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Effect of Replacement of Sodium Chloride with Mineral Salts on Rheological Characteristics of Wheat Flour

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ABSTRACT

The effect of sodium chloride and different mineral salts on dough rheology for preparation of low sodium bakery products were studied on three commercial flours A, B and C. Five mineral salts viz. KCl, $MgCl_2$, $CaCl_2$, $MgSO_4$ and Na_2SO_4 were used to replace NaCl at 0, 25, 50 and 100% level. Of all the salts studied for replacement of NaCl, KCl had little effect on farinographs, Na_2SO_4 had maximum strengthening effect and $CaCl_2$ followed by $MgCl_2$ had distinctive weakening effect. Addition of salts increased the paste viscosities in all the three flours. Paste viscosities were maximum when NaCl was replaced with Na_2SO_4. From the results it was found that sodium chloride can be easily replaced with other salts without having any adverse effect on dough rheology.

Key words: Kymograph, mineral salts, rheology, farinograph, pasting properties

INTRODUCTION

Wheat is a unique cereal having gluten protein which gives viscoelastic properties to the dough for bread making. The other major constituents of wheat grain are starch, fibre (Non-starch Polysaccharides (NSP) lignin (Coskuntuna *et al*., 2008). The protein, fat, carbohydrate and ash content of wheat flour as reported by Ahmed *et al*. (2008) was 11.80,1.50,72.40 and 1.50%, respectively whereas Yasar (2002) reported crude protein ranging from 7.84 to 14.11% in different wheat cultivars. Any production of cereal based baked product passes through dough formulation. Dough is a viscoelastic material having complex rheological properties which involves many mechanical steps such as kneading, rolling, laminating and forming etc., followed by dough leavening during fermentation and oven rise during baking (Launay and Michon, 2006). Besides chemistry rheometry is a necessary and powerful technique for explaining and predicting the quality of cereal foods (Weipert, 1990).

A variety of instruments based on various principles and techniques has been developed and applied to the study of dough rheology (Sroan and Kaur, 2004; Peressini, 2001). Farinograph is the most widely used to understand rheological behavior during dough mixing (Anonymous, 1990; Pomeranz and Meloan, 1994). Farinograph is a recording dough mixer that measures torque needed for mixing dough at a constant speed and temperature. The resistance offered is integrated with time and traced on kymograph chart in form of curve. This curve is used to evaluate various rheological parameters such as dough development time, dough strength, dough stability etc (Anonymous, 1990).

Amylograph measures important aspects of starch rheology during pasting such as gelatinization temperature and changes in viscosity with temperature and time. When starch based foods are heated in an aqueous environment they undergo a series of changes known as gelatinization and pasting (Odedeji and Adeleke, 2010). These pasting properties of starch help to evaluate crumb characteristics and loaf volume (Kusunose *et al.*, 1999). The ingredients present in the flour affect the results. Of all the ingredients used in baked food products salt is the most essential ingredient and it performs functions in baking and so it is not just a seasoning or flavour enhancer (Gisslen, 2005). That cannot be duplicated by any other ingredients (Niman, 1981).

Common salt (NaCl) is used as a flavour enhancer and dough stabilizer where the strengthening effect of salt helps to insure good dough handling properties (Salovaara, 2009). Salt is added to strengthen the gluten and to convert the action of yeast for controlled expansion of the dough (Mondal and Dutta, 2008). Salt influences gluten behavior, decreases yeast activity in the dough, thus retarding gas production and enhances bread flavor (Miller and Hoseney, 2008).

There is evidence that high sodium intake may raise blood pressure, increasing the risk of heart attack or stroke (Palar and Strum, 2009; Taormina, 2010). The average salt (NaCl) consumption in the western diet is 11g/person/day (Lynch *et al.*, 2007) 75% of which is obtained from processed foods with bread products contributing to at least a quarter of dietary sodium intake (Luchian and Canja, 2010). Worldwide, bread is one of the most consumed foodstuffs with an average consumption ranging from 41 to 303 kg^{-1} year per capita (Rosell, 2011). Due to the diverse and important role of NaCl in bakery products, the reduction of NaCl levels may have an impact on the product quality and functional properties. The partial replacement of sodium chloride with another electrolyte instead of the mere reduction of sodium chloride in the formula offers the opportunity to maintain the electrolyte concentration (Salovaara, 1982a). Work has been done to study the effect of partial replacement of NaCl with KCL in cheese (Katsiari *et al.*, 1998; El-Bakry *et al.*, 2010; Cernikova *et al.*, 2010), reduction of salt on dough and bread characteristics (Lyncha *et al.*, 2009) with very few studies on the impact of the replacement of NaCl with other mineral salts on rheology of dough. The objective of this study was to investigate effect of sodium chloride replacement with other mineral salts vizpotassium chloride, magnesium chloride, magnesium sulfate, calcium chloride, sodium sulfate and their effect on rheological properties of wheat flour.

