness of the texture, taste and overall acceptance [20].

Methods and tools for data analysis

To analyze the results, a completely randomized plan was used. Data analysis was carried out using analysis of variance and comparison of the mean of data with Duncan’s test at a probability of 5%. All tests were carried out three times and analyzed using SPSS Software v.20 (IBM Analytics, USA).

RESULTS AND DISCUSSION

Gluten index by mechanical method

Significant differences were seen in the gluten index of treatments ($p \leq 0.05$). The highest rates of this index were seen in the control group and Treatment 2 (50% potassium chloride and 50% sodium chloride) as 60.0 ±50.28. The lowest gluten index was observed in Treatment 4 (Table 2).

Measurement of the particle size

Results of the particle size measurement using a sifter with meshes of 106, 125, 150, and 180 µm are shown in Table 3.

Flour microbial test

The microbial count of flour showed that Treatment 4 (100% potassium chloride) included no *S. cerevisiae* in all dilutions. The number of yeasts was zero in all treatments with 0 and 10^{-6} dilutions. Moreover, Treatment 2 (50% potassium chloride and 50% sodium chloride) included the greatest quantity of yeasts in 10^{-1}, 10^{-2}, $10^{-3,}$ and 10^{-4} dilutions. The minimum quantity of yeasts was seen in Treatment 1 (25% potassium chloride and 75% sodium chloride) (Fig. 1).

Farinographic characteristics of dough

Results of the farinograph characteristics of bread containing various quantities of sodium chloride and potassium chloride are shown in Table 4. Investigation of water absorption levels of dough showed increases by substituting more potassium chloride with sodium chloride, except for Treatment 3 (75% potassium chloride and 25% sodium chloride). Although no significant differences were seen in treatments ($p > 0.05$), significant differences were observed in the quantity of dough development time in treatments ($p \leq 0.05$) the highest and the lowest dough development times were reported in the control group (1.0 ±6.21) and Treatment 4 (5.0 ±0.05), respectively. Dough stability in various treatments showed significant differences ($p \leq 0.05$) as Treatment 2 included utmost stability in treatments (10.0 ±30.26). Treatment 2 demonstrated the minimum level of softening in

Table 2: Results of flour gluten index (Mean ± Standard Error).

Treatment	Control	T_1	T_2	T_3	T_4
Gluten index	50.28^{a}±60.0	50.59^{ab}±57.2	50.28^{a}±60.0	50.44^{ab}±54.1	50.86^{b}±52.0

Different letters of each row are meaningful (P≤0.05)

Table 3: Results of flour particle size (Mean ± Standard Error).

Treatment	106 (μm)	125 (μm)	150 (μm)	180 (μm)
Particle size (%)	5.50	7.50	9	15

Table 4: Farinographic features of dough (Mean ±Standard deviation), Contains different amounts of sodium chloride and potassium chloride.

	Water absorption (%)	Dough development time (min)	Dough stability (min)	Degree of softening after 12 min (BU)	Farinograph quality number
Control (100% NaCl)	1.03±53.20^{a}	0.21±1.60^{c}	0.5±7.40^{b}	1.45±38.0^{c}	2.08±88.0^{b}
Treatment 1 (75% NaCl, 25% KCl)	1.72±54.0^{a}	0.47±4.0^{a}	0.29±7.0^{bc}	0.88±52.0^{a}	0.88±67.0^{c}
Treatment 2 (50% NaCl, 50% KCl)	0.75±54.4^{a}	0.32±4.0^{a}	0.26±10.3^{a}	0.57±28.0^{d}	0.57±92.0^{a}
Treatment 3 (25% NaCl, 75% KCl)	3.58±52.0^{a}	0.11±3.0^{b}	0.57±6.0^{c}	0.57±54.0^{a}	1.20±62.0^{d}
Treatment 4 (100% KCl)	0.81±55.0^{a}	0.05±5.0^{a}	0.15±6.10^{c}	0.88±55.0^{a}	0.57±57.0^{d}

Different letters in each column indicate significant differences among the Means at a time

