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Rheological, Antioxidant and Sensory Properties of Sodium Reduced Wheat Flour Bread with Mahaleb (Prunus mahaleb L.)

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Abstract

20% and 40% reduction of sodium content of wheat bread and the effects of addition of mahaleb kernel powder (*Prunus mahaleb* L.) were examined in order to determine the quality characteristics of the wheat flour dough and bread. The rheological properties of dough and antioxidant, sensory properties of sodium reduced wheat bread made with different levels of mahaleb kernel powder were determined. Extensibility, maximum strength, energy values of dough was similar with the control formulation and pH value of the dough increased with increasing potassium chloride and mahaleb content. Spesific volume of bread increased, crumb colour was lighter, and crust colour was darker, crumb hardness decreased with increasing mahaleb content. Antioxidant activity of breads by DPPH method increased with increasing mahaleb content with no potassium chloride. No significant difference was determined between the antioxidant activities of fresh breads by ABTS method. The results of sensory evaluation showed that the colour of fresh bread which has the highest amount of potassium chloride and mahaleb was different from the others, whereas colour of stored bread which has the highest amount of potassium chloride without mahaleb was different from the others. Firmness of fresh and stored breads decreased with increasing mahaleb content. Mahaleb aroma had no significant ($p>0.05$) effect on the saltiness perception of breads. Increase in mahaleb content did not change the bitterness of fresh breads, in contrast, bitterness increased in stored breads. In terms of overall acceptance, 20% reduced sodium 2% mahaleb containing fresh and stored breads were preferred.

Keywords: Bread; Sodium Reduction; Mahaleb

Introduction

Increasing demand to eat healthier foods led the researchers and food industry to optimize food formulations. Some food components determined to have negative effects on human health at high levels. Research conducted in recent years indicates that daily sodium intake level exceeds the recommended limits, worldwide. Sodium chloride improves the quality characteristics of food products preferred by producers and consumers. On the other hand, studies indicate that sodium as a component of salt taken in access (max. 2400 mg sodium/day) has negative effects on human health [1-3]. Since, bread is a food consumed continuously and in large amount, in many countries, this increases sodium intake in diets. It came into question to use sodium substitutes such as potassium chloride, calcium chloride, magnesium acetate for sodium reduction in bakery products. Considering the studies, the most commonly used sodium substitute is potassium chloride but potassium chloride has bitter/metallic taste therefore usage limit is restricted. In a study conducted in Spain on bread already on the market 0.5% of NaCl replaced with potassium citrate (27.7% reduction in sodium) [4]. Some studies indicated that substitution of sodium salt may affect physical properties of dough. On the other hand, when used in certain amount, changes on dough rheology are acceptable [5-7]. Also, it is represented that sodium reduction in bread may cause some technological and sensory problems [8]. Salt usage has an important role for the rheological properties of dough. Research shows that salt can stabilize the gluten networks, thus increasing the gas holding capacity and gas holding duration of the dough. Also, salt affects viscoelastic properties of the dough and the sensory characteristics of the bread as well as the volume of the bread. Rheologically, it is known that metal chloride salts such as sodium chloride strengthen the gluten structure [9,10]. Salt provides a smooth bread-in structure and porous viscoelastic structure [11]. Some studies showed that the quality of dough and bread decreased significantly when sodium chloride was reduced [12]. After sodium reduction, loss of bread flavor was pointed out as the important case that should be of concern, so many studies were conducted to improve the flavor of sodium reduced bread. For this purpose, the effects of different herbs and spices such as; turmeric powder [13], ginger powder [14], glasswort on bread flavor and quality were evaluated in bread formulations [15].

Mahaleb (*Prunus mahaleb* L.) is a wild species of cherry known as rootstock of cherry and sourcherry and there are two kinds of mahaleb including white (*Prunus mahaleb* L.) and black (*Monechma ciliatum* (Jacq.) Milne-Redh) [16,17]. The pulp and seeds of mahaleb fruit is used in food industry; mahaleb kernel powder is used in bakery and dairy products for the purpose of enhancing flavor while mahaleb flesh is used limitedly, as raw material of medicines and locally in the production of wine, pestil and jelly [18]. Mahaleb fruit is fragrant and has a sour taste whereas mahaleb kernel is also fragrant but it has a bitter taste, it creates almond flavor after chewing [19-21]. It is stated that mahaleb has positive effects on health in terms of its protein, oil, fatty acid composition, phenolic compounds, antioxidant and antimicrobial activity [22,23].