MATERIALS AND METHODS

Commercial wheat flour was procured from three local flour mills: Flour A from Luxmi Electric Flour Mills, Ludhiana, Flour B from Sukhchain Roller Flour Mills, Ludhiana and Flour C from Gilco Agro Private Ltd., Ludhiana for the year 2006. Flour samples were analyzed for chemical composition (Table 1) according to AACC (Anonymous, 1990) procedures.

Commercially in baking salt is used at the level of 1.5-2.0%. Five minerals salts viz KCl, $MgCl_2$, $CaCl_2$, $MgSO_4$, Na_2SO_4 were used to replace NaCl at 25, 50 and 100% levels.

Farinograph characteristics: Farinograph is the most frequently used equipment for empirical rheological measurements (Razmi-Rad *et al.*, 2007). Farinograph characteristics of the flour were investigated without (control) and with addition of sodium chloride (2% of flour wt. basis) and its replacement with mineral salts at 25, 50 and 100% levels according to AACC method of Anonymous (1990). From the farinograph, the water absorption (%) Dough Development Time (DDT min), mixing tolerance index (BU), stability (min) and softening (BU) were studied.

Table 1: Chemical composition of wheat flours

Characteristics items	Flour A	Flour B	Flour C	CD* (0.05)
Protein (%N×5.7)	9.84	10.01	10.09	0.133
Fat (%)	0.83	0.87	0.82	NS
Ash (%)	0.62	0.51	0.50	0.027
Free fatty acid (% oleic acid)	0.02	0.01	0.01	0.002
Wet gluten (%)	27.07	30.40	29.53	1.378
Dry gluten (%)	10.13	11.20	10.67	0.753
Damaged starch (%)	7.17	7.63	8.60	0.389
Diastatic activity (mg maltose/10 g at 30°C h^{-1})	191.50	207.00	251.00	4.199
Total sugars (mg maltose/10 g)	201.67	170.50	167.13	0.912
Reducing sugars (mg maltose/10 g)	33.50	28.00	21.33	0.881
Sedimentation value (mL)	23.00	24.00	25.00	1.289
Falling number	534.00	473.00	475.00	19.639
Pigments (carotene ppm)	2.41	1.99	1.96	0.019
Minerals (ppm)				
Sodium	9.46	17.61	11.60	0.79
Potassium	1726.50	1534.20	1735.70	0.26
Calcium	315.50	176.30	170.30	0.75
Magnesium	371.60	304.20	409.90	0.50
Phosphorus	1086.00	1162.20	1297.00	0.26
Iron	9.78	9.83	11.60	0.37

*CD (Critical difference) at $p<0.05$

Amylograph characteristics: Amylograph characteristics of flour were investigated without (control) and with addition of NaCl (2% on flour wt. basis) and its replacement with mineral salts at 25, 50 and 100% levels, according to AACC method of Anonymous (1990). From Amylograph gelatinization temperature (°C) peak viscosity (B.U.) temperature at peak (°C), viscosity at 95 (°C) were studied.

Statistical analysis of data: The data collected on different characteristics were analyzed with the help of factorial design in CRD (Cochran and Cox, 1957). All results have been reported at moisture level of 14-100 kg^{-1} of dry solids, unless otherwise stated. Each value is mean of three observations.

RESULTS AND DISCUSSION

Farinograph characteristics: Farinographic curve characteristics such as water absorption, dough development time, stability, mixing tolerance index and softening of flours A, B and C after replacement of NaCl (2% level) with other mineral salts such as KCl, $MgCl_2$, $CaCl_2$, $MgSO_4$ and Na_2SO_4 at 25, 50 and 100% levels are presented in Table 2.

Water absorption (WA): At fixed water absorption, the maximum consistency of flours A, B and C with salt levels were below 500 BU. So the amount of water had to be decreased to centre them on 500 BU line. At fixed water absorption, some salts at certain levels centered on 500 BU.

