EFFECTS OF FERMENTED PRODUCTS AND SODIUM CHLORIDE SUBSTITUTES ON SELECTED PROPERTIES OF WHITE BREAD AND DOUGH

By

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EFFECTS OF FERMENTED PRODUCTS AND

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PROPERTIES OF WHITE BREAD AND DOUGH

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Title of Study: EFFECTS OF FERMENTED PRODUCTS AND SODIUM CHLORIDE SUBSTITUTES ON SELECTED PROPERTIES OF WHITE BREAD AND DOUGH.

Major Field: FOOD SCIENCE

Reducing sodium content in bread is a challenging proposition since sodium chloride contributes to more than saltiness perception in bread products. The objective of this study was to assess the effect of salt substitutes and fermented products (wheat-soybean tempe flour and sourdough) on flavor profile and rheological properties of bread. Tempe is an Indonesian traditional fermented food which is made by fungi fermentation of soybeans and other legumes.The desirable taste, flavor, texture, acidity and aroma are produced by the hydrolysis of substrates by enzymes. Sourdough process is very simple and is based on naturally occurring yeasts in the cereal grains. A commercial wheat flour with protein content 11 ± 0.5% was treated with sourdough (0, 11, 17 and 33% w/w) and tempe (0, 2, 3.5 and 5% w/w) and baked. Three sensory analysis sessions were conducted to determine the seven parameters flavor profile by 80 untrained panelists. This study showed that for saltiness score, the combination of 17% sourdough, 3.5%, panelists could not detect the difference in saltiness perception between 0.75 and 1.5% NaCl. One commercial wheat flour with protein content 11.8% was treated with different levels sodium chloride (0.75, 1.5 and 2.0%), wheat-soybean tempe flour (2 and 3.5%) and sourdough (17 and 33%) following a Randomized Complete Block Design with 3 replicates to analyze the rheological properties. Increase in development time, stability time and breakdown time was observed with elevation of NaCl levels. Development time and breakdown time decreased with increase in sourdough (17 vs 33%). A set of three commercial wheat flours with protein content 9.8, 10.9 and 13.4% was treated with sodium chloride (control) as well as five commercial NaCl substitutes following a Randomized Complete Block Design with 3 replicates to analyze the effect on rheological properties. Mixing properties showed that development time and stability time were directly proportional to the level of salt. Maximum resistance to extension (R_{max}) and area under the curve increased with an increase of NaCl level. NaCl resulted in a higher area than commercial NaCl substitutes when each level of salt was analyzed.

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CHAPTER I

INTRODUCTION

Statement of problem

Recently, there has been a lot of research going on regarding the effect of sodium chloride (table salt) on human health. It is being reported that high consumption of sodium chloride can result in cardiovascular diseases and other health issues as well (Elliott et al., 2007) (du Cailar et al., 2002). Bread is a staple food throughout the world and has been found to be a major source of dietary sodium (Greenfield et al., 1984) (James et al., 1987) and it is responsible for an average of 30% of the daily salt intake (Girgis et al., 2003). Reduction of salt in bread therefore, has an adverse effect on the bread quality for consumer acceptance and industrial machinability. Salt improves dough handling and processing (Hutton, 2002) and final product characteristics (Kilcast and Angus, 2007b). Possible alternatives of salt have been tried. 32% of the sodium in bread has been replaced successfully by a mixture of magnesium chloride, potassium chloride and magnesium sulfate. The resulting breads were comparable to regular bread with respect to flavor and texture (Charlton et al., 2007).

Purpose of study

i. To analyze the effect of fermented products (wheat-soybean tempe flour and sourdough) in white bread with respect to flavor profile as evaluated by sensory analysis.

ii. To investigate the effect of fermented products (wheat-soybean tempe flour and sourdough) in the rheological properties of dough namely farinograph and extension properties.
iii. To determine the effect of commercial sodium chloride (NaCl) substitutes on the farinograph and extension properties of dough. Three commercial wheat flours, one soft red winter wheat (F1) and two hard red winter wheat (F2 and F3) protein contents 9.8, 10.9 and 13.4% respectively were studied.

Hypothesis

Null hypotheses of this study are

i. There is no significant difference in the scores (sensory analysis) of the bread with fermented products when compared with control treatment which was devoid of fermented products.
ii. There is no significant difference in the rheological properties (mixing and micro-extension) between treatments with and without fermented products in it.
iii. There is no significant difference in the rheological properties (mixing and micro-extension) between control treatment (NaCl) and treatments with commercial sodium chloride (NaCl) substitutes.

Alternate hypothesis

If the null hypotheses is rejected, then the effect of fermented products i.e. sourdough and wheat-tempe flour will be explained in terms of possible factors that affected flavor parameters of bread and rheological properties (mixing and extension) of dough. Also, the effect of commercial sodium chloride substitutes (NaCl) on rheological and empirical properties (mixing and extension, respectively) will be explained.

Assumptions

It is assumed that interaction effect of different levels of sodium chloride, sourdough and wheat-soybean tempe will produce a significant effect on the nutritional quality and sensory attributes in the ferm ented product fortified white bread. Lactic acid is produced as the main product of carbohydrate fermentation by sourdough lactic acid bacteria. Therefore, an acidic taste will be provided by sourdough. Wheat-soybean tempe flour is assumed to have a desirable taste, flavor, texture, acidity and aroma are produced by the hydrolysis of substrates by enzymes. The interaction of the fermented products as a whole can lead to a complex flavor profile that might lead the panelists of sensory evaluation not to detect the lower levels of sodium chloride as compared to regular bread. Fermentation of wheat and soybean during formation of tempe flour alters the baking characteristics. Therefore, it is assumed different levels of sourdough, tempe and sodium chloride will lead to machinable dough. The commercial sodium chloride substitutes are also assumed to affect the rheological properties of wheat dough.

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CHAPTER II

REVIEW OF LITERATURE

Mixing properties

NaCl serves as an important role in food and it differs from each kind of food from manufacturing until the end product is achieved. We have learned earlier that the maximum sodium intake is from baked products like bread, typically 100-200 mg of sodium in 1 ounce of a bread slice (Beck, 2012). So, researchers have been constantly trying to reduce the sodium content by testing with different salts mixtures so as to attain palatable end product. Studies have been focused on the impact of NaCl on mixing properties of dough using the Farinograph (Galal et al., 1978)**.** The dough showed a relatively marked change when salt was added to the flour, especially 1.5%; there was an increase of 2 min in the dough development and 1.4% decrease in water absorption (Galal et al., 1978). With the addition of NaCl there was a considerable decrease in water absorption and increase in dough development time. This phenomenon was explained by a charge shielding of proteins by NaCl and an increase in protein crosslinking. At a constant dough consistency and varying water absorption, the addition of 0.25% salt decreased water absorption by 1.2%, while with 1 and 2% salt, the water absorption decreased by 2.3 and 3%, respectively (Galal et al., 1978). At constant water absorption (60%), the dough consistency decreased by 40BU with the addition of 0.25% salt. At higher absorptions the decrease was smaller. At 60% absorption, the dough consistency decreased to 70 BU and 90 BU by addition of 1% and 2% salt respectively (Hlynka, 1962b). The decrease in water absorption was explained by changes of free (mobile) and bound water (Bushuk and Hlynka, 1964). It was proposed that salt increases the amount the free water in the dough system by altering the gluten structure. The salt occupies the sites where the bound water had previously occupied and thus the water absorption is less with the addition of salt. It was further interpreted that when salt is added to the dough system (pH 5.5-6.0) the intramolecular and intermolecular repulsion decreased by interacting with the charged groups on the protein molecules. So, the salt ions interact with the proteins and it decreases the amount of water which the gluten can bind (Galal et al., 1978). In a Farinograph test the dough consistency increased with decreased pH by acetic acid in the absence of sodium chloride. But on the other hand, the consistency decreased to a very low value with the addition of salt (Tanaka et al., 1967).