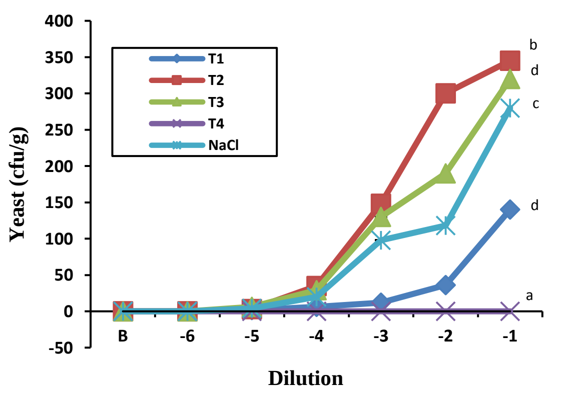

Fig. 1: Flour microbial count (Mean ±Standard deviation), different letters of each column are meaningful (P≤0.05).

treatments after 12 min (28.0 ±0.57), which included significant differences with other treatments ($p \leq 0.05$). The maximum quantity of this factor was reported in Treatment 4 (55.0 ±0.88), which showed no significant differences with Treatments 1 and 3 (p>0.05). Farinograph quality numbers in various treatments demonstrated significant differences within treatments ($p \leq 0.05$), which included the highest quantity in Treatment 2 (92.0 ±0.57).

Extensograph characteristics of dough

Dough energy

Significant differences were seen in energy levels within the treatments ($p \leq 0.05$). Within 45 min, the highest and the lowest levels of energy were seen in Treatment 3 (51.0 ±0.57) and the control group (63.0 ±10.20), respectively, with significant differences within the treatments ($p \leq 0.05$). Within 90 min, the lowest level of energy was observed in Treatment 3 (51.0 ±0.57) with no significant differences with Treatment 2 (54.0 ±1.85) ($p > 0.05$). In Treatments 3 and 4, energy was at the lowest level within 135 min with significant differences, compared to the control group and Treatments 1 and 2 ($p > 0.05$). Within 135 min, the highest level of energy was reported in the control group (64.0 ±20.02) with no significant differences with Treatment 2 (Fig. 2).

Resistance to extension

Significant differences were found in treatments by studying levels of resistance to extension ($p \leq 0.05$)

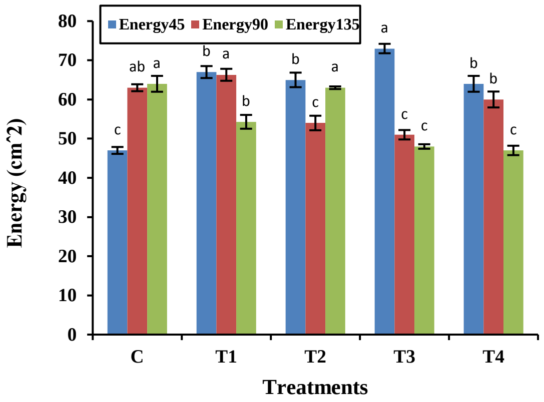

Fig. 2: Amount of energy at 45, 90, and 135 minutes in cm^2 (Mean ±Standard deviation); different letters in each column indicate significant differences (P ≤ 0.05).

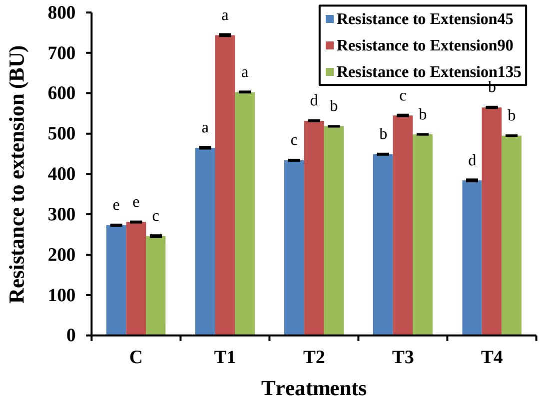

Fig. 3: Resistance to extension at 45, 90, and 135 minutes in BU (Mean ±Standard deviation); different letters in each column indicate significant differences (P ≤ 0.05).

ss the control group and Treatment 1 showed the lowest (47.0 ±0.88) and the highest (67.0 ±10.52) resistance levels to extension respectively within 45 min with significant differences within treatments ($p \leq 0.05$). The minimum resistance to extension was seen in the control group (281.0 ±1.20) within 90 min with significant differences from other treatments ($p \leq 0.05$). Within 135 min, resistance to extension included the lowest levels in Treatments 3 and 4 and the highest levels in Treatment 1 (603.0 ±0.15) (Fig. 3).