To centre other curves at 500 BU statistically significant variations were observed in water absorption for flour, salt and proportion. Even all the possible interactions were significant. Comparing the flours, flour C had maximum WA followed by B and A in the order. There was

Table 2: Effect of salt substitutes on farinograph curve characteristics of flour A, B and C

Salt	Salt proportion	Water absorption (%)	Dough development time (min)	Stability (min)	Mixing tolerance index (BU)	Softening (BU)
Flour A						
Control (without salt)	0:0	58.7	2.00	3.25	70	105
NaCl	100:0	58.1	2.00	7.00	45	95
NaCl: KCl	75:25	57.3	2.25	8.10	45	100
	50:50	57.7	2.25	7.30	35	100
	0:100	58.7	2.00	4.18	40	110
NaCl: $MgCl_2$	75:25	56.7	2.25	6.40	40	90
	50:50	56.7	2.00	6.20	55	115
	0:100	56.3	2.00	4.60	75	120
NaCl: $CaCl_2$	75:25	57.1	2.00	6.80	35	100
	50:50	58.7	2.00	5.30	45	105
	0:100	58.7	1.75	3.40	80	113
NaCl: $MgSO_4$	75:25	58.7	2.00	3.30	30	90
	50:50	58.1	2.00	7.90	35	110
	0:100	58.1	2.25	4.80	60	115
NaCl: Na_2SO_4	75:25	56.1	2.00	7.40	40	65
	50:50	56.7	2.00	8.30	40	60
	0:100	58.7	2.00	8.00	35	60
Flour B						
Control (without salt)	0:0	61.6	2.00	5.10	50	90
NaCl	100:0	60.6	2.00	8.30	25	60
NaCl: KCl	75:25	59.6	2.25	9.00	30	60
	50:50	59.6	2.25	8.90	15	75
	0:100	60.6	2.25	7.10	20	80
NaCl: $MgCl_2$	75:25	59.8	2.50	8.60	50	105
	50:50	59.8	2.25	6.70	55	100
	0:100	60.4	2.00	5.00	60	110
NaCl: $CaCl_2$	75:25	59.8	2.25	8.30	55	105
	50:50	59.8	2.25	7.60	56	110
	0:100	60.4	2.25	4.90	65	115
NaCl: $MgSO_4$	75:25	60.4	1.75	9.20	40	90
	50:50	58.4	2.25	8.20	35	100
	0:100	58.8	2.25	6.20	45	100
NaCl: Na_2SO_4	75:25	58.7	2.00	9.00	35	70
	50:50	62.0	2.00	10.10	35	65
	0:100	60.6	2.00	9.60	30	64
Flour C						
Control (without salt)	0:0	61.9	2.00	3.75	65	110
NaCl	100:0	60.6	2.00	13.30	40	70
NaCl: KCl	75:25	61.0	2.50	12.70	35	55
	50:50	62.0	2.00	9.20	20	65
	0:100	60.6	1.75	6.60	35	90
NaCl: $MgCl_2$	75:25	61.0	2.00	9.70	20	70
	50:50	61.0	2.00	6.00	40	90
	0:100	60.9	1.75	3.30	45	95
NaCl: $CaCl_2$	75:25	60.4	2.00	9.20	45	80
	50:50	60.4	2.00	7.00	60	110

Table 2: Countinued

Salt	Salt proportion	Water absorption (%)	Dough development time (min)	Stability (min)	Mixing tolerance index (BU)	Softening (BU)
	0:100	61.0	1.75	4.00	65	115
NaCl: $MgSO_4$	75:25	61.2	2.00	8.90	30	65
	50:50	60.4	2.00	9.30	25	70
	0:100	60.6	2.25	6.60	30	90
NaCl: Na_2SO_4	75:25	60.4	2.00	9.10	40	70
	50:50	60.4	2.25	8.00	30	60
	0:100	60.4	2.00	9.40	20	60
CD at 5% for						
Flour		0.189	NS	0.050	1.102	0.739
Salt		0.244	NS	0.065	1.423	0.954
Level		0.244	0.191	0.065	1.423	0.954

decrease in WA of control (with salt) than control (without salt) in flours. Linko *et al*. (1984) also reported decreased farinograph water absorption in wheat flour with increasing sodium chloride concentrations. For flour B and C, maximum decrease in WA was with $MgCl_2$ and Na_2SO_4 in flour A, $MgCl_2$ and $CaCl_2$ in B flour and $CaCl_2$ and Na_2SO_4 in C flour with WA to centre the curve at 500 BU was almost same as for control (with salt). 100% replacement of NaCl with KCl, $CaCl_2$ and Na_2SO_4 in flour A and flour C recorded significantly high WA with all the salts and at all the levels than A and B flours. NaCl: KCl in the proportion of 50: 50 even recorded highest WA than control though statistically non-significant in flours C.