An increase in the peak height of the dough was observed with increased concentrations of NaCl and KCl (Lang et al., 1992). The effect of different salts on the mixograph properties (NaCl, KCl, KNO_3, Na_2SO_4, $CaCl_2$ and $MgSO_4$) was studied at 1.3% and 2.6% concentrations. The peak height was decreased by using 2.6% KNO_3 at a low absorption (58%), but was increased at higher absorption as compared to the control (KNO_3 0%). $CaCl_2$ showed a very little effect in peak height whereas for Na_2SO_4 the peak height increased at all concentrations. 2.6% $MgSO_4$ resulted in a greater peak height as compared to other salts. The increase of peak height, rather than decrease, shows that the behavior of the sulfates did not result from the residual traces of sulfites (Lang et al., 1992).Various aspects of mixograph properties of dough have been investigated. Before starting the mixograph, NaCl (0-10%) has been added to water (Danno and Hoseney, 1982). With increasing amounts of salts up to 5%, there was an increase in the width and height of the mixogram curves but at 10% salt, the water was not incorporated into the dough. The mixing time of the flour increased from 4 min to 7 min with 5 % salt (Danno and Hoseney, 1982). The addition of 2% dry salt to flour increased the mixing time whereas 2% salt in the form brine did not lengthen it (Sanchez et al., 1973) as quoted by (Danno and Hoseney, 1982). The authors also worked with various levels of Sodium Dodecyl Sulfate (SDS). Moderate concentration of SDS (0.5 and 1%) generated similar curves and wide mixogram curves at the peak. But, with increased level of SDS (2 and 3 %) resulted in shorter mixing times. There is a different angle to the scenario of the over mixed dough considering NaCl and SDS addition. When 5% of dry NaCl was added to the dough and mixed for 10 min, the mixogram reflected a rapid broadening at the thin tail as well as an increase in the curve height. Similar results were obtained when 1% SDS was added to the over mixed dough (Danno and Hoseney, 1982).

Farinograph

A number of studies have been reported on the dough mixing properties analyzed with a farinograph which are listed in Table 1. The effect of salt, water and temperature on dough rheology with five levels of each variable namely salt (0, 1, 2, 3 and 4%), water (50, 56, 62, 68 and 74%) and temperature (20, 25, 30, 35 and 40°C) and the non-linearity among them were studied. Each of these variables had significant effects on dough consistency, hydration and total energy which were measured by a farinograph in Farinograph Units (FU)(Farahnaky and Hill, 2007). At 20 min, the dough consistency decreased with the addition of water from 50 to 74% and the salt from 0 to 4%. When studying the effect of salt on hydration time, it was observed that salt level had a minor effect as compared to water and temperature. In fact, water and temperature had a positive effect whereas salt had a negative effect (Farahnaky and Hill, 2007). Farinograph studies indicated that the water absorption increased with the decreased rate of NaCl concentration (40-0 g/kg flour)(Beck et al., 2011).The authors proposed that the decreasing protein hydration capacity was due to the competition of the sodium and chloride and water molecules on the protein surface. This may also result in a more interconnected protein structure leading to a more stable, flexible and less sticky dough. A decrease in dough stability was observed with reduced NaCl, 18.47 min for dough mixed with 40g NaCl/kg flour vs 3.73 min for the reference dough (without salt), with levels of >15g/kg (Beck et al., 2011). An interesting fact was also recorded that the effect of overmixed wheat dough can be reversed by the use of NaCl (Danno and Hoseney, 1982). The dough which has become sticky and lost its elastic properties can be regained back to a less sticky and more elastic state with the addition of NaCl (Danno and Hoseney, 1982).

Table 1. List of studies of rheological properties of NaCl on wheat dough.

Author	Methodology	Results
(Galal et al., 1978)	Mixing (farinograph) properties of dough as affected by addition of salt and organic acids. Mixing time and stability of dough was studied.	Salt increased the mixing time and stability of dough. The original mixing profile of the flour could be restored by decreasing the amount of salt from 1.5% to 1%.
(Hlynka, 1962b)	Effect of salt on dough consistency, absorption rate and dough development time in the farinograph.	Increase of NaCl leads to decrease in water absorption and dough consistency. Increase in NaCl leads to increase in dough development time.

Author	Methodology	Results
(Tanaka et al., 1967)	Effect of acid and salt on the mixing (farinogram) and extensibility (extensigram) of dough.	Mixing properties (absence of NaCl results in increased dough consistency and vice-versa at low pH). Without NaCl, the resistance showed a fixed lower level at pH 5.9-4.3. With NaCl, resistance increased when pH was reduced for 5.8-4.2 whereas in absence or presence of salt, extensibility showed a marked decrease.
(Lang et al., 1992)	Effects of acidification, sodium chloride, and moisture levels on wheat dough	An increase in the mixogram peak height of the dough with the increased concentrations of NaCl.
(Farahnaky and Hill, 2007)	Effect of salt, water and temperature on dough rheology was modeled. Consistency, hydration and total energy was measured by a farinograph.	Addition of NaCl- decrease in dough consistency and total energy, increase in hydration time (low water levels). The effect of salt was low compared to temperature and added water.
(Beck et al., 2011)	Rheological properties of wheat dough at different levels of sodium chloride (NaCl) addition ranging from 0 to 40 g NaCl/ kg wheat flour.	Water absorption increased with decreased rate of NaCl concentration (40-0 g NaCl/kg flour)

NaCl preserving effects

Sodium chloride has been used for preservation since ages. The key to its antimicrobial activity of salt is based on the water activity. Water activity (a_w) of food is defined as the ratio of the partial pressure of water in the atmosphere in equilibrium with the system (p) to the partial pressure of pure water (atmosphere in equilibrium) at the same temperature (p_0).

Where, $a_w = p/p_0$ (Beck, 2012).

Water activity can also be defined in terms of equilibrium relative humidity (ERH= $100a_w$). The growth of the microorganisms can be reduced with the addition of salt as they maintain a certain defined level of cytoplasmic water (Kilcast and Ridder, 2007). Bread displays a moisture content which typically ranges from 18-42% (ERH= 88-95%). The water activity of bread therefore is between 0.88-0.95 (Kilcast and Ridder, 2007). Sodium chloride addition plays a pivotal role here since at this moisture content (rather RH) the bread is susceptible to spoilage, so by the addition of salt the moisture content can be reduced and thus it takes more time for the bacterial or mold spoilage (Hammes and Gänzle, 1997b). The yeast leavening rate is indirectly affected by NaCl since it lowers the oxygen solubility (Kilcast and Ridder, 2007).The effect of reduction NaCl is on the yeast activity since the yeast cell membrane changes the electro-chemical potential when it comes in contact with Na^+ and Cl^- ions (Kilcast and Ridder, 2007). Therefore the role of addition of NaCl is important to prevent microbial growth and also to control the yeast's leavening activity. Now the question of reduction or replacement of sodium chloride arises. If NaCl is replaced partially or fully, a loss of shelf-life and loss of stability of the products is observed (Bidlas and Lambert, 2008). Since, the microbial growth depends on water activity, sodium chloride replacers have different capacity of suppressing water activity and therefore it will affect the microbial stability and shelf-life of food products (Samapundo et al., 2010).The effect of reduced NaCl on the growth of molds and on the microbial spoilage of bacteria was studied. There was no significant change in the mold growth (*Penicillium roqueforti*) when the NaCl was reduced by 30% i.e. from 18g NaCl/kg flour to 12 g NaCl/kg flour (Samapundo et al., 2010). Thus, a safety limit is yet to be analyzed for prevention of microbial growth and the necessity to include preservatives. A study of staling of bread with reference to NaCl was conducted where three levels of NaCl were used (0.3, 0.6 and 1.2% NaCl) and was compared with a reference (without NaCl) (Lynch et al., 2009b). Bread without NaCl was comparatively harder (higher crumb hardness) after 120 h of storage than the breads with salt. The authors concluded that there is an impact of salt on the bread staling behavior (Lynch et al., 2009b). The changes in bread staling have been explained by two factors. The first being the fact that the dough is too highly viscous for allowance of expansion of gas bubbles and secondly the dough not being capable for retaining the gas bubbles which therefore might disperse during proofing and oven rise (Onyango and Mutungi, 2008). Consequently, the lost gas directly leads to the decrease in crumb porosity and increase of crumb firmness (Onyango and Mutungi, 2008). Starch retrogradation increased almost linearly with NaCl reduction. This is probably based on the theory that by NaCl addition the larger Na^+ ions are entrapped instead of smaller H^+ ions inside the starch molecules, leading to less starch recrystallization. The discussion of positive effects of sourdough on bread is very important. Sourdough represents a "clean label" and lactic acid bacteria have been considered ''generally regarded as safe'' organisms. Sourdough improved mineral bioavailability. Phytates are present in the cereals in the form of insoluble complex which reduces the bioavailability of minerals. But low pH activity by chemical or microbiological acidification of wheat dough helps to solubilize the phytate complex (Korakli et al., 2002).