In the scientific literature there are studies available regarding the nutritional properties of mahaleb and its use bakery products [16]. To our knowledge, information regarding the effects of mahaleb on the characteristics of sodium reduced dough and bread is not available. On the other hand, there isn't any study showing that the mahaleb usage affects the dough rheology but, it is indicated that mahaleb seeds have a bitter taste which is determinative for the usage amounts [20]. In this direction, this study aimed 20% and 40% sodium reduction for wheat bread by using potassium chloride as a salt substitute and mahaleb kernel powder was added for improving the quality characteristics. The rheological, antioxidant and sensory properties of sodium reduced wheat bread made with different levels of mahaleb kernel powder were determined.

Materials and Methods

Materials

The commercial bread flour (Has Un, Turkey) (Type 650) were used for bread making. The composition of wheat flour were determined as; moisture 12.7%, ash 0.75% dm, wet and dry gluten 31.8 and 9.7%, sedimentation value 31 ml, falling number 348.5 second. Fresh yeast (Yuva, Turkey), sodium chloride (Billur, kitchen salt with iodine, Turkey), food grade potassium chloride (Merck, Germany), white mahaleb (*Prunus mahaleb* L.) seeds (Defne, Turkey) were used. Bread flour was stored in 50 kg bags, mahaleb seeds was kept in locked plastic bags at ambient temperature and they were ground by using coffee mill (Sinbo, Turkey) and sieved (<500 µm) before it is used in bread formulations. All the reagents and chemicals used were of analytical grade.

Dough and Bread Preparation

For the production of bread Detmold Standard Bread Making Method was used [24]. Flour was ventilated in the mixer, yeast, salt (sodium chloride, potassium chloride) and mahaleb were added, and all ingredients were mixed to have homogenized mixture. Water was added to the mixture and dough was kneaded to a certain consistency. After fermentation and ventilation process, fermented dough was sliced into 400 g portions and dough was shaped. After the last fermentation process, shaped dough was baked at 220 0C for 20 minutes. The water level of the control dough was 59%. This level was maintained for all experiments to allow fair comparison between rheological properties and baking results. Baking process was performed in triplicate. Bread formulations were given in (Table 1). Control bread contained sodium chloride in 1.2%, potassium chloride and mahaleb was not added to control bread. In the other formulations sodium chloride varied between 1.2-0.72%, whereas potassium chloride varied between 0-0.48%. Potassium chloride was used as a salt substitute up to 0.48% because, it is stated that 30% of the salt can be substituted by potassium chloride, higher levels can cause metallic taste [25]. Mahaleb amount was determined by preliminary tests, using more than 4% mahaleb caused unacceptable bitter taste.

Bread formulations	Sodium chloride (%)	Potassium chloride (%)	Mahaleb (%)
1 (control)	1.2	0	0
2	1.2	0	2
3	1.2	0	4
4	0.96	0.24	0
5	0.96	0.24	2
6	0.96	0.24	4
7	0.72	0.48	0
8	0.72	0.48	2
9	0.72	0.48	4

Table 1: Sodium chloride, potassium chloride and mahaleb levels of bread formulations

Analysis of Dough

Extensogram properties (extensibility, maximum strength and energy values) of dough which have different levels of sodium chloride, potassium chloride and mahaleb were determined according to the ICC-Standard by using Brabender extensograph [26]. pH measurements were conducted with pH-meter (WTW pH 7110) after 10 g dough was dissolved in 100 ml pure water [27].

Analysis of Bread

Bread samples were cooled for 2 hours at room temperature (22±2 °C) prior to instrumental and chemical analysis and sensory analysis was carried out after breads were cooled for 4 hours. Breads were stored in CPP (Cast Polypropylene) bags at 22±2 °C for 3 days. After storage period, firmness of bread crumb and antioxidant activity of breads were determined, also sensory analysis was carried out.