Decrease in WA was due to alteration of gluten structure in such a way that the salt occupied the sites which were occupied by the bound water (Srivastava *et al*., 1994). The effects of electrolytes on rheological dough properties are based on gluten protein aggregation. Ions may theoretically enhance either protein association or dissociation. When sodium chloride is present, association is dominant because NaCl strengthens the dough and reduces WA (Bennett and Ewart, 1965; Galal *et al*., 1978). Ionic hydrophobic bonds are involved in these reactions. Bernardin (1978) and Wehrli and Pomeranz (1969) found marginal decrease in WA with 50-75% substitution of NaCl with Kcl and $MgCl_2$. Similar results were also earlier reported by Galal *et al*. (1978) and Guy (1986).

Dough development time (DDT): Table 2 shows that flours A, B and C did not differ significantly with regards to dough development time with time ranging from 1.75 to 2.50 min. Similarly, salts did not vary significantly from one another. However, in some combinations there was statistically significant variation in the dough development time. In flour A (Table 2) NaCl:KCl 75:25 and 50:50 resulted in slight increase in DDT and it decreased slightly with 100% substitution of NaCl. In flour B (Table 2) NaCl in combination with KCl at all the three replacement levels, $CaCl_2$ at all the three replacement levels and $MgSO_4$ at 50 and 100% replacement levels improved the DDT with respect to control. However, with $MgSO_4$ substitution at 25% level reduced the DDT.

Different response was observed in flour C (Table 2), KCl at 25% replacement level increased DDT even more than control, at 50% replacement level DDT remained same as that for control and at 100% replacement level DDT decreased from control. Similarly, DDT decreased with 100% $CaCl_2$ substitution and 100% $MgSO_4$ substitution levels. However, it increased significantly at 50%

replacement level of Na_2SO_4. Increase of DDT with magnesium and sodium sulfate salts have been reported by Salovaara (1982b) and Bernardin (1978). Whereas our results show that DDT decreases with the substitution of magnesium sulphate.

Stability: Stability differed significantly for flour, salt, level and all other possible interactions (Flour A, B and C (Table 2)) Stability values for control (without salt) of flour B was more than flour A and flour C in the order showing more tolerance of doughs to mixing. For control (NaCl 2%) stability value of flour C was more than flour A and B in the order.

With other mineral salts there was improvement in stability for flour A and B but in flour C improvement was less than salt NaCl. In flour A and B there was improvement in stability with KCl at 25 and 50% level but at 100% replacement level dough stability decreased. Incorporation of $MgCl_2$ and $CaCl_2$ salts decreased the dough stability. Decrease was more at 100% replacement level in all the three flours. For $MgSO_4$ in flours A and B at 50% replacement levels stability values remained nearly same (7.90, 8.20 min, respectively) as that for NaCl control. In flour B dough stability improved at 25% replacement of NaCl with $MgSO_4$. But there was sharp, decrease in dough stability at 100% replacement level. For $NaSO_4$ as the substitution level increased, there was improvement in dough stability. In flour C, there was improvement in stabilities with increase in salt substitution levels. But it remained less than NaCl control. Overall stability values were maximum in the flour B.

Improvement in the stability with salt KCl and at increasing level has been reported by Srivastava *et al.* (1994). Earlier Salovaara (1982b) have reported that $CaCl_2$ and $MgCl_2$ reduced stability whereas $MgSO_4$ increased it.

Mixing tolerance index (MTI): Analysis of variation on mixing tolerance index of flour A, B and C revealed significant differences in flours, salts and proportions (Table 2).

MTI for flours A, B and C for control (without salt) was 70, 50 and 65 BU, respectively means weakening of flour dough was in decreasing order from flour A, C and B. With addition of NaCl, MTI values were less for three flours, indicating increased tolerance of dough towards mixing. Salt type and levels also affected MTI. Values for MTI were comparable to $NaCl_2$ when it was replaced with KCl at 25 and 100% level for all the three flours.