Fermentation and baking

The fermentation process comprises two parts namely "intermediate proofing" and "final proofing" which are before and after molding respectively. The dough development is considered as a process of continuous stretching of the gas cell membranes in a biaxial direction. This leads to the hardening of the gluten network and therefore it affects the gluten structure. Fermentation is extremely important due to the flavor development attributes (Sluimer, 2005).

By conducting an experiment on the Rheofermentometer, it was observed that the reduction of salt lead to a maximum increase in the dough height because it increased the total volume of the released gas. It was also observed that with the increase in the gas production, the gluten network weakened due to the reduction of NaCl and consequently, the gas was not retained in the dough and CO_2 was lost (Lynch et al., 2009b).This was explained on the basis of effect of salt on yeast activity. The salt inhibits the yeast growth due to the osmotic pressure and the action of the sodium and chloride ions on the semi permeable membrane of yeast cells (Miller and Hoseney, 2008). With the reduction of salt, there is a higher CO_2 production due to the increased yeast activity (Miller and Hoseney, 2008). The dough with reduced salt led to excessive fermentation and resulted in much more gassy and acidic dough and the baked loaf displayed poor texture and open grain (Matz, 1992). Reduced NaCl leads to an increase in the loaf volume (Beck et al., 2012). In a comparison study with 40 g NaCl/kg flour and 5 g NaCl/kg flour the loaf volume increased significantly by 55% from 3.6 cm^3/g flour to 5.6 cm^3/g flour (Beck, 2012). According to (Beck, 2012), the decrease in the loaf volume with high amounts of NaCl occurs due to two factors. Firstly, the NaCl strengthens the protein network to the extent where the inner cell gas pressure was too low to aid the expansion of dough further. This explanation was in support of (Lynch et al., 2009b). At a slightly acidic pH (6.0) in wheat dough, the gluten surface molecules repulse each other since they display positive charge, With the addition of a low level of NaCl (0.05 mol/L), the charge repulsion of the amino acids on the surface of the gluten protein is being cancelled out and consequently, gluten acts as a neutral dipole. This ionic bond by electron sharing may reduce the electrostatic repulsion and therefore, there is a protein network development. Second, in support of the statement by (Miller and Hoseney, 2008), it was explained that high levels of NaCl resulted in a retarded yeast activity. With higher concentrations of NaCl outside the yeast cell and low solute concentration inside the cell, the water draws out of the cell thereby limiting the leavening activity of the cell. An estimation of gas production and the ability of dough to retain gas, allowing evaluation of the fermentative capacity of flours and yeast activity is performed by the use of a rheofermentometer. Dough height during maximum dough development (H_m) and the height at the end of the test (h) increased significantly, by 182% while decreasing the NaCl from 40g NaCl/ kg to 20g NaCl /kg equivalent to 50% reduction. The time taken for the dough to reach the maximum height (T_1) was less for the dough without NaCl compared to the dough with NaCl because the former dough could not retain the produced gas. The total volume of CO_2 (V_T) increased significantly with decrease in NaCl from 40 g NaCl/kg to 0g NaCl/kg. A question was posed while performing the test: if all doughs would reach the maximum height, what would be the fermentation time for each dough. So, Beck considered flour which contained 20 g NaCl/kg and the height of 60 mm as a reference. Dough without NaCl took a proofing time of 45 min to attain the height of 60 mm whereas the dough with 20 g NaCl /kg took 118 min for proofing. A similar trend can be observed regarding the retention volume of CO_2 (V_R), since the reduction of NaCl led to more fermentation and production of CO_2 by yeast. NaCl had no effect in crumb firmness between 0 and 20 g NaCl/kg flour (Beck et al., 2011).

NaCl substitutes

In the discussion of reduction of sodium in baked products sodium replacers need to be used at levels such that the technological, baking, preserving and sensory properties are maintained. NaCl substitutes are sodium replacers such as potassium, calcium, magnesium and lithium in the form of chloride salts; anions like phosphate and glutamate were a part of the study. Salts like lithium and ammonium chloride had a negative side in spite of having a salt-like taste since it was not heat stable and especially for lithium due to its toxic accountability (Charlton et al., 2007). Potassium chloride has been preferred in terms of replacement (Roselt et al., 1995).

Reports that to 20% NaCl can be replaced by KCl in wheat bread without affecting the sensory attributes (Salovaara, 1982b) (Braschi et al., 2009; Charlton et al., 2007) contrasted with the result of some other researcher who claimed the KCl gives bitter, metallic and chemical taste in wheat pastries (Salovaara, 1982a) (Bartoshuk, 2000). In support of the statement by Salovaara (1982a), it was also stated that in case of substitution of sodium salts with potassium salts at higher levels (30-50%), the foods produced an off flavor. When calcium chloride ($CaCl_2$) was used as sodium replacer a different behavior in taste at different concentration was reported. At low concentration of 1mM, it tastes bitter, sweet and sour but at a higher concentration of 100mM, $CaCl_2$ displays a much more salty and bitter taste (Lawless et al., 2003) (Tordoff, 1996). The cations were also taken into consideration and when iodide, gluconate and sulfate salts were used, they caused an off-flavor or a rubbery texture in bread (Takano and Kondou, 2002). All the salts that have been used to replace sodium like KCl, $CaSO_4$ and $CaCl_2$ have found to decrease the loaf volume (Danno and Hoseney, 1982). This might be possible due to the change in the yeast leavening activity, same effect has been found in other salts like $NaPO_4$, $NaSO_4$ and NaJ (Danno and Hoseney, 1982). Magnesium salt ($MgSO_4$) has been found to be bitter in higher concentrations but salty in low concentrations and therefore, it can be used as a sodium replacer if combined at different concentrations with other substances (Delwiche et al., 1999; Lawless et al., 2003) (Shallenberger, 1993).

Since most of the sodium replacers have been found to be bitter, research has been done to reduce the bitterness in the form of bitterness blocking and saltiness enhancing. Initially, sweeteners have been used to decrease the bitterness. Sucrose (Kilcast and Angus, 2007a), trehalose (Toshio et al., 1997), lactose (Kilcast and Angus, 2007a) and thaumatin (Birch, 2000) has been experimented. Thaumatin displays a more sugar-like behavior and therefore may not be helpful in baking bread (Kilcast and Angus, 2007a). However, 2, 4-dihydroxybenzoic acid has been found effective in masking bitterness without affecting sweetness (Kurtz and Fuller). Another bitter blocker described was, adenosine 5'- monophosphate (AMP) (Ming et al., 1999).