Dough extensibility

Significant differences were observed in dough extensibility within the treatments ($p \leq 0.05$). Within 45 min, dough extensibility showed the highest levels in Treatments 3 and 4 (123.0 ±10.52) with no significant differences from the control group (121.0 ±0.57) ($p > 0.05$). Within 90 min, the highest level of dough extensibility was observed in the control group (133.0 ±70.88) with significant differences with other treatments ($p \leq 0.05$). Moreover, the maximum level of dough extensibility was reported in the control group within 135 min (143.1 ±0.45) (Fig. 4).

Maximum dough resistance

The maximum dough resistance was seen in Treatment 1 within 45 min (485.70 ±4.20) (Fig. 5) with significant differences from other treatments ($p \leq 0.05$). No significant differences were recorded between the control group and Treatment 2 within 45 min ($p > 0.05$). The highest levels of dough resistance were seen in Treatments 1 and 2 within 90 min (754.70 ±1.52) while the lowest level was observed in the control group (344.70 ±1.73). Moreover, the maximum and the minimum dough resistances were observed in Treatment 1 (607.00 ±0.57) and 2 (322.30 ±1.45) respectively within 135 min.

Resistance index

Significant differences were reported between the resistance indices of the treatments ($p \leq 0.05$). Results showed the lowest value in the control group (2.00 ±0.08) and the highest one in Treatments 3 and 4 (3.00 ±0.17) within 45 min with significant differences in treatments ($p \leq 0.05$). Within 90 min, the minimum resistance index was observed in the control group (3.0 ±0.11). Within 135 min, the minimum and the maximum resistance indices were seen in the control group (2.0 ±0.12) and Treatment 2 (15.60 ±0.33), respectively (Fig. 6).

Extensograph quality index (quality number)

Significant differences were recorded between the treatments in extensograph quality number ($p \leq 0.05$). Extensograph quality number showed the lowest value in control group (3.0 ±0.05) within 45 min with no significant differences in Treatments 2, 3, and 4 ($p > 0.05$). Within 90 min, the minimum extensograph quality number was seen in the control group (2.0 ±0.16) with significant differences from other treatments ($p \leq 0.05$). Moreover, the maximum and the minimum extensograph quality numbers were respectively observed in Treatment 2 (55.40 ±0.88) and the control group (3.0 ±0.08) within 135 min (Fig. 7).

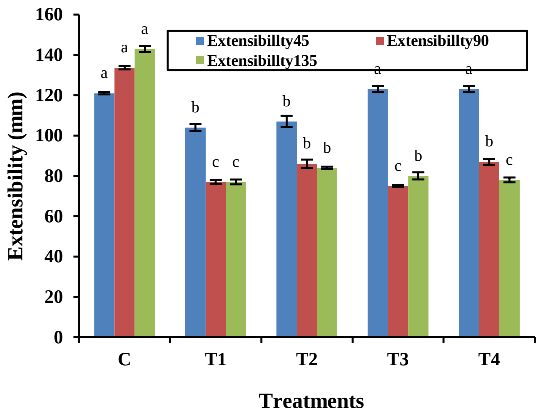

Fig. 4: Dough extensibility at 45, 90, and 135 minutes in mm (Mean±Standard deviation); different letters in each column indicate significant differences (P ≤ 0.05).

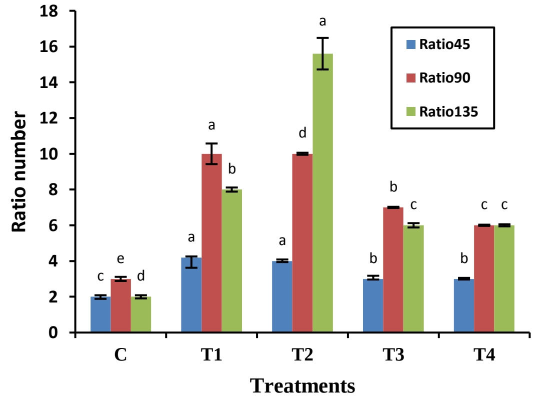

Fig. 6: Resistance index (Mean±Standard deviation); different letters in each column indicate significant differences (P ≤ 0.05).