Bread specific volume was determined by rape seed displacement method and results were given as bread volume/bread weight (cm3/g) [28]. ICC method was used for the moisture content and results were indicated as percentage (%) [29]. Crumb and crust colour of breads were determined by using Konica Minolta CR-400. L*, a*, b* values at 9 different points of the bread crust and L*, a*, b* values at 3 different points of 3 slices of breads were measured [30]. Results were indicated as a mean of measured points. Crumb hardness of fresh and stored breads was determined by using TA-XT.Plus Texture Analyzer 12337 according to the AACC [31]. Antioxidant activity of fresh and stored breads were specified according to the DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) methods [32,33]. Results were indicated as a μmolar trolox/g extract. The same extraction procedure was used for both of the antioxidant activity methods as suggested by Balestra et al. [14]. Supernatant was diluted with methanol to 50 ml for DPPH method. 1950 μl DPPH was added to 25, 50, 75 μl extract and solutions were incubated at room temperature for 20 minutes. After incubation time, absorbance values were measured at 517 nm and % of inhibition was calculated [32]. Antioxidant activities of extracts were expressed as a trolox equivalent by using methanol-trolox solution as a standard solution and results were expressed as a μmolar trolox/g extract. For the ABTS method, ABTS.+ radical solution was prepared and analysis was carried out as suggested by Re et. al. [33].

Sensory evaluation was carried out on bread samples with same percentage of salt but different percentage of mahaleb (Prunus mahaleb L.) 4 hours after baking and 3 days after storage. Ranking test was applied to 2 cm thick slice of bread [34], coded with 3 digit numbers. 14 panelists evaluated the quality characteristics of breads such as colour (lightness-darkness), firmness, saltiness, bitterness and overall acceptability.

Statistical Analysis

Objective and sensory analyses were performed in triplicate. The data obtained from the objective and sensory analyses were evaluated with the Variance Analysis (ANOVA) and Duncan test by using SPSS Statistics 21 program.

Results and Discussion

Dough formulations	Extensibility (mm)			Maximum resistance (BU)			Energy (cm^2)		
	45. Minute	90. Minute	135. Minute	45. Minute	90. Minute	135. Minute	45. Minute	90. Minute	135. Minute
1	115 ± $1.41^{ab,\dagger}$	103 ± $2.83^{c,*}$	99.5 ± $2.12^{ab,*}$	1049.5 ± $54.45^{b,*}$	1078.5 ± $19.09^{b,*}$	1092 ± $0.0000^{c,*}$	161.5 ± $6.36^{ab,\dagger}$	143 ± $2.83b^{c,*}$	139.5 ± $0.71^{ab,*}$
2	116.5 ± $4.95^{ab,*}$	97.5 ± $6.36^{abc,*}$	105.5 ± $12.02^{ab,*}$	964 ± $38.18^{a,*}$	1092 ± $0.00^{b,\dagger}$	1039.5 ± $54.45^{b,*\dagger}$	153.5 ± $14.85^{a,*}$	141.5 ± $12.02^{abc,*}$	138.5 ± $20.51^{ab,*}$
3	143.5 ± $16.26^{c,\dagger}$	105 ± $1.41^{c,*}$	106 ± $1.41^{ab,*}$	938.5 ± $2.12^{a,*}$	1004 ± $66.47^{a,*}$	937 ± $24.04^{a,*}$	174.5 ± $3.54^{abc,\dagger}$	137 ± $8.49^{ab,*}$	130 ± $7.07^{ab,*}$
4	104 ± $0.00^{a,\Delta}$	94 ± $0.00^{ab,\dagger}$	89.5 ± $0.71^{a,*}$	1088 ± $0.00^{b,*}$	1088.5 ± $4.95^{b,*}$	1092 ± $0.00^{c,*}$	159.5 ± $2.12^{ab,\Delta}$	142.5 ± $0.71^{abc,\dagger}$	126.5 ± $3.54^{a,*}$
5	118 ± $1.41^{ab,\dagger}$	104.5 ± $2.12^{c,*}$	107 ± $2.83^{b,*}$	1092 ± $0.00^{b,*}$	1090 ± $2.83^{b,*}$	1092 ± $0.00^{c,*}$	174.5 ± $3.54^{abc,\dagger}$	156 ± $0.00^{cd,*}$	154.5 ± $6.36^{ab,*}$
6	127.5 ± $4.95^{bc,\dagger}$	104 ± $4.24^{c,*}$	103 ± $5.66^{ab,*}$	1038 ± $52.33^{b,*}$	1090 ± $2.83^{b,*}$	1092 ± $0.00^{c,*}$	181.5 ± $19.09^{bc,*}$	157 ± $5.66^{cd,*}$	148.5 ± $4.95^{ab,*}$
7	117.5 ± $13.44^{ab,\dagger}$	89 ± $2.83^{a,*}$	92.5 ± $4.95^{ab,*\dagger}$	1092 ± $0.00^{b,*}$	1090 ± $2.83^{b,*}$	1092 ± $0.00^{c,*}$	161.5 ± $7.78^{ab,\dagger}$	127.5 ± $4.95^{a,*}$	132 ± $11.31^{ab,*}$
8	122 ± $2.83^{ab,*}$	98.5 ± $2.12^{bc,*}$	97 ± $11.31^{ab,*}$	1092 ± $0.00^{b,*}$	1092 ± $0.00^{b,*}$	1092 ± $0.00^{c,*}$	182 ± $2.83^{bc,\dagger}$	143.5 ± $0.71^{bc,*}$	138.5 ± $19.09^{ab,*}$
9	132 ± $5.66^{bc,\dagger}$	114 ± $5.66^{d,*\dagger}$	106 ± $8.49^{ab,*}$	1072 ± $24.04^{b,*}$	1092 ± $0.00^{b,*}$	1090 ± $2.83^{c,*}$	198 ± $15.56^{c,\dagger}$	170 ± $8.49^{d,*\dagger}$	156 ± $12.73^{b,*}$