Going with these experiments many new substances have been tried, which enhances the salt perception of a material which tastes salty without a significant increase in the sodium content. L-lysine and L-arginine were one of the salt boosters which was from fermented starch and they stimulate the salt perceptions (Kilcast and Ridder, 2007). Sodium, potassium and calcium lactates were also considered to be salt enhancers (Kilcast and Angus, 2007a; Takano and Kondou, 2002) (Steven, 1973). There has been an argument related to some dipeptide derived from L-Ornithine which increases saltiness (Tada et al., 1984). Contrasting this statement in 1987, it was re-experimented and seen that the saltiness of Orn-Tau-HCl derived was the result from the residual NaCl present as a process of the preparation (Tuong and Philippossian, 1987). Monosodium glutamate acts as a taste enhancer but enhances salt perception as well (Ball et al., 2002) (Roininen et al., 1996) (Kilcast and Ridder, 2007)**.** However, only one component cannot replace sodium because of several factors but a combination of different materials can be used in optimum concentration to achieve the proper taste and preserve it successfully to a greater extent.

Sourdough

Sourdough process of making bread is very primitive because of the naturally occurring yeasts in the cereal grains, and it was predominant until nineteenth century when the specially prepared baker's yeast came into existence (Pederson, 1971). (Seibel and Brummer, 1991) suggested a definition of sourdough as "dough made of cereal products (and other ingredients, if required), liquids, and microorganisms (such as lactic acid bacteria and yeasts) in an active state. Acidification (fermentation) produced by these substances is a continuous process. The activity of the microorganisms is never interrupted. Microorganisms contained in the flour can also be activated in the course of this process." The association between acidification and bacterial metabolism caused by lactic acid bacteria and yeasts in sourdoughs was first shown in 1894 (Hammes and Gänzle, 1997a). In wheat flour a myriad species of lactic acid bacteria occur which include members of genera Lactobacillus, Lactococcus, Pediococcus, Enterococcus and Leuconostoc (Hammes and Vogel, 1997). There are certain methods by which a culture can be started, equal amounts of flour and water are mixed to form dough and allowed to stand at 26-35°C.The gram-negative enteric bacteria present in the flour initiated the process of fermentation. The dough becomes acidic with the domination of the lactic acid bacteria in it (Röcken and Voysey, 1995). Sourdoughs have been classified into three types according to the technology applied for the production of sourdoughs (Bo¨cker et al., 1995). In Type 1 dough, a continuous propagation technique is used to maintain the activity of microflora, which is acquired by the multi-stage process. *Lactobacillus sanfranciscensis* usually dominates and is isolated from the sourdough of this type. In Type 1 sourdough, the microbes which are sensitive to low pH levels and therefore if ambient temperatures and acidification is maintained, then the acid-resistant microbes will be dominant. With the increase in the demand of modern baking technologies, Type 2 sourdough has become prevalent which are produce by continuous propagaton and extended fermentation times. As compared to Type 1 sourdoughs, Type 2 sourdoughs can be produced in larger volumes which are softer and also can be stored up to 1 week. A single fermentation time of 15-20 hours is employed which reduce the gas formation by lactic acid bacteria; baker's yeast is also used for leavening purposes. The microflora present in the sourdough is *L. pontis, Lactobacillus panis, Lactobacillus reuteri, and Lactobacillus fermentum* (Vogel et al., 1999). Type 3 sourdoughs are artificially composed and dried and the starter culture has been chosen according to their stability to sustain drying. The isolates which match these properties have been identified as *Lactobacillus plantarum, Lactobacillus brevis, and Pediococcus pentosaceus* (Bo¨cker et al., 1995).

Sensory analysis

The sensory analysis of bread is conducted according to color, texture, volume and flavor. However, the characteristic aroma of bread is the major parameter which determines the acceptability amongst consumers. The flavors that contribute to bread consists of volatile and non-volatile compounds which includes acids, alcohols, ethers, aldehydes, ketones, esters, furans, hydrocarbons, lactones, pyrroles, pyrazines and sulfur compounds. More than 540 compounds have been detected in the complex fraction of bread (Quilez et al., 2006). Salt and lactic acid are the main non-volatile compounds that affect the flavor of bread (Calvel, 2001). For the manufacture of sourdough fermented wheat germ (SFWG) bread, *Lactobacillus plantarum* LB1 and *Lactobacillus rossiae* LB5 were isolated from wheat germ and used as starters. As determined by sensory analysis, SFWGB had a more acidic taste and flavor and resulted saltier than raw wheat germ bread (RWGB) and wheat flour bread (WFB) (Rizzello et al., 2010).The perception of saltiness in wheat bread is again affected by the crumb texture and release of sodium ions during chewing. Two types of breads were created each having a difference in proofing time. The coarse-pored bread (90/120 min vs 20/40 min as control proofing time) lead to a significantly faster release if sodium as compared to a fine-pored bread (0/0min) which was measured in-mouth and by mastication simulator. This method resulted in a significantly higher saltiness perception in 90/120 min bread as compared to 20/40min bread. Therefore, saltiness perception was affected by velocity of sodium release and by crumb texture. Modification of crumb texture can be used to reduce salt in wheat bread (Konitzer et al., 2013) (Pflaum et al., 2013). Usage of coarse-grained NaCl in bread-making led to enhanced saltiness perception and thereby allowing a 25% reduction of sodium yet maintaining the taste quality (Konitzer et al., 2013).

Studies have given an outlook about sensory adaptation of salt and sour modalities (Delwiche et al., 1999). The specific sodium-specific receptor for salty taste is provided by epithelial sodium channel in the tongue whereas a non-specific salt receptor is a variant of vanniloid receptor-1 non-selective cation channel, TRPV1 (Delwiche et al., 1999).

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CHAPTER III

ASSESSMENT OF SODIUM CHLORIDE, WHEAT-SOYBEAN TEMPE FLOUR AND SOURDOUGH ON THE FLAVOR PROFILE OF WHITE BREAD

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Abstract

The sodium content in bread comes from NaCl for developing gluten maintaining the palatability and texture of bread. Reducing sodium content in bread is a challenging proposition since sodium chloride contributes to more than saltiness perception in bread products. The objective of this study was to evaluate the effect of sodium chloride and fermented products (wheat-soybean tempe flour and sourdough) on the flavor profile of white bread. A commercial wheat flour (protein content 11%) was treated with sourdough (0, 11, 17 and 33% w/w) and tempe (0, 2, 3.5 and 5% w/w) and baked using AACC International Optimized Straight Dough Bread Baking Method. Sensory analysis was conducted with 80 untrained panelists. 5% tempe significantly decreased the scores of all flavor parameters whereas sourdough levels (11, 17 and 33%) and NaCl levels (0.5, 1.0 and 1.5%) did not have any significant effect. 2% tempe and sourdough levels (0, 17 and 33%) did not have any significant effect on bread flavor profile scores. NaCl (0, 0.75 and 1.5%) significantly increased the bread flavor profile scores except aroma. Regarding saltiness score, in the treatment of 17% sourdough and 3.5% tempe, panelists did not detect differences in saltiness perception between 0.75 and 1.5% NaCl. This study suggests that the fermented products enhanced the saltiness perception even when lower levels of NaCl were used. Therefore, fermented products can be used as a partial replacement of sodium chloride in bread.

Keywords: Bread, sensory evaluation, fermented products, tempe, sourdough

Introduction

Sodium chloride (NaCl) has important functions in bread characteristics such as improving sensory attributes by imparting flavor, improved bread texture, controlled fermentation rate and increase of shelf life by reduced mold spoilage (Man et al., 2007).The technological effects of salts include development of gluten structures during dough mixing process, inhibition of yeast growth resulting in reduced gas release during fermentation and control of water activity in baked products (Hammes and Gänzle, 1997b). Bread is a staple food worldwide and a major source of dietary sodium (Greenfield et al., 1984; James et al., 1987), responsible for an average of 30% of the daily salt intake (Girgis et al., 2003). Different methods of sodium reduction such as using sodium substitutes and gradual reduction of salt over time have been suggested to reduce the risk of cardiovascular diseases.