MTI for KCl at 50% replacement was less than NaCl control. As the replacement level of $MgCl_2$ and $CaCl_2$ increased, MTI increased means both the salts had weakening effect on dough. At $MgCl_2$ 100% substitution level, MTI for flours A, B and C were 75, 60 and 45 BU, respectively. With $CaCl_2$ at 100% substitution level MTI for flours A, Band C was 80, 65 and 65 BU, respectively. $MgSO_4$ had strengthening effect on dough at all replacement levels in flours C. In flour A and B its strengthening effect decreased with increase in replacement level. Na_2SO_4 salt had strengthening effect on dough. As the replacement level of Na_2SO_4 increased, MTI decreased in all the three flours. Values for MTI at 100% replacement for flours A, B and C was 35, 30 and 20 BU. Strengthening effect of Na_2SO_4 was more in flour C and less in flour B.

Salt increased the tolerance of dough to mixing. As sodium chloride concentration increases, there is formation of a protein network. It appears that sodium chloride neutralizes the electrostatic repulsion of gluten protein. The consequence is increased mixing time (Heidolph *et al.*, 2011). This was apparent from the decreasing value of MTI with respect to control without salt. Decrease in MTI value with addition of salt has been reported by Salovaara (1982b), Kaur and Bains (1987) and Srivastava *et al.* (1994). Salt $CaCl_2$ followed by $MgCl_2$ had weakening effect on the mixing properties of dough irrespective of the levels as compared to other salts.

Softening: Softening varied significantly with respect to flours, salts and levels and all other possible interactions (Table 2). Softening values for control (without salt) was higher for flour C than flour A and B. With NaCl incorporation in the system there was decrease in softening values which were 95, 60 and 70 B.U, respectively for flours A, B and C. With the other salt types and levels softening values differed significantly. There was similar trend in change of softening values with salts KCl, $MgCl_2$, $CaCl_2$ and $MgSO_4$ in all the three flours as for the MTI. As the replacement level of these salts increased, there was increase in softening values which were even more than NaCl. But opposite trend was observed with salt Na_2SO_4. In this case as the replacement level increased, there was decrease in softening values. At 100% substitution with Na_2SO_4, values for softening were even less than NaCl 100% in flours A, B and C, respectively showing that Na_2SO_4 salt had maximum strengthening effect on the dough. Addition of salts made dough more elastic. This was indicated by increase in bandwidth of the respective farinograms. Srivastava *et al.* (1994) reported the increase in the width of band. Of all the salts studied for replacement of NaCl, KCl had least effect on farinograms, Na_2SO_4 had maximum strengthening effect and $CaCl_2$ followed by $MgCl_2$ had distinctive weakening effect on the farinogram.

Amylograph curve characteristics: Results of pasting characteristics of flours A, B and C as influenced by various salt substitutes in flour water suspension are presented in Table 3.

Gelatinization temperature (GT): There was significant variation in mean GT for different flours, different salts and different levels. In flour A (Table 3), GT increased with all the salts as compared to control without salt. But no definite trend was observed within the different levels of substitution except for $MgSO_4$ at substitution level of 50: 50 where the values for GT were same or less than that with NaCl control. With flour B (Table 3) no definite pattern was observed with regards to GT but overall it was found that GT increased significantly with the salt addition more at 50: 50 replacement levels than 100% replacement level of NaCl. Whereas, with flour C (Table 3) a different pattern was observed with different salts the GT, though it was more than unsalted control, was even less than 100% sodium chloride. KCI at 100% replacement showed least GT. $MgSO_4$ at 50:50 replacement level showed least GT.

$MgSO_4$ and $NaSO_4$ at 100% replacement level had highest GT which showed maximum inhibition of enzymes. So response of different flours were different to different salts with respect to GT. Marginal decrease in GT with different salts has been reported by Srivastava *et al.* (1994).

Peak viscosity (PV): Peak viscosity (Table 3) differed significantly with respect to flour, salt, level and all possible interactions. For control (without salt) maximum peak viscosity was for flour B (727 BU) followed by C (660 BU) and A (545 BU) in the order. These results are supported by the results of diastatic estimation (Table 1).