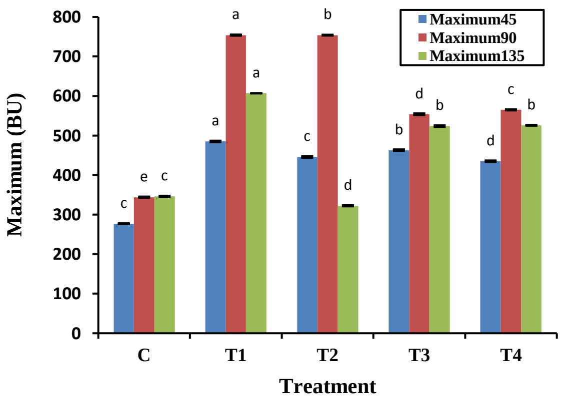

Fig. 5: Maximum dough resistance at 45, 90, and 135 minutes in BU (Mean±Standard deviation); different letters in each column indicate significant differences (P ≤ 0.05).

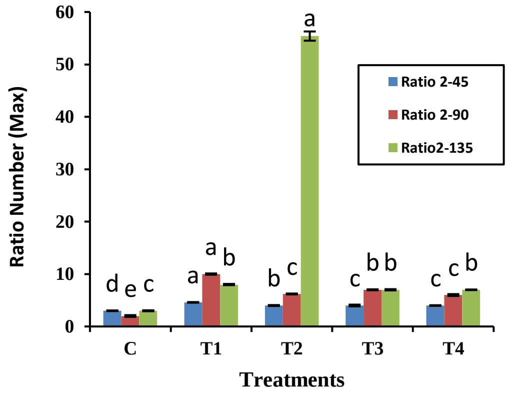

Fig. 7: Extensograph quality index (quality number) (Mean ±Standard deviation); different letters in each column indicate significant differences (P ≤ 0.05).

Sensory evaluation of bread

Results of the bread sensory evaluation are presented in Table 5. Investigation of the bread's physical shape demonstrated no significant differences between the treatments (p > 0.05). Although Treatment 2 included the most satisfaction among other treatments (3.0 ±85.08). No significant differences were reported in the bread volume of the treatments (p > 0.05). The maximum bread volume was reported in Treatment 2 (3.0 ±75.10). Although the best bread crust color was observed in Treatment 1 (4.0 ±0.05), no significant differences were seen in bread crust color in other treatments (p > 0.05). The highest and the lowest values of bread cracking and fracture were in Treatment 2 (4.0 ±0.0) and the control group (3.80 ±0.09), respectively. Bread texture colors were similar in the control group and Treatment 2 (4.0 ±0.0). Significant differences were seen in the smell of bread between Treatment 4 and other treatments (p ≤ 0.05) as Treatment 4 showed the least satisfaction with the bread smell (3.50 ±0.11). In addition, the least satisfaction with bread texture occurred in Treatment 4 (2.80 ±0.15). In this study, significant statistical differences were reported in the porosity of treatment bread (p ≤ 0.05). the lowest level of porosity was observed In Treatment 4, (2.45 ±0.21) with no significant differences with Treatment 3 (2.95 ±0.18). Investigation of bread taste showed various meanings within the treatments (p ≤ 0.05); however, no significant differences were shown in the control group and Treatments 1 and 2 (p > 0.05). Moreover, the least satisfying bread taste belonged to Treatment 4 (2.0 ±85.18).

Table 5: Sensory evaluation of bread (Mean ±Standard deviation); contains different amounts of sodium chloride and potassium chloride.

	Control	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Physical shape	0.08±3.85[a]	0.09±3.75[a]	0.08±3.85[a]	0.01±3.6[a]	0.06±3.9[a]
Bread volume	0.1±3.65[a]	0.09±3.75[a]	0.1±3.65[a]	0.09±3.8[a]	0.1±3.65[a]
Crust color	0.05±3.95[a]	0.05±4.0[a]	0.05±3.95[a]	0.05±3.95[a]	0.05±3.95[a]
Cracking & fracture	0.09±3.8[a]	0.08±3.85[a]	0.0±4.0[a]	0.05±3.95[a]	0.06±3.9[a]
Texture color	0.0±4.0[a]	0.08±3.85[a]	0.0±4.0[a]	0.09±3.8[a]	0.08±3.85[a]
smell	0.08±3.85[a]	0.05±3.95[a]	0.08±3.85[a]	0.08±3.85[a]	0.11±3.5[b]
Bread texture	0.1±3.7[a]	0.13±3.5[a]	0.1±3.7[a]	0.1±3.35[a]	0.15±2.8[b]
Porosity	0.18±3.5[a]	0.16±3.4[a]	0.18±3.5[a]	0.18±2.95[b]	0.21±2.45[b]
taste	0.0±4.0[a]	0.08±3.85[a]	0.05±3.95[a]	0.1±3.3[b]	0.18±2.85[c]