*, †, Δ indicate significant differences of time-dependent change of dough which have different percentages sodium chloride, potassium chloride and mahaleb

Table 2: The extensibility, maximum resistance and energy values of dough formulation

The pH values of dough were found in between 5.86-6.29 and pH values increase with the increase in potassium chloride and mahaleb amount (data not given). There were statistically significant differences ($p<0.05$) among pH values of dough's. Extensibility, maximum resistance, energy values of dough with different contents were measured for a given time (45., 90., 135. min.) and according to the time-dependent change (between 45. and 135. min.) (Table 2). The extensibility values of dough which contained same amount of sodium chloride and potassium chloride, different amount of mahaleb increased and significant difference ($p<0.05$) were determined between the dough containing "%1.2 NaCl+%0 KCl and %0, %4 Mahaleb" and "%0.96 NaCl+%0.24 KCl and %0, %2, %4 Mahaleb". In the study conducted by Lynch et al. [12], no significant differences ($p>0.05$) was determined among the extensibility values of dough which had different sodium chloride content. The hardness of the dough which contained "%1.2 NaCl+%0 KCl" decreased with increasing mahaleb amount ($p<0.05$). Significant differences ($p>0.05$) were determined with time-dependent change of maximum resistance values of dough. Lynch et al. [12], found that the maximum resistance value of dough which contained 1.2% NaCI was found to be statistically different from the dough which did not contain sodium chloride. There was an increase in energy values of dough which contained sodium chloride and potassium chloride at a given time, while decrease was determined for the dough which contained only sodium chloride.

The specific volume of bread which contain "%1.2 NaCl+%0 KCl+%0 Mahaleb" was different from the others ($p<0.05$). The breads with same mahaleb content had the similar volume. There was an increase in specific volume with increasing mahaleb content. Significant differences ($p<0.05$) were determined among moisture contents of breads. The breads which contain same mahaleb content had the similar moisture content on the other hand there was a decrease in moisture content (%) with increase in mahaleb content (Table 3).