Sourdough is considered one of the oldest forms of biotechnological processes in food production (Röcken and Voysey, 1995). Usage of sourdough has improved bread flavor attributed to increased levels of acetic acid, 2-methylpropanoic acid, and 3-methylbutanoic acid. Sourdough at 5-20% sourdough resulted in a significant ($p < 0.05$) increase in the bread loaf volume as compared to control bread without sourdough (Hansen and Hansen, 1996). Reports of aroma volatiles during baking were attributed to precursor compounds like ornithine, leucine, and phenylalanine that accounted for the formation of aroma volatiles during baking. It also provided substrates for the microbial conversion of amino acids and flavor precursor compounds (Thiele et al., 2002) (Schieberle, 1996). Empirical techniques used in the rheology of fermented dough (sourdough) have shown a decrease in resistance to extension and increase in both extensibility and degree of softening (Di Cagno et al., 2002). The positive influence of lactic acid bacteria on the crumb aroma of wheat bread has been studied (Hansen and Hansen, 1996). 2-phenylethanol has been reported as of the most potent odorants of the wheat crumb (Grosch and Schieberle, 1997) which increased in sourdough-enriched wheat bread (Gassenmeier and Schieberle, 1995).

Volatile components of sourdough are dependent on the starter culture and flour (Hansen and Hansen, 1994a). Chemically acidified dough also lead to the generation of some volatile compounds (Hansen and Hansen, 1994b) but the intensity of flavor in bread with biological preferment was higher compared to breads with chemical acidification (Thiele et al., 2002). The improved levels of amino acids especially ornithine in doughs were associated with improved bread flavor (Thiele et al., 2002). Sourdough fermented wheat germ was saltier than wheat flour and raw wheat germ bread. Authors attributed this to the acidification and proteolysis by some selected lactic acid bacteria (Rizzello et al., 2010).

A study on the effect of sodium chloride (NaCl) on the flavor white wheat bread and whole meal sour rye bread described the flavor of unsalted bread as “drying” or ‘pasteboardy”. In both breads, NaCl had a strong correlation ($p < 0.01$) with overall palatability, saliva stimulating sensation and sourness perception. There was also a strong negative correlation ($p < 0.01$) between salty and pasteboardy parameters. The reduction of NaCl beyond 1% in white bread negatively affected flavor whereas the sour rye bread provided more operative range of salt reduction (Salovaara, 1982a). There was a strong preference for bread with 1.25% NaCl (w/w). The untrained panelists did not detect significant differences in flavor when breads with 0.75 and 1.5% NaCl were compared with 1.25% NaCl (Collyer, 1966).

Tempe is an Indonesian traditional fermented food which is made by fungi fermentation of soybeans and other legumes (Astuti et al., 2000). Tempe is known for its attractive flavor, texture and improved digestibility compared to non-fermented soybeans (Nout and Kiers, 2005). The desirable taste, flavor, texture, acidity and aroma are produced by the hydrolysis of substrates by enzymes (Hachmeister and Fung, 1993).There is a modification of chemical compounds resulting from the fermentation stage of tempe and is contributed by mold activity which mostly ceases after 46 hours of incubation (Bisping et al., 1993). It was found that a good pattern of amino acids was produced when soy and wheat were mixed in a 1: 1 w/w ratio (Wang et al., 2009).

Different chemical (potassium chloride, magnesium chloride, magnesium sulphate) and natural salt sub stitutes (sourdough and tempe) have been used for reduction of sodium chloride in bread. Limited information is available on the usage of tempe, sourdough and NaCl in combination for modulation of flavor parameters. Therefore, the objective of this study was to analyze the effect of fermented products such as sourdough and tempe on the flavor profile of white bread samples.

2. Materials and Methods

2.1 Materials

Commercial all- purpose and whole wheat flour , and soybeans were purchased from local supermarket. Billing hard red winter wheat grain was donated by Oklahoma Seed Improvement Association (Stillwater, OK) and tempe mix culture inoculum (LIPI, Indonesian Institute of Science, Bandung, Indonesia) was donated by Dr. Erni Murtini (Oklahoma State University, Stillwater OK).

2.2 Experimental

2.2.1 Sourdough preparation

Sourdough culture was prepared as described by (Suas, 2008) . The method consisted of five day feeding schedule. On Day 1, 0.5 kg of whole wheat flour and 0.5 kg all-purpose flour was mixed with 1kg of tap water and incubated for 24 h. On Day 2, 0.5 kg of bread flour, 0.5 kg of H_2O and 0.5 kg of the previous day starter was mixed and fermented for 6-8 h, and the same procedure was repeated after 16 h on Day 2. A similar schedule and formula was applied after every 6-8 h and 16 h from Day 3 through Day 5. The fermentation temperature was about 27℃. A mature sourdough is also known as levain and it is defined as the natural preferment used to ferment the sourdough.

2.2.2 Tempe preparation

Wheat-soy bean tempe was prepared as described by Murtni (2014). Briefly, soy beans and wheat grain were used at 1:1 ratio (w/w) and soaked overnight. Wheat and soy beans were boiled separately for 15-20 minutes and cooled at room temperature by rinsing independently. The seed coat of the soy beans was peeled off manually. The soy and wheat were mixed and the inoculum (0.1% mix cultures tempe starter) added. The mixture was packed in zip locked type of bags forming a slab. The bags were perforated to provide aeration, incubated in a damp and slightly warm environment at 30±2 °C for 36-48 h. The fermented mixture was dried in the oven at 60 °C (Fisher Scientific Company LLC., Grand Prairie, TX), milled in Kitchen Mill (Blendtec, West Orem, UT) and sifted through 40 mesh sieve. Tempe flour was packed in a closed tight plastic jar and stored at -4 ℃ until it was needed.

2.2.3 Baking and sensory analyses

Three baking and sensory analyses sessions were conducted using combinations of sourdough (11, 17 and 33%), tempe (0, 2.0, 3.5 and 5.0%) and NaCl (0, 0.5, 0.75, 1.0 and 1.5%). Baking test was performed using a straight dough optimized procedure according to approved 10-10.03 method (AACC International, 2000). The dough was mixed in a 100-g mixer (Swanson-Working pin-type, National Mfg. Co. TMCO Inc, Lincoln, NE) and the optimum baking mixing times were obtained from various baking trials. After baking, the breads were cooled down and kept in polythene zip-lock bags for 24 h. Bread loaves were sliced and then cut in quarters for sensory analyses. Consumer test was conducted with 80 untrained panelists at the Oklahoma State University campus in Stillwater, OK. A sample of the ballot is in Appendix II. A nine-point hedonic scale was used to evaluate seven flavor parameters of bread (salty, sweetness, sour, pasteboardy, aroma, bitter, and overall palatability).The panelists were students, staff and faculty members aged from 18 to 60. The sensory evaluation was approved by Institutional Review Board (IRB) at Oklahoma State University as reported in Appendix II . This study was accomiplished in coordination with my colleague and co-author Ms. Rabia Javid.

2.2.4 Statistical Analysis

Statistical analysis was done using SAS 9.3 (SAS Institute, Cary, NC) version. Analysis of Variance (ANOVA) was done in a split plot arrangement in a randomized complete block design.

3. Results and discussion

3.1 Sensory analysis of baked bread

3.1.1 First session

In the first baking and sensory analysis, levels of the three treatments were selected at 0.5, 1.0 and 1.5% NaCl; 0 and 5% tempe; 11, 17 and 33% sourdough.