Different letters in each column indicate significant differences among the Means at a time

Discussion

Chemical and physical assessments of flour

Flour maintenance can be analyzed by assessing the content of the flour moisture. The moisture of less than 14% is better for flour maintenance [21]. Results of this study revealed that the flour moisture was less than 14%, showing longer flour maintenance. An assessment of the ash, the quantity was carried out to the refining mill. Indeed, the higher the quantity of ash in flour, the worse the cooking quality. Hence, the number of crusts increases. If the falling number is less than 150 s, flour produces sticky dough [21]. When the falling number ranges 200–250, the dough cannot bulk out perfectly and thus the color of the bread becomes light brown and the bread crust and surface become wrinkled and brittle, respectively [22]. In this study, the flour falling number ranged 300–350. A high Zeleny number indicates the strength of the flour. Zeleny number is a function of protein content and flour gluten quality. It means that the quantity of flour sediment is linked to the quantity of wet gluten; hence, the quality of gluten and the ability to bake flour can be recognized and the quantity is linked to the quantity and quality of gluten [23]. During the sedimentation assessment of flour, wheat flour mixed with lactic acid, alcohol, and color swelled and then precipitated. The more desirable the flour gluten, the greater the level of swelling and consequently the volume of sediment. In the assessment of Zeleny, sediment volumes of greater than 40 mm are good while those of less than 20 mm are inadequate. In the latter form, the dough becomes loose and moist because flour absorbs less water, which is not appropriate for machine bread production [21]. The results of this study on pH were similar to the results of *Gusmao et al.* [16] study on the replacement of potassium chloride with sodium chloride in French bread with pH in wheat flour included 5.66–5.86. Furthermore, pH value from this study was close to that of *Egan et al.* [24] study.

Gluten Index

Studies in several countries have shown that flours used to bake bread should include a gluten index of 60–90 [25]. A gluten index of greater than 95 shows strong gluten, while indices less than 60 demonstrate poor flour for bread production [26]. In the present study, the control group and Treatment 2, which included the gluten indices of 60.0 ±50.28, showed better conditions than those of the other treatments. Moreover, the minimum gluten index belonged to Treatment 4 (52.0 ±50.86).

Determination of particle size

The particle size of the flour in diameter is an important factor in the bread baking process [27]. *Sullivan et al.* [28] have argued that flour with various particle sizes includes various chemical compositions. The particle size of flour greatly affects water absorption during the mixing of water with flour. The smaller the flour particles are, the more water they absorb. If the flour particles are big, they are not well hydrated; hence, it causes spots in final products as well as releases large quantities of starches during cooking [29]. Furthermore, flour with a particle size of greater than 132 μm includes higher water absorption rates, compared with that with a particle size of greater than 85 µm with similar characteristics [30]. Sodium chloride is one of the major ingredients in baking bread, playing important microbiological qualitative roles in sensory evaluations [31]. Investigating the effects of sodium chloride on stable growth and metabolism of *S. cerevisiae*, *Watson* [32] showed that *S. cerevisiae* was able to grow in treatments containing sodium ions as well as those containing potassium ions (sodium ion-free). In a wheat-flour fermentation study, *Svec* and *Hruskova* [33] demonstrated that the purpose of fermentation in bakery industries was to increase dough volumes. In fact, the final volumes and specific bread structures depend on the volume of carbon dioxide produced by the yeasts, which is extremely effective in the quality of the final products. Based on *Beck et al.* [34] study on the effects of sodium chloride on wheat flour doughs, decreases in sodium chloride result in increases in bread volume. Studies have been carried out on the replacement of sodium chloride by potassium chloride in various industries as partial replacement of potassium chloride by sodium chloride in meat products with no threats to microbiological stability and safety of the products during production and storage has been recommended by *Mudalal* and *Petracci* [35] and *Nachtigall et al.* [36]. Results of the current study showed the effectiveness of potassium chloride in Treatments 2 and 3 as replacements of 50 and 75% of potassium chloride led to better conditions, compared to the control group (100% sodium chloride). It seems that sodium chloride and potassium chloride act similarly in controlling the growth of microorganisms in foods [17]; however, information in this field is currently limited. Based on the studies, potassium chloride can completely or partially be replaced with no changes in the molarity of salt to protect foods against microbial agents, regardless of the food groups [37].