In all the three flours peak viscosities increased after the addition of NaCl. In flour A (Table 3) KCl at 25% replacement level, $MgCl_2$ at 50% replacement level, $CaCl_2$ at 25% replacement level, Na_2SO_4 at 25% replacement level exhibited maximum paste viscosities. Within the replacement levels the viscosities were least at 100% replacement level. Response of flour B (Table 3) to different salt concentrations on PV was different but overall the PV increased with salts except for $CaCl_2$ at 100% substitution level. The values for PV were maximum at lower levels of substitutions. Maximum viscosity of 925 BU was observed in flour B with salt $CaCl_2$ at 100% level of substitution. Response of C flour to different salts at different concentrations (Table 3) was that the NaCl

Table 3: Effect of salt substitutes on amylographic curve characteristics of flour A, b and C

Salt	Salt proportion	Gelatinization temperature (°C)	Peak viscosity (BU)	Peak viscosity temperature (°C)	Viscosity at 95°C (BU)
Flour A					
Control (without salt)	0:0	60.50	545	92.13	460
NaCl	100:0	63.50	635	92.88	560
NaCl: KCl	75:25	62.00	715	91.75	590
	50:50	62.75	600	91.75	510
	0:100	62.00	600	92.13	510
NaCl: $MgCl_2$	75:25	62.75	690	91.00	525
	50:50	63.50	695	90.25	490
	0:100	62.00	630	90.25	470
NaCl: $CaCl_2$	75:25	62.75	715	90.25	470
	50:50	63.50	690	90.63	530
	0:100	62.00	684	90.25	570
NaCl: $MgSO_4$	75:25	62.00	695	91.75	595
	50:50	65.00	640	90.63	540
	0:100	61.25	460	90.63	440
NaCl: Na_2SO_4	75:25	63.50	710	92.50	600
	50:50	63.50	675	92.50	620
	0:100	63.50	620	92.50	640
Flour B					
Control (without salt)	0:00	61.25	727	91.00	600
NaCl	100:0	63.50	805	92.13	680
NaCl: KCl	75:25	64.25	910	93.25	840
	50:50	65.00	778	92.50	660
	0:100	65.00	820	92.50	740
NaCl: MgCl2	75:25	64.25	895	92.13	750
	50:50	65.00	850	92.13	710
	0:100	62.75	820	91.00	680
NaCl: CaCl2	75:25	64.25	870	91.75	680
	50:50	63.00	860	90.75	680
	0:100	63.50	925	90.25	710
NaCl: MgSO4	75:25	62.75	880	93.75	850
	50:50	62.00	870	92.13	720
	0:100	62.00	790	91.00	590
NaCl: Na2SO4	75:25	64.50	805	92.60	750
	50:50	64.25	885	93.25	760
	0:100	63.50	870	91.75	770
Flour C					
Control (without salt)	0:00	62.00	660	91.75	540
NaCl	100:0	64.25	760	91.75	610
NaCl: KCl	75:25	64.25	740	91.38	560
	50:50	63.88	820	91.75	660
	0:100	62.75	810	91.75	680
NaCl: MgCl2	75:25	63.50	840	91.75	710
	50:50	62.75	790	91.38	600
	0:100	63.88	760	91.75	680
NaCl: CaCl2	75:25	63.50	790	91.75	610
	50:50	62.00	815	91.00	600

Table 3: Countinued

Salt	Salt proportion	Gelatinization temperature (°C)	Peak viscosity (BU)	Peak viscosity temperature (°C)	Viscosity at 95°C (BU)
	0:100	63.50	880	90.63	680
NaCl: MgSO4	75:25	63.50	795	92.50	650
	50:50	62.75	780	91.00	580
	0:100	64.25	740	92.50	620
NaCl: Na2SO4	75:25	62.75	840	91.75	630
	50:50	62.75	835	92.50	710
	0:100	65.00	830	93.25	785
CD at 5% for:					
Flour		0.118	0.635	0.132	0.715
Salt		0.153	0.82	0.17	0.923
Level		0.153	0.82	0.17	0.923

increased the PV. PV further increased with substitution of NaCl with other salts and was maximum at lowest level of substitutions.

Increase in paste viscosities of dough after the addition of salt has been well documented by Guy (1985), Harinder and Bains (1990) and Srivastava *et al.* (1994) which could be attributed to suppressed enzymatic activity in the presence of salt (Galal *et al.*, 1978). Salt substitutes further increased the paste viscosities of doughs.

Peak viscosity temperature (PVT): Statistically peak viscosity temperature differences were significant (Table 3) for flour, salt, level and all the possible interactions. Among the control flour A showed maximum value for PVT (92.13°C) as compared to flour B (91.00°C) and flour C (91.75°C) and there was slight increase in PVT after the addition of NaCl in flour A and B but it remained same in flour C. Though statistically significant there was only a little change in PVT at different salt substitution level varying from salt to salt and no definite trend was observed. Change in peak viscosity and peak viscosity temperature with the addition of salt have been reported by D'Appolonia (1972), Kaur and Bains (1987) and Srivastava *et al.* (1994).