Bread formulations	Specific volume (cm^3/g)	Moisture (%)
1	2.31 ± 0.23^{a}	37.3 ± 0.32^{e}
2	3.09 ± 0.27^{c}	35.2 ± 0.65^{bc}
3	3.41 ± 0.1^{ef}	34.6 ± 0.13^{ab}
4	2.75 ± 0.03^{b}	37.8 ± 0.63^{e}
5	3.18 ± 0.09^{cd}	36 ± 0.24^{d}
6	3.32 ± 0.04^{de}	35 ± 0.12^{abc}
7	2.80 ± 0.09^{b}	37.7 ± 0.27^{e}
8	3.28 ± 0.09^{cde}	35.5 ± 0.18^{cd}
9	3.55 ± 0.16^{f}	34.4 ± 0.19^{a}

Table 3: The specific volume and moisture content of bread formulations

Significant differences ($p<0.05$) among L* and b* values of the bread crumbs were determined. It was observed that L* values increased with increase in mahaleb content; it means light crumb colour. The b* values of breads which had 4% mahaleb content were different from the others (Table 4).

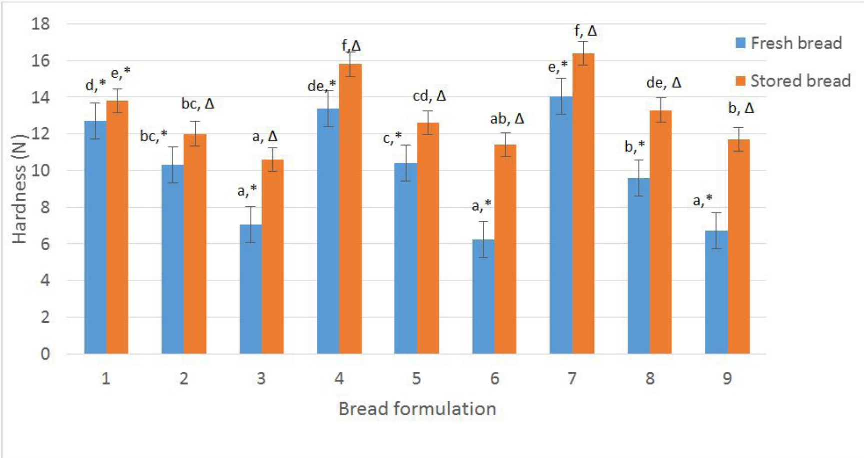
Bread formulations	Crumb colour			Crust colour		
	L* values	a* values	b* values	L* values	a* values	b* values
1	69.9 ± 0.36^{a}	0.637 ± 0.31^{abc}	17 ± 0.49^{bc}	66.5 ± 0.89^{c}	8.88 ± 0.43^{a}	27.3 ± 0.86^{d}
2	73.5 ± 0.64^{cde}	0.866 ± 0.18^{abc}	16.8 ± 0.52^{bc}	61.6 ± 0.45^{b}	12.1 ± 0.88^{c}	24.6 ± 0.68^{bc}
3	74.5 ± 0.92^{e}	1.06 ± 0.18^{c}	16.2 ± 0.22^{a}	56.4 ± 0.93^{a}	12.9 ± 0.42^{cde}	22.5 ± 0.79^{a}
4	71.4 ± 0.53^{bc}	0.639 ± 0.49^{abc}	17 ± 0.35^{bc}	67 ± 0.71^{c}	9.13 ± 0.88^{a}	26.7 ± 0.5^{d}
5	73 ± 0.59^{bcd}	0.764 ± 0.46^{abc}	16.9 ± 0.38^{bc}	62.2 ± 0.92^{b}	12.3 ± 0.82^{cd}	23.9 ± 0.64^{b}
6	74.1 ± 0.32^{cde}	0.897 ± 0.38^{bc}	16.7 ± 0.42^{ab}	56.6 ± 0.78^{a}	13.2 ± 0.78^{def}	22.7 ± 0.91^{a}
7	72.4 ± 1.11^{b}	0.411 ± 0.15^{a}	17.2 ± 0.23^{c}	66.8 ± 0.83^{c}	11 ± 0.43^{b}	27.4 ± 0.64^{d}
8	73.3 ± 0.28^{cde}	0.545 ± 0.14^{ab}	17 ± 0.26^{bc}	62.4 ± 0.74^{b}	13.5 ± 0.49^{ef}	25.1 ± 0.64^{c}
9	74.5 ± 1.01^{de}	0.913 ± 0.30^{bc}	16.3 ± 0.27^{a}	56.6 ± 0.98^{a}	14.1 ± 0.61^{f}	22 ± 0.77^{a}