3.1.1.1 Saltinesss

3.1.1.1.1 Effect of NaCl

The effect of NaCl (0.5, 1.0 and 1.5%) with treatments of sourdough (11. 17 and 33%) and tempe (0 and 5%) on bread saltiness scores were reported in Appendix III Table 1. Analysis of effect of the NaCl in saltiness in bread showed that there was no significant difference in saltiness scores ($p > 0.05$). This suggests that the panelists cannot differentiate between the levels of NaCl in the given combinations of these treatments. When the sourdough content was 11%, panelists provided higher saltiness scores for treatment of 0% tempe (6.1= slightly liked) than those which had 5% tempe in it (4.9 = neither liked nor disliked). This shows that samples with no tempe had scores inclined more towards “slightly liked” by panelists whereas the samples which had 5%

tempe ranged between “slightly disliked” and “neither liked nor disliked” by the panelists. With the sourdough level 17% and tempe 0%, still no significant difference in saltiness scores was observed between the salt levels. The overall mean saltiness score was 6.4 which suggested that the samples ranked between “slightly liked” and “moderately liked” by the panelists. Panelists gave lower saltiness score (4.9) for samples containing 17% sourdough and 5% tempe. In the presence of 33% sourdough and 0% tempe no significant difference was observed in the saltiness scores with the three levels of NaCl ($p > 0.05$) as seen in Appendix III Table 1. The mean saltiness score was 6.7, which indicates that it was “moderately liked” by the panelists. When 5% tempe was included along with 33% sourdough, no significant difference in saltiness scores were reflected. The overall mean of the saltiness scores was 5.2 and indicates that the panelist decisions were more inclined towards “neither liked nor disliked” (Appendix III Table 1).

3.1.1.1.2 Effect of tempe

The effect of tempe (0 vs 5%) at given levels of sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%) in bread saltiness score is reported in Table 1. All comparisons were highly significant ($p< 0.05$) with 5% tempe decreasing the saltiness scores in all treatments. 0% tempe led to saltiness scores ranging between “slightly liked” and “moderately liked”. When bread samples contained 11% along with 0.5% NaCl, it was seen that 0% NaCl scored significantly higher (6.2) than 5% tempe (4.8 = neither liked nor disliked). 0% tempe scored significantly better (6.1) than 5% tempe (4.7 = neither liked nor disliked) in samples which had 11% sourdough and 1% NaCl. At 1.5% NaCl and 11% sourdough, 0% tempe provided with significantly higher scores (6.1) than 5% tempe (5.3= neither liked nor disliked). When sourdough was 17% along with 1% NaCl, 0% tempe displayed significantly higher scores (6.1) of saltiness than 5% tempe (4.9). With 17% sourdough and 1% NaCl, 0% tempe received significantly higher scores (6.4) than 5% tempe (5.1= neither liked nor disliked). The combination of 17% sourdough with 1.5% NaCl portrayed the same pattern of result, 0% tempe scored significantly better (6.6) than 5% tempe (4.5=

slightly disliked).When 33% sourdough and 0.5% NaCl was present, 0% tempe provided significantly higher scores (6.3) than samples which had 5% tempe (4.8= neither liked nor disliked). With the NaCl increased to 1% and sourdough being 33%, significantly higher scores of saltiness was obtained for samples with 0% tempe (6.8) than samples with 5% tempe (5.4= neither liked nor disliked). When NaCl was yet increased to 1.5% along with 33% sourdough, 0% tempe reflected higher scores (6.9) than 5% tempe (5.5 = between "neither liked nor disliked" and "slightly liked").

3.1.1.1.3 Effect of sourdough

The effect of sourdough (11, 17 and 33%) at given levels of tempe (0 vs 5%) and NaCl (0.5, 1.0 and 1.5%) in bread saltiness score is summarized in Appendix III Table 2. Sourdough at 33% in combination with 5% tempe and 1.5% NaCl had higher scores ($p < 0.05$) than 17% sourdough at the same treatment levels of tempe and NaCl (average scores 5.5 vs 4.5, respectively). All other treatment levels of sourdough, tempe and NaCl had similar bread saltiness scores ($p > 0.05$) (Table 3). This suggests that only at the 5% tempe and 1.5% NaCl representing the highest levels in these treatments, the panelists were able to perceive differences in saltiness levels.

3.1.1.2 Bitterness

3.1.1.2.1 Effect of NaCl

Mean scores of bitterness perception on breads as affected by NaCl levels (0.5, 1.0 and 1.5%) at given levels of sourdough (11, 17 and 33%) and tempe (0 and 5%) are reported in Appendix III Table 3. There was no effect ($p > 0.05$) of NaCl levels on bitterness scores in all the treatment combinations. This suggests that the NaCl levels do not affect bitterness scores in bread at the combinations of this study.

3.1.1.2.2 Effect of tempe

The effect of tempe (0 and 5%) in combination with sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%) on bitterness scores of bread are reported in Table 2. In all treatment combinations 5% tempe had significantly lower ($p< 0.0004$) scores compared to 0% tempe. When bread samples contained 11% sourdough with 0.5% NaCl, 0% tempe scored significantly higher (5.7 = slightly liked) than 5% tempe (3.8 = slightly disliked). In samples with 11% sourdough and 1% NaCl, 0% tempe got significantly better bitterness scores (5.9 = slightly liked) than 5% tempe (3.9 = slightly disliked). Lastly, in bread samples with 11% sourdough and 1.5% NaCl, bitterness score for 0% tempe was significantly higher (5.8 = slightly liked) than 5% tempe (4.5 = between "slightly disliked" and "slightly liked").When 33% sourdough, 0.5% NaCl was present 0% tempe received significantly higher scores (6.1 = slightly liked) of bitterness than 5% tempe (3.8 = slightly disliked). When sourdough was 17% and combined with 0.5% NaCl, 0% tempe obtained significantly higher scores for bitterness (6.0 = slightly liked) than that which had 5% tempe (3.8 = slightly disliked).Samples containing 1% NaCl and 17% sourdough, 0% tempe received significantly higher scores (6.0 = slightly liked) than that of 5% tempe (3.8 = slightly disliked).With 17% sourdough and 1.5% NaCl, samples obtained significantly higher scores (6.1 = slightly liked) with 0% tempe than 5% tempe (3.8 = slightly disliked). Samples with 33% sourdough and 1% NaCl being present, 0% tempe provided significantly higher scores (6.1 = slightly liked) than that of 5% tempe (4.3 = slightly disliked). Similarly samples with 33% sourdough and 1.5% NaCl secured significantly higher scores of bitterness for sample containing 0% tempe (5.8 = slightly liked) than when 5% tempe was present (3.8 = slightly disliked).

3.1.1.2.3 Effect of sourdough

The effect of sourdough (11, 17 and 33%) at given levels of tempe (0 vs 5%) and NaCl (0.5, 1.0 and 1.5%) in bread bitterness score is summarized in Appendix III Table 4. There was no effect (p> 0.05) of NaCl levels on bitterness scores in all the treatment combinations. Samples with 0% tempe and 0.5% NaCl had an overall mean score 5.9 (slightly liked). Samples with 0% tempe and 1% NaCl, the average score was 6 (slightly liked).With 1.5% NaCl and 0% tempe, the mean score for bitterness was 5.8. With the presence of 5% tempe and 0.5% NaCl, the average score was 3.8 (slightly disliked). When bread samples had 1% NaCl along with 5% tempe, the average score for the three levels of sourdough was 4.2 (slightly disliked). Similarly, 5% tempe and 1.5% NaCl, the average score was 4.0 (slightly disliked) for the three levels of sourdough (11, 17 and 33%).

3.1.1.3 Sourness

3.1.1.3.1 Effect of NaCl

The effect of NaCl (0.5, 1.0 and 1.5%) at sourdough (11. 17 and 33%) and tempe (0 and 5%) on bread sourness scores reported in Appendix III Table 5. Salt did not have a significant effect on the sourness score of breads (p > 0.05). Sample with 11% sourdough and 0% tempe was slightly liked by the panelists (5.6). When 17% sourdough and 0% tempe was present in the sample, the overall mean score for sourness was 6.0 (slightly liked) which was similar for sample with 33% sourdough and 0% tempe (6.1 = slightly liked). Samples with 11% sourdough and 5% tempe scored 4.1(slightly disliked). Samples with 17% sourdough and 5% tempe scored 4.2 and finally samples with 33% sourdough and 5% tempe received a sourness score 4.6 (neither liked nor disliked).