Viscosity at 95°C: Paste viscosity at 95°C was also found to vary statistically significant between flour, salt, level and all the possible interactions. Trends of change were similar to that of change in peak viscosity i.e., more values for viscosity were observed in all the three flours with NaCl (100%) than control (without salt). Trends with substitution of salt NaCl with other salts at different levels also remained the same. Addition of Na_2SO_4 as replacement of NaCl in all the flours had maximum viscosity at 95°C. Viscosity of wheat flour and wheat flour-sweet potato blends were studied by Adeleke and Odedeji (2010).

CONCLUSION

Based on the study it can be concluded that with the addition of salts water absorption decreased as compared to NaCl. There were non-significant changes in dough development time. Stability of the dough improved with the substitution of KCl, $MgCl_2$ and $CaCl_2$. At 25% substitution with other salts such as KCl, $MgCl_2$, $MgSO_4$ and Na_2SO_4 peak viscosity further increased but as the substitution level further increased peak viscosity decreased. Replacement of NaCl with other salts modified the mixing and pasting properties of dough. Replacing at least a part of sodium chloride with potassium or other salts should therefore be nutritionally beneficial.

REFERENCES

Adeleke, R.O. and J.O. Odedeji, 2010. Functional properties of wheat and sweet potato flour blends. Pak. J. Nutr., 9: 535-538.

Ahmed, M., M. Burhan Uddin, A. Sorifa and E. Jong-Bang, 2008. Effect of processing treatments on quality of cereal based soyabean fortified instant weaning food. Pak. J. Nutr., 7: 493-496.

Anonymous, 1990. Approved Methods. American Association of Cereal Chemists, St. Paul, Minnesota.

Bennett, R. and J.A.D. Ewart, 1965. The effect of certain salts on doughs. J. Sci. Food Agric., 16: 199-205.

Bernardin, J.E., 1978. Gluten protein interaction with small molecules and ions-the control of flour properties. The Baker's Digest, 8: 20-23.

Cerníkova, M., F. Bunka, M. Pospiech, B. Tremlova, K. Hladka, V. Pavlínek and P. Brezina, 2010. Replacement of traditional emulsifying salts by selected hydrocolloids in processed cheese production. Int. Dairy J., 20: 336-343.

Cochran, W.G. and G.M. Cox, 1957. Experimental Designs. John Wiley and Sons, Inc., New York, pp: 95-106, 244-276.

Coskuntuna, L., K. Fisun and C. Fatma, 2008. Effect of chemical content and physical characteristics on nutritional value of wheat varieties collected from thrace region. Pak. J. Nutr., 7: 218-221.

D'Appolonia, B.L., 1972. Effect of bread ingredients on starch gelatinization properties as measured by the amylograph. Cereal Chem., 49: 532-543.

El-Bakry, M., F. Beninati, E. Duggan, E.D. O'Riordandoi and M. Sullivan, 2010. Reducing salt in imitation cheese: Effects on manufacture and functional properties. Food Res. Int., 10.1016/j.foodres.2010.12.013

Galal, A.M., E. Varriano-Marston and J.A. Johnson, 1978. Rheological dough properties as affected by organic acids and salt. Cereal Chem., 55: 683-691.

Gisslen, W., 2005. Professional Baking: Chapter 3 Ingredients. 4th Edn., John Wiley and Sons Inc., Hoboken, New Jersey, pp: 29-64.

Guy, E.J., 1985. Effect of sodium chloride levels on sponge doughs and breads. Cereal Food World, 30: 644-648.

Guy, E.J., 1986. Effect of KCL levels on functional and baking properties of sponge doughs and hedonic ratings of their breads. Cereal Foods World, 31: 421-425.

Harinder, K. and G.S. Bains, 1990. High á-amylase flours: Effect of pH, acid and salt on rheological properties of dough. Cereal Chem., 67: 588-594.

Heidolph, B.B., D.K. Ray, S. Roller, P. Koehler, J. Weber, S. Slocum and M.W.J. Noort, 2011. Looking for my lost shaker of salt replacer: Flavor, function, future. Cereal Foods World, 56: 5-18.

Katsiari, M.C., L.P. Voutsinas, E. Alichanidis and I.G. Roussis, 1998. Manufacture of Kefalograviera cheese with less sodium by partial replacement of NaCl with KCl. Food Chem., 61: 63-70.