$^{a, b, c, d, e}$ Indicate significant differences among crumb colour values of bread formulations which have different percentages salt and mahaleb

Table 4: The crumb and crust colour values of bread formulations

Significant differences ($p<0.05$) among L*, a* and b* values of the bread crusts were determined (Table 4). L* values decreased with increase in mahaleb content, which means dark crust colour. It was observed that a* values increased with increasing mahaleb content. Also, b* values of crust colour of bread which had same mahaleb content were similar to each other and b* values decreased with increasing mahaleb content.

Significant differences ($p<0.05$) among hardness values of fresh and stored breads were determined (Figure 1). Crumb hardness values of fresh and stored breads with same mahaleb content were similar to each other and decreased with increasing mahaleb content. In other words, the breads with more mahaleb content were softer than the others at the end of the storage time.



$^{a, b, c, d, e, f}$ Indicate the significant differences between fresh bread crumb hardness and stored bread crumb hardness which have different percentages salt and mahaleb

$^{*, \Delta}$ Indicate the significant differences between fresh bread crumb hardness and stored bread crumb hardness which have same percentages salt and mahaleb

Figure 1: Crumb hardness of fresh and stored bread formulations

In a study conducted by Lynch *et al.* [12], sodium chloride content of bread was reduced from 1.2% to 0.6, 0.3 and 0%, the bread firmness increased with decreasing sodium chloride content. The hardness of bread with 0.6% sodium chloride content was similar with the hardness of bread which did not include sodium chloride. No significant differences ($p<0.05$) were determined among 2 days stored breads. After 5 days of storage, the bread which did not contain sodium chloride was significantly harder than the others. In a study conducted by Liem *et al.* [13], hardness of bread increased with increasing turmeric powder content. Also, ginger powder added to bread showed the same effect [14].

The antioxidant activity of fresh and stored breads which did not contain mahaleb was significantly different from the formulations which contain mahaleb (Table 5). Considering the fresh breads which did not contain potassium chloride, antioxidant activity increased significantly with increasing mahaleb content whereas, antioxidant activity did not increase significantly with increasing mahaleb content for fresh breads containing potassium chloride. On the other hand, the antioxidant activity of stored breads which contained same amount of salt and different amount of mahaleb, increased significantly. No significant differences were determined among the antioxidant activity of fresh and stored breads with 2 and 4% mahaleb amount ($p<0.05$).

The antioxidant activity of fresh breads which did not contain mahaleb was significantly different from the formulations which contain mahaleb, by ABTS method (Table 5). Considering the fresh breads which did not contain potassium chloride, antioxidant activity increased significantly with increasing mahaleb content whereas, antioxidant activity did not increase significantly with increasing mahaleb content for fresh breads containing potassium chloride. In other words, increasing mahaleb content did not increase the antioxidant activity of fresh bread. On the other hand, the antioxidant activity of stored breads increased with increasing mahaleb content, but this increase was significant for 4% mahaleb content ($p<0.05$). Antioxidant activity of mahaleb decreased after baking. It was thought that high baking temperature might cause reduction in the antioxidant components. Different results were attained by using different antioxidant activity methods. It might be because of having different activities of antioxidants to produced radicals [35].