3.1.1.3.2 Effect of tempe

The effect of tempe (0 and 5%) in combination with sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%) on sourness scores of bread are reported in Appendix III Table 6. Tempe at 5% significantly reduced (p< 0.05) the score of sourness in bread when compared to no tempe (0%) treatments. A reduced score means the flavor profile of bread analyzed for sourness perception was less liked. Comparing the treatments with 11% sourdough and NaCl (0.5, 1.0 and 1.5%), 0%

tempe had average sourness scores of 5.6 (slightly liked). When 5% tempe was present the sourness scores were significantly reduced ($p < 0.05$) to 3.8, 4.4 and 4.2 (slightly disliked). A similar trend was observed for treatment with 17 and 33% sourdough as well. When 5% tempe was present in combination with 17% sourdough, the scores reduced to 4.2, 4.3 and 4.2 (slightly disliked). Also, treatment combination of 33% sourdough along with 5% tempe led to reduction of scores to 4.4, 4.7 and 4.9 (slightly disliked and neither liked nor disliked).

3.1.1.3.3 Effect of sourdough

The effect of sourdough (11, 17 and 33%) at given levels of tempe (0 vs 5%) and NaCl (0.5, 1.0 and 1.5%) in bread sourness score is summarized in Appendix III Table 7. Samples with 0% tempe and 0.5% NaCl scored 5.7 (slightly liked) on an average. Samples with 0% tempe and 1% NaCl, the overall mean score is 5.9 (slightly liked). With 1.5% NaCl and 0% tempe, the mean score was 6.1 (slightly liked) for three levels of sourdough. With the presence of 5% tempe and 0.5% NaCl, the mean score was 4.1 (slightly disliked). When the salt level was 1% along with 5% tempe, the mean score for the three levels of sourdough was 4.4 (slightly disliked). Similarly, 5% tempe and 1.5% NaCl, the mean score was 4.4 (slightly disliked) for the three levels of sourdough.

3.1.1.4 Sweetness

3.1.1.4.1 Effect of NaCl

The effect of NaCl (0.5, 1.0 and 1.5%) at sourdough (11. 17 and 33%) and tempe (0 and 5%) on bread sweetness scores reported in Appendix III Table 8.When the effect of salt on the sweetness of bread was analyzed, it was observed that the variation in the level of NaCl did not have a significant effect on sweetness scores of the treatments ($p > 0.05$). For samples containing 11% sourdough, panelists provided significantly higher scores to those which had no tempe (5.8) than those with 5% tempe in it (4.4). This shows that samples which no tempe was slightly liked by panelists whereas the samples which had 5% tempe was slightly disliked by the panelists. When the sourdough level was 17% with 0% tempe, no significant difference in scores was observed by variation of salt levels, however the overall mean score was 6.1 suggesting that the samples were slightly liked by the panelists. Panelists gave a comparatively low score (4.4 = slightly disliked) for samples which had 17% sourdough and 5% tempe. In the presence of 33% sourdough and 0% tempe no significant difference was observed in the sweetness scores. The overall mean of the scores is 6.2, which indicates that these breads were slightly liked by the panelists. When 5% tempe was included along with 33% sourdough, no significant difference in scores were reflected. The average of the scores being 5.1 indicates that the panelists neither liked nor disliked the bread samples.

3.1.1.4.2 Effect of tempe

The effect of tempe (0 and 5%) in combination with sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%) on sweetness scores of bread are reported in Appendix III Table 9. Tempe at 5% significantly decreased ($p< 0.05$) sweetness scores in most of the treatment combinations except for 33% sourdough and 0.5% NaCl. In the latter combination there is only a trend to a reduced sweetness score but it is not significant. When sourdough was 11% along with 0.5% NaCl, it was seen that sample with no tempe scored significantly higher (6.0 = slightly likes) than 5% tempe (4.5 = between “slightly disliked” and “neither liked nor disliked”). 0% tempe scored significantly higher 6.0) than 5% tempe (4. 2 = slightly disliked) in samples which had 11% sourdough and 1% NaCl. At 1.5% NaCl and 11% sourdough, samples without tempe provided significantly higher scores (5.6= slightly liked) than 5% tempe (4.7 = slightly disliked) ($p < 0.05$). When sourdough was 17% along with 1% NaCl, 0% tempe received significantly higher scores (6.1 = slightly liked) than 5% tempe (4.4 = slightly disliked). The combination of 17% sourdough with 1.5% NaCl portrayed the same pattern of result, 0% tempe scored significantly better (6.0 = slightly liked) than 5% tempe (4.7 = slightly disliked). When 33% sourdough and 0.5% NaCl was present, samples without tempe did not provide significantly different scores than that of 5% tempe, however overall mean scores was 5.3 which means the panelists neither liked nor disliked the sample ($p > 0.05$). With the 1% NaCl and 33%sourdough, significantly higher scores of sweetness were obtained for samples with 0% tempe (6.6 = moderately liked) than samples with 5% tempe (4.8 = slightly disliked). When NaCl was 1.5% along with 33% sourdough, samples without tempe reflected higher sweetness scores (6.4 = moderately liked) than 5% tempe (5.3 = neither liked nor disliked) (Appendix III Table 9).

3.1.1.4.3 Effect of sourdough

The effect of sourdough (11, 17 and 33%) at given levels of tempe (0 and 5%) and NaCl (0.5, 1.0 and 1.5%) on bread sweetness score is summarized in Appendix III Table 10. No significant difference in results was observed between each block of treatment comparison ($p > 0.05$). However, there was a variation in the score for each comparison which represents a fixed NaCl and tempe content. Samples with 0% tempe and 0.5% NaCl scored 5.9 (slightly liked) on an average. Samples with 0% tempe and 1% NaCl, the average score is 6 (slightly liked). With 1.5% NaCl and 0% tempe, the mean score was 6.1 (slightly liked). With the presence of 5% tempe and 0.5% NaCl, the average score was 4.6 (slightly disliked). When the salt level was 1% along with 5% tempe, the average score for the three levels of sourdough was 4.5 (slightly disliked). Similarly, for samples containing 5% tempe and 1.5% NaCl, the mean score was 4.7 (slightly disliked).

3.1.1.5 Pasteboardy

3.1.1.5.1 Effect of NaCl

The effect of NaCl (0.5, 1.0 and 1.5%) at given levels of sourdough (11. 17 and 33%) and tempe (0 and 5%) on bread pasteboardy scores reported in Appendix III Table 11. It seemed that the variation in salt levels did not leave any significant impact on the pasteboardy mouth feel of the bread (p> 0.05) (Table 13). The highest score (6.1 = slightly liked) was obtained by samples which had 11% sourdough, 0% tempe and the three NaCl levels. Also in the list is the bread which contains 33 and 17% sourdough, 0% tempe which scored 5.7 (slightly liked). This was followed by samples which contained 5% tempe and the three levels of sourdough (4 - 4.2 = slightly disliked).

3.1.1.5.2 Effect of tempe

The effect of tempe (0 and 5%) in combination with sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%) on pasteboardy scores of bread are reported in Appendix III Table 12. Tempe does have a significant impact on pasteboardiness score($p < 0.05$).When the bread samples contained 11% sourdough and 0.5% NaCl, treatments without tempe scored significantly higher (6.1 = slightly liked) than 5% tempe (4.2 = slightly disliked). In samples with 11% sourdough and 1% NaCl, 0% tempe got significantly higher scores (6.5 = slightly liked) than 5% tempe (4.1 = slightly disliked). Lastly, in bread samples with 11% sourdough and 1.5% NaCl, 0% tempe scored significantly higher (5.6= slightly liked) than 5% tempe (4.1 = slightly disliked). With samples containing 17% sourdough and 0.5% NaCl, 0% tempe obtained significantly higher scores for pasteboardiness (5.8 = slightly liked) than that which had 5% tempe (4.0 = slightly disliked).When the NaCl level was 1% with 17% sourdough, samples without tempe received significantly higher pasteboardy scores (5.8 = slightly liked) than that of 5% tempe (4.4 = slightly disliked).With 17% sourdough and 1.5% NaCl, samples scored significantly higher (5.9 = slightly liked) with 0% tempe than 5% tempe (4.4 = slightly disliked).When 33% sourdough, 0.5% NaCl was present 0% tempe received significantly higher scores (5.6 = neither like nor disliked) of pasteboardiness than 5% tempe (3.9 = slightly disliked). Samples with 33% sourdough and 1% NaCl being present, 0% tempe scored significantly higher (6.0 = slightly liked) than that of 5% tempe (4.2 = slightly disliked). Similarly samples with 33% sourdough and 1.5% NaCl secured significantly higher scores for sample containing 0% tempe (5.9 = slightly liked) than when 5% tempe was present (4.7 = slightly disliked).