Sodium chloride causes changes in water absorption, which affects the formation of viscoelastic networks in doughs [38]. Due to the ionic nature of salts, extensive interactions with water (bipolar structure) and macromolecules are created [31]. The level of water absorption is an extremely important factor for bread quality and the economy. Furthermore, it predicts increases in distribution of dough materials, hydration, and development of gluten protein networks and hence increases in the product yields [39]. Results of investigation for the replacement of sodium chloride by potassium chloride and magnesium acetate in *Charlton et al.* [3] study showed no significant differences in rheological characteristics of brown bread prepared with alternative salts; similar to the results of this study. In addition, the results of *Kaur et al.* [40] study on the effects of replacement of sodium chloride by mineral salts on rheological characteristics of wheat flours showed decreases in water absorption in flours containing sodium chloride, compared with those containing no sodium chloride. Decreases in water absorption occurred due to the changes in gluten structure since salt molecules were replaced by water molecules [41].

In this study, significant differences were seen in dough development times in treatments ($p > 0.05$) and the minimum and the maximum development times were observed in the control group and Treatment 4, respectively. No significant differences were reported between Treatments 1, 2, and 3. Results of this study showed that the development time of sodium chloride varied from that of potassium chloride. Processes of dough swelling can be investigated through dough development time. Shorter dough formation times on graphs are linked to shorter kneading times of the doughs [42]. Decreases in dough development time cause the inappropriate formation of dough due to the weakness of gluten networks, which includes negative effects on bread volumes [43]. Based on *Lopes et al.* [44] and *Chen et al.* [45] studies, that development times increased by replacing sodium chloride with magnesium sulfate or sodium sulfate.

Parameters of dough development time and stability reveal the strength of the flour. The greater the values are, the stronger the doughs are [46]. Results of this study showed positive effects of potassium chloride instead of sodium chloride as Treatment 2 (50% potassium chloride and 50% sodium chloride) included the highest stability in the treatments with significant statistical differences. Results of *Kaur et al.* [40] study on the effects of sodium chloride replacement by mineral salts on rheological characteristics of wheat flour demonstrated significant differences in the treatments. In flours containing 50% potassium chloride, stability was improved. However, in flours containing 100% sodium chloride, dough stability decreased. Improvements in dough stability using sodium chloride have been reported by *Carcea et al.* [41]. Naturally, degrees of softening vary depending on the type of flour and level of salts. The addition of salts to flour increases dough elasticity [40]. Results of this study showed that Treatment 2 included the lowest degree of softening after 12 min. *Kaur et al.* [40] study showed significant differences in treatments with the replacement of potassium chloride with sodium chloride. Moreover, sodium sulfate included the minimum level of looseness in the treatments, and calcium chloride and magnesium chloride included significant effects on farinograph assessment.

Long dough development time and stability with low degrees of softening and high degrees of quality of farinographs are characteristics of strong doughs [47]. Therefore, weak and strong flours show low and high farinograph quality numbers, respectively [48]. In the present study, Treatment 2 included the highest farinograph quality number, which could be due to the increases in stability and decreases in softening of the doughs. The surface below the extensograph curve is considered the criterion of dough energy. The more the surface is, the stronger the dough is as a criterion of extensibility and maximum resistance to extension [49]. Dough energies less than 37 and more than 162 cm^2 make flours weak and strong, respectively. Desired flour quality is linked to the average energy level (nearly 32 cm^2) [50]. Results of this study showed that all the treatments included the desirable quality.

Increasing sodium chloride in bread formulations increases bread resistance to extension and dough development [51, 52]. This mechanism is associated with the enhancement of gluten proteins using carbon dioxide [15]. Similar effects of sodium chloride and potassium chloride on resistance to extension of dough could be explained by similar chemical characteristics of sodium and potassium and their ionic interactions and protein stabilities [15]. Based on this study, the lowest and the highest resistances to extension at 45, 90, and 135 min were recorded for the control group and Treatment 1 (75% sodium chloride and 25% potassium chloride), respectively. Similarly, *Sayar et al.* [15] showed significant differences between the treatments as replacements of 25 and 50% sodium chloride with potassium chloride presented the highest resistance to extension.