Bread formulations	DPPH Method		ABTS Method	
	Antioxidant activity of fresh bread (µM Trolox/g extract)	Antioxidant activity of stored bread (µM Trolox/g extract)	Antioxidant activity of fresh bread (µM Trolox/g extract)	Antioxidant activity of stored bread (µM Trolox/g extract)
1	263.62 ± 25.14^{a,*}	340.58 ± 13$^{a,\Delta}$	1517.71 ± 166.26^{a,*}	1244.82 ± 79.02$^{a,\Delta}$
2	363.01 ± 49.06^{cd,*}	452.11 ± 34.62$^{de,\Delta}$	1732.46 ± 67.84^{b,*}	1364.12 ± 109.35$^{ab,\Delta}$
3	422.63 ± 45.39^{e,*}	477.02 ± 45.79^{e,*}	1962.33 ±162.18^{c,*}	1470.42 ± 180.66$^{bc,\Delta}$
4	329.59 ± 26.44^{bc,*}	374.04 ± 28.28$^{ab,\Delta}$	1555.07 ± 110.42^{a,*}	1441.83 ± 120.8b^{c,*}
5	403.3 ± 28.9^{de,*}	426.05 ± 29.15^{cd,}	1933.03 ± 123.2^{c,*}	1670.54 ± 182.24$^{d,\Delta}$
6	406.29 ± 25.69^{de,*}	440.81 ± 25.95^{de,*}	1990.2 ± 81.52^{c,*}	1896.33 ± 82.24^{e,*}
7	294.49 ± 34.17^{ab,*}	346.43 ± 23.94$^{a,\Delta}$	1392 ± 195.52^{a,*}	1422.61 ± 88.84^{bc,*}
8	317.14 ± 25.46^{bc,*}	396.75 ± 30.25$^{bc,\Delta}$	1949.31 ± 119^{c,*}	1575.11 ± 163.01$^{cd,\Delta}$
9	339.09 ± 48.13^{bc,*}	416.66 ± 19.08$^{cd,\Delta}$	2047.98 ± 56.87^{c,*}	1917.68 ± 114.87$^{e,\Delta}$

$^{a, b, c, d}$ Indicate significant differences among different percentages sodium chloride, potassium chloride and mahaleb

$^{*, \Delta}$ Indicate significant differences between fresh and stored breads which have same percentages of sodium chloride, potassium chloride and mahaleb

Table 5: Antioxidant activities of fresh and stored breads by DPPH and ABTS methods

The results of sensory analysis of fresh breads evaluated at the day of baking, showed significant ($p<0.05$) difference among crumb colour, firmness, bitterness, overall acceptability (Table 6). The colour of fresh bread with "0.72% NaCl + 0.48% KCl + 4% Mahaleb" which has the highest amount of potassium chloride and mahaleb was different from the others. The firmness of breads with same amount of mahaleb was similar. Also the breads with 4% mahaleb were determined as the softest samples. Mahaleb addition had no significant ($p>0.05$) effect on saltiness perception of the bread. The bitterness of breads without mahaleb was different from the others and bitterness of breads with different mahaleb levels was similar with each other. The overall acceptability of breads containing potassium chloride and 4% mahaleb were determined to be lower than the others.

Breads evaluated after 3 days of storage showed significant ($p<0.05$) difference for crumb colour, firmness, bitterness and overall acceptability. The colour of stored bread with "0.72% NaCl + 0.48% KCl + 0% Mahaleb" was different from the others. Different mahaleb content had no influence on the colour of breads which had different salt content. The firmness of sodium reduced breads without mahaleb was similar. Breads with same mahaleb content but with different salt content were also similar. The bitterness of breads with 4% mahaleb was found to be higher than the other mahaleb levels. It was found that mahaleb content did not make any difference on overall acceptability of breads. Storage time had no significant ($p>0.05$) effect on the properties of stored breads of same formulations such as colour, firmness, saltiness, bitterness and overall acceptability.