3.1.1.5.3 Effect of sourdough

The effect of sourdough (11, 17 and 33%) at given levels of tempe (0 vs 5%) and NaCl (0.5, 1.0 and 1.5%) in bread pasteboardy score is summarized in Appendix III Table 13. No significant difference of means was observed between each treatment comparison ($p > 0.05$). Samples with 0% tempe and 0.5% NaCl had a mean score 5.7 (slightly liked) .Samples with 0% tempe and 1% NaCl, received a mean pasteboardy score of 6 (slightly liked).With 1.5% NaCl and 0% tempe, the average score was 5.7(slightly liked) for three levels of sourdough. With the presence of 5% tempe and 0.5% NaCl, the average score was 4.0 (slightly disliked). When the salt level increased to 1% along with 5% tempe, the average score for the three levels of sourdough was 4.2 (slightly disliked). Similarly, in 5% tempe and 1.5% NaCl, the average score was 4.3 (slightly disliked) for the three levels of sourdough (11, 17 and 33%).

3.1.1.6 Aroma

3.1.1.6.1 Effect of NaCl

The effect of NaCl (0.5, 1.0 and 1.5%) at given levels of sourdough (11. 17 and 33%) and tempe (0 and 5%) on bread aroma scores reported in Appendix III Table 14. With 33, 16 and 11% sourdough being present along with 0% or 5% tempe, the variation in the NaCl levels did not have any significant change in scores within themselves ($p > 0.05$). However, when looking at the whole data, there is a change of score amongst the comparison of treatments. The highest score (around 6= slightly liked) was obtained by samples which had 11, 17 and 33% sourdough alone without tempe. This was followed by samples which contained 11, 17 and 33% NaCl along with 5% tempe (around 5 = neither like nor disliked).

3.1.1.6.2 Effect of tempe

The effect of tempe (0 and 5%) in combination with sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%) on aroma scores of bread is reported in Appendix III Table 15. Significant variation between the comparison treatments was observed ($p < 0.05$). When bread samples contained 11% sourdough along with 0.5% NaCl, it was seen that samples without tempe scored significantly higher (7.0 = like moderately) than 5% tempe (4.5= between "slightly disliked" and "neither liked nor disliked") for aroma. Samples without tempe scored significantly better (6.2 = slightly liked) than 5% tempe (5.2 = neither liked nor disliked) for aroma when 11% sourdough and 1% NaCl was present. At 1.5% NaCl and 11% sourdough, 0% tempe provided with significantly higher scores (6.3 = slightly liked) than 5% tempe (5.1 = neither liked nor disliked). When sourdough was 17% along with 0.5% NaCl, 0% tempe displayed significantly higher scores (6.3 = slightly liked) of aroma than 5% tempe (5.0 = neither liked nor disliked). With 17% sourdough and 1% NaCl, 0% tempe received significantly higher scores (6.3 = slightly liked) than 5% tempe (4.8 = neither liked nor disliked). The combination of 17% sourdough with 1.5% NaCl portrayed the same pattern of result, 0% tempe scored significantly better (6.6 = between "slightly liked" and "moderately liked") than 5% tempe (4.8 = neither liked nor disliked). A similar pattern of results were observed in treatments with 33% sourdough combined with the different levels of salt.

3.1.1.6.3 Effect of sourdough

The effect of sourdough (11, 17 and 33%) at given levels of tempe (0 vs 5%) and NaCl (0.5, 1.0 and 1.5%) in bread pasteboardy score is summarized in Appendix III Table 16. No significant effect in aroma scores was observed between each treatment comparison ($p > 0.05$). However, there was a variation in the score for each treatment comparison which represents a fixed NaCl and tempe content. Samples with 0% tempe and 0.5% NaCl scored 6.4 (slightly liked) on an average with three levels of sourdough. Samples with 0% tempe and 1% NaCl, the average score is 6.4 (slightly liked).With 1.5% NaCl and 0% tempe, the average score was 6.4 (slightly liked) for three levels of sourdough. With the presence of 5% tempe and 0.5% NaCl, the average score was 4.9 (neither liked nor disliked). When the salt was 1% along with 5% tempe, the overall mean score for the three levels of sourdough was 5 (neither liked nor disliked). Similarly, 5% tempe and 1.5% NaCl, the average score was 4.9 (neither liked nor disliked) for the three levels of sourdough.

3.1.1.7 Overall palatability

3.1.1.7.1 Effect of NaCl

The effect of NaCl (0.5, 1.0 and 1.5%) at sourdough (11. 17 and 33%) and tempe (0 and 5%) on bread palatability scores is reported in Appendix III Table 17. No significant difference in scores ($p> 0.05$) was observed. When bread samples contained 11% sourdough, panelists provided higher scores for samples that had 0% tempe (6.1= slightly liked) than those which had 5% tempe in it (4.2 = slightly disliked). This shows that samples with no tempe were slightly liked by panelists whereas the samples which had 5% tempe were slightly disliked by the panelists. When the samples contained 17% sourdough without tempe, no significant difference in scores was observed between the salt levels, however the average score was 6.4 which say that the samples were slightly liked by the panelists. Panelists gave a comparatively lower score (4.2 = slightly disliked) for samples which had 17% sourdough and 5% tempe. In the presence of 33% sourdough and 0% tempe no significant difference was observed in the scores with the three levels of NaCl ($p > 0.05$). The mean score was 6.5, which indicates that these breads were slightly liked by the panelists. When 5% tempe was included along with 33% sourdough, no significant difference in scores was reflected. The overall mean score was 4.3 indicating that the panelists slightly disliked the bread samples.

3.1.1.7.2 Effect of tempe

The effect of tempe (0 and 5%) at given levels of sourdough (11. 17 and 33%) and NaCl (0.5, 1.0 and 1.5%) on bread palatability scores is reported in Table 3. Tempe at 5% did have a significant effect on the overall palatability of the bread samples ($p < 0.05$) (Table 20). When the sourdough content was 11% with 0.5% NaCl, 0% tempe scored significantly higher (6.1) than 5% tempe (4.0). In samples with 11% sourdough and 1% NaCl, 0% tempe got significantly higher scores (6.3) than 5% tempe (4.4). Lastly, in bread samples with 11% sourdough and 1.5% NaCl, 0% tempe scored significantly higher (6.0) than 5% tempe (4.3). When sourdough was 17% and combined with 0.5% NaCl in bread samples, 0% tempe obtained significantly higher scores for overall palatability (6.3) than those with 5% tempe (4.4).When the NaCl level was increased to 1% with 17% sourdough, 0% tempe received significantly higher scores (6.4) than that of 5% tempe (4.1).With 17% sourdough and 1.5% NaCl, samples scored significantly higher (6.7) with 0% tempe than 5% tempe (4.2). In samples with 33% sourdough and 0.5% NaCl, 0% tempe received significantly higher scores (6.3) than 5% tempe (4.2). Samples with 33% sourdough and 1% NaCl being present, 0% tempe provided significantly higher palatability scores (6.6) than 5% tempe (4.6). Similarly samples with 33% sourdough and 1.5% NaCl secured significantly higher scores of palatability for sample containing 0% tempe (6.7) than when 5% tempe was present (4.2).

3.1.1.7.3 Effect of sourdough