Results of this study showed that dough extension in potassium chloride treatments was lower than that in the control group, which represents less energy consumption for breaking the dough. In other words, dough resistance decreased to the extension. Therefore, it could be reported that treatments containing potassium chloride included looser doughs [53]. Investigating the effects of lyotropic neutral salts on dough extensibility, *Preston* [54] reported that the use of sodium chloride increased dough extension and resistance. *Tanaka et al.* [52] showed that extensibility in doughs containing 3% sodium chloride was higher than that in doughs containing 0% of sodium chloride. Based on *Lynch et al.* [55] study, increases in dough resistance with lower levels of sodium chloride (0–1.2%) were linked to increases in sodium chloride. Naturally, optimum doughs include good resistance to extension; however, most doughs include relative extensibilities. Doughs with high resistance to an extension are usually tight and tough, which produces troubles for extensograph devices. Bread baking is affected by relationships between the maximum dough resistance and its extensibility because it is indirectly responsible for the expansion of fermentation processes [56]. The maximum dough resistance includes 150–400 in weak flours, 500–700 in strong flours, and more than 700 in hard flours, using extensograph device. Based on these results, the control group containing 100% sodium chloride was considered weak flour, whereas Treatments 1 and 2 were classified as strong flour.

Tronsmo et al. [57] have argued that resistance to extension and hardness index (resistance) of dough indicate protein contents in flours and the high ratios of non-extractable protein polymers. Therefore, resistance to extension is associated with flour proteins when sodium chloride is included in doughs [58]. *Beck et al.* [34] study showed that by decreasing sodium chloride, the structure of the protein gluten networks changed from more to fewer protein particles. Although the presence of sodium chloride preserves gluten hydration, no direct evidence is available to support this hypothesis and its effects on gluten microstructures and rheological characteristics of doughs [58]. Several studies have shown the effects of sodium chloride on increases in dough development time, resistance, elasticity, and stability [59, 60].

Types of salts to replace sodium chloride must be selected carefully because selected salts can seriously affect product quality [61]. Potassium chloride is potentially a good alternative to sodium chloride and can form appropriate supplements with sodium chloride due to its unique physical characteristics [62]. In the present study, the physical shape of doughs showed no significant differences between the treatments ($p > 0.05$). Results of the *Sayar et al.* [15]

study on the effects of dough and bread characteristics with partial replacements of sodium chloride by potassium chloride indicated no significant differences in the treatments. However, *Gusmao et al.* [16] study did not show significant differences between the treatments in the replacement of potassium chloride with sodium chloride in French bread despite the changes in concentrations of sodium chloride and potassium chloride.

Usually, bread volume is one of the most important factors in bread acceptance. Decreases in bread volume occur due to decreases in dough extensibility and dilution of the gluten networks as well as interactions of non-gluten proteins with other flour compounds, which decrease the storage capacity of the gases in doughs [63]. Changes in bread color can occur because of the changes in water volume, proteins, starch gelatinization, and free water in various baking steps [64]. Baked bread with no sodium chloride includes lighter colors [65]. Decreases in Maillard reaction can produce paler bread because of the decreased quantity of free sugars and further yeast activity, which consumes further sodium chloride. Therefore, further sugars are produced, which decrease the color of the bread crusts [66]. This study showed that the color of the bread crusts included no significant differences between the treatments ($p > 0.05$), although the highest satisfaction with the bread crust color was linked to Treatment 1. Hence, it could be concluded that decreased sodium chloride was compensated by the increased quantity of potassium chloride.

Bread cracking can occur due to gas formation caused by excessive fermentation in the gluten networks. In fact, the dough wall cracks and tears due to the high pressure of the gas, and ultimately gas produced by the yeast activity is exhausted from the dough mass. Moreover, a lack of salts leads to fragile and cracked structures in bread [31]. However, the results of this study showed no significant differences in bread cracking and fracture between the treatments ($p > 0.05$). However, the minimum bread cracking and fracture were reported in the control group. Results of *Gusmao et al.* [16] study on partial replacement of potassium chloride by sodium chloride in French bread those of and Pourali and Rofegarinejad [67] study on effects of decreasing salt concentrations and salt replacing with potassium chloride on the sensory characteristics of barbari bread regarding bread crispness and fracture showed no significant differences in the treatments.