Bread formulations	Colour		Firmness		Saltiness		Bitterness		Overall acceptability	
	Fresh	Stored	Fresh	Stored	Fresh	Stored	Fresh	Stored	Fresh	Stored
1	34± $1.41^{e,*}$	34± $1.41^{c,*}$	36.5± $2.12^{cd,*}$	34± $2.83^{d,*}$	28.5± $3.54^{a,*}$	28.5± $3.54^{a,*}$	15± $2.83^{a,*}$	20.5± $2.12a^{b,*}$	32± $4.24^{d,*}$	29± $1.41^{bc,*}$
2	25.5± $2.12^{bc,*}$	26± $2.83^{b,*}$	29.5± $3.54^{bc,*}$	29.5± $2.12^{cd,*}$	24.5± $2.12^{a,*}$	28.5± $2.12^{a,*}$	32± $5.66^{b,*}$	23.5± $3.54^{b,*}$	27.5± $3.54^{abcd,*}$	30± $1.41^{bc,*}$
3	24± $2.83^{b,*}$	23.5± $2.12^{ab,*}$	17± $2.83^{a,*}$	22.5± $2.12^{b,*}$	29.5± $3.54^{a,*}$	26± $2.83^{a,*}$	35.5± $2.12^{b,*}$	39± $2.83^{d,*}$	23.5± $3.54^{abc,*}$	26± $2.83^{ab,*}$
4	32.5± $2.12^{de,*}$	35± $2.83^{c,*}$	38.5± $3.54^{d,*}$	40.5± $3.54^{e,*}$	27.5± $4.95^{a,*}$	23± $2.83^{a,*}$	15.5± $3.54^{a,*}$	15± $1.41^{a,*}$	29± $2.83^{bcd,*}$	29.5± $2.12b^{c,*}$
5	27.5± $2.12b^{cd,*}$	26.5± $2.12^{b,*}$	28± $2.83^{b,*}$	26.5± $2.12^{bc,*}$	24± $1.41^{a,*}$	26.5± $2.12^{a,*}$	31.5± $3.54^{b,*}$	30.5± $2.12^{c,*}$	34± $1.41^{d,*}$	33.5± $2.12^{c,*}$
6	23± $2.83^{b,*}$	23± $2.83^{ab,*}$	17± $4.24^{a,*}$	16± $1.41^{a,*}$	31.5± $4.95^{a,*}$	33.5± $2.12^{a,*}$	37± $2.83^{b,*}$	38± $2.83^{d,*}$	22.5± $2.12^{ab,*}$	22.5± $2.12^{a,*}$
7	36.5± $3.54^{e,*}$	41.5± $3.54^{d,*}$	38.5± $3.54^{d,*}$	41± $2.83^{e,*}$	29± $2.83^{a,*}$	25.5± $3.54^{a,*}$	15.5± $3.54^{a,*}$	15.5± $2.12^{a,*}$	32± $2.83^{d,*}$	31± $2.83b^{c,*}$
8	30.5± $3.54^{cde,*}$	23.5± $2.12^{ab,*}$	27.5± $2.12^{b,*}$	26.5± $2.12^{bc,*}$	30± $2.83^{a,*}$	27.5± $2.12^{a,*}$	30± $4.24^{b,*}$	29± $1.41^{c,*}$	30± $1.41^{cd,*}$	30.5± $2.12b^{c,*}$
9	15.5± $6.58^{a,*}$	18± $2.83^{a,*}$	16.5± $3.54^{a,*}$	15.5± $2.12^{a,*}$	25.5± $3.54^{a,*}$	29± $2.83^{a,*}$	36± $2.83^{b,*}$	40.5± $2.12^{d,*}$	21± $2.83^{a,*}$	22± $1.41^{a,*}$

$^{a, b, c, d}$ indicate significant differences among different percentages sodium chloride, potassium chloride and mahaleb

* indicates significant differences between fresh and stored bread with same percentages sodium chloride, potassium chloride and mahaleb

Table 6: Results of ranking test of fresh and stored breads

Conclusion

Sodium reduction up to 40% showed no effect on technological properties of bread. Addition of mahaleb powder at different percentage (from 0% to 4%) changed the rheological properties and pH values of dough. On the other hand, bread volume increased, bread crumb and firmness decreased, bread crumb colour get lighter and bread crust colour get darker. Antioxidant activities of fresh and stored bread changed and antioxidant activity of mahaleb decreased after baking process. Sensory evaluation of the breads demonstrated that the colour of fresh bread which has the highest amount of potassium chloride and mahaleb was different from the others, on the other hand colour of stored bread which has the highest amount of potassium chloride and without mahaleb was different from the others. Firmness of fresh and stored breads decreased with increasing mahaleb content. It was determined that mahaleb aroma had no significant ($p>0.05$) effect on the saltiness perception of the fresh and stored bread. In terms of overall acceptability, 20% reduced sodium and 2% mahaleb bread formulations were preferred.

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