Kaur, H. and G.S. Bains, 1987. High alpha-amylase flours: Effect of pH, acid and salt on paste characteristics. Cereal Chem., 64: 356-363.

Kusunose, C., T. Fujii and H. Matsumoto, 1999. Role of starch granules in controlling expansion of dough during baking. Cereal Chem., 76: 920-924.

Launay, B.L. and C. Michon, 2006. Rheology of Wheat Flour Doughs: Measurement. In: Encyclopedia of Agricultural, Food and Biological Engineering, Heldman, D.R. (Ed.). Taylor and Francis, New York, UK..

Linko, P., H. Harkonen and Y.Y. Linko, 1984. Effects of sodium chloride in the processing of bread baked from wheat, rye and barley flours. J. Cereal Sci., 2: 53-62.

Luchian, M.I. and C.M. Canja, 2010. Effect of salt on gas production in bread dough. Bull. Transilvania Univ. Brasov. Ser. II, 3: 167-170.

Lynch, E.J., M.M. Moore and E.K. Arendt, 2007. A technological approach to reducing sodium in bread. Cereal Foods World, 52: 23-23.

Lynch, E.J., F. Dal Bello, E.M. Sheehan, K.D. Cashman and E.K. Arendt, 2009. Fundamental studies on the reduction of salt on dough and bread characteristics. Food Res. Int., 42: 885-891.

Miller, R.A. and R.C. Hoseney, 2008. Role of salt in baking. Cereal Foods World, 53: 4-6.

Mondal, A. and A.K. Datta, 2008. Bread baking: A review. J. Food Eng., 86: 465-474.

Niman, C.E., 1981. Salt in bakery products. Cereal Foods World, 26: 116-118.

Odedeji, J.O. and R.O. Adeleke, 2010. Pasting characteristics of wheat and sweet potato flour blends. Pak. J. Nutr., 9: 555-557.

Palar, K. and R. Sturm, 2009. Potential societal savings from reduced sodium consumption in the US adult population. Am. J. Health Promotion, 24: 49-57.

Peressini, D., 2001. Evaluation methods of dough rheological properties. Tecnica-Molitoria, 52: 337-379.

Pomeranz, Y. and C.E. Meloan, 1994. Rheology. Food Analysis Theory and Practice. 3rd Edn., Chapman and Hall, Inc., New York, pp: 449-483.

Razmi-Rad, E., B. Ghanbarzadeh, S.M. Mousavi, Z. Emam-Djomeh and J. Khazaei, 2007. Prediction of rheological properties of Iranian bread dough from chemical composition of wheat flour by using artificial neural networks. J. Food Eng., 81: 728-734.

Rosell, C.M., 2011. The Science of Doughs and Bread Quality. In: Flour and Breads and their Fortification in Health and Disease Prevention, Preedy, V., R. Watson and V. Patel (Eds.). Academic Press, Spain, pp: 3-14.

Salovaara, H., 1982a. Effect of partial sodium chloride replacement by other salts on wheat dough rheology and breadmaking. Cereal Chem., 59: 422-426.

Salovaara, H., 1982b. Sensory limitations to replacement of sodium with potassium and magnesium in bread. Cereal Chem., 59: 427-430.

Salovaara, H., 2009. Technologies for Salt reduction in bread: Issues, problems and solutions. Salt in Bread: Technical, Taste and other Parameters for Healthy Eating. Seminar 21. Centre de Conferences Albert Borschette (ccab) 36, rue Froissart B-1040 Brussels.

Srivastava, A.K., V.R. Patel and P.H. Rao, 1994. Effect of common salt substitution on the dough characteristics and break quality. J. Food Sci. Technol., 31: 15-18.

Sroan, B.S. and A. Kaur, 2004. Effect of antioxidants on farinograph and amylograph characteristics of wheat flour. Int. J. Food Properties, 7: 379-391.

Taormina, P.J., 2010. Implications of salt and sodium reduction on microbial food safety. Crit. Rev. Food Sci. Nutr., 50: 209-227.

Wehrli, H.P. and Y. Pomeranz, 1969. The role of chemical bonds in dough. Bakers Digest, 43: 22-26.

Weipert, D., 1990. The benefits of basic rheometry in studying dough rheology. Cereal Chem., 67: 311-317.

Yasar, S., 2002. *In vitro* and *in Vivo* variability in the nutritional compositions of wheat varieties. Pak. J. Nutr., 1: 248-256.