Three of the four major sensory characteristics of bread (texture, taste, and color) are affected by salt additions [5]. However, no significant differences were recorded in the present treatments by decreasing sodium chloride as the bread texture colors were similar in the control group and Treatment 2. Color is one of the quality criteria for consumers. Excessive paleness of bread is associated with its poor taste and short storage times, while excessive darkness is associated with over-baked bread. Sodium is responsible for the aroma of bread, which increases its sweetness. Satisfaction of the bread smell showed that Treatment 4 (sodium chloride-free) included the minimum satisfaction by the evaluators. In Pourali and Rofegarinejad [67] study, no significant differences in the aroma of bread were detected when assessing the effects of decreased salt concentrations and salt replacement by potassium chloride on the sensory characteristics of Barbie bread.

As previously stated, sodium chloride plays important role in developing gluten networks during dough mixing [5]. Thus, sodium chloride is important for general consumer acceptance [68]. The ratio of gluten and starch is one of the most important factors in the hardness of bread, including significant effects on the elastic changes during bread storage. In addition, duration, quality of fermentation, and baking conditions affect the hardness and staling of the bread [53]. After baking, water is translocated from the bread texture to its crust, which causes hardness of the bread, especially in filled bread [69]. In the present study, bread texture analysis showed that the lowest satisfaction of bread texture belonged to Treatment 4 (sodium chloride-free). However, *Pourali* and *Rofegarinejad* [67] did not report significant differences in the hardness of bread. *Charlton et al.* [3] successfully replaced 32% of sodium chloride with a mixture of magnesium chloride, potassium chloride, and magnesium sulfate as the produced bread was comparable to conventional bread in texture and taste.

Carbon dioxide produced during the fermentation causes porosity of the dough texture [70] and alcohol produced in this process is one of the factors of spongy bread [71].

By partially neutralizing acids from fermentation, sodium chloride prevents sourness of pieces of bread, especially when the fermentation time is long, controlling the fermentation rate and strengthening and accelerating gluten network formation. Results of this study showed that the minimum porosity was in Treatment 4 (sodium chloride-free), which included no significant differences from Treatment 3 (25% sodium chloride and 75% potassium chloride). Moreover, Matz [68] reported that doughs with insufficient salt contents led to excessive fermentation, which increased the gases and acidity of the doughs and ultimately produced bread with weak textures and open seeds [5]. Therefore, the replacement of more than 50% of potassium chloride decreased the porosity of the bread.

Potassium chloride includes metallic or bitter taste and when the proportion of replacement by sodium chloride is high, the bitterness increases significantly [6]. In *Braschi et al.* [12] study, bread samples with a 50% replacement of potassium chloride with sodium chloride received overall customer acceptance with weak taste. *Takano* and *Kondou* [72] reported that the replacement of 75% potassium gluconate with sodium chloride was acceptable as standard bread. Replacement of 100% potassium chloride with sodium chloride led to significant decreases in the taste of bread [15]. Based on the results from this study, the tastes of the bread significantly varied within the treatments ($p \leq 0.05$). However, 100 and 75% replacements of potassium chloride did not include appropriate tastes in treatments. However, the addition of 25 and 50% potassium chloride did not show significant differences with the control group despite the bitter taste of potassium chloride. Moreover, the replacement of 50% of sodium chloride with potassium chloride in baguettes was acceptable with no changes in the taste of the bread.

CONCLUSIONS

Bread is one of the most important foods worldwide, and is one of the major sources of nutrients. Since bread is one of the important sources of salt and high sodium intake is associated with high blood pressure, cardiovascular diseases, decreased bone mineral density, gastric cancers, and obesity, decreases in sodium chloride of bread formulations can considerably decrease consumer mortality. Therefore, researchers have carried out studies to find alternatives for sodium chloride in bread. One of these alternatives is potassium chloride, which includes physiological benefits such as the protective effects of potassium against several pathological diseases affecting the cardiovascular system, kidneys, and bones. The results of this study showed that potassium chloride was an appropriate substitute for sodium chloride. Flour microbial tests, dough rheological characteristics, and sensory characteristics evaluation of the baguettes with potassium chloride were significant. Hence, the possibility of producing low-sodium chloride bread and proportionally replacing the chemical with potassium chloride with no significant effects on the quality of the bread can help prevent and control common non-communicable diseases. In conclusion, the replacement of 50% potassium chloride with sodium chloride seems appropriate for the production of baguettes of good quality.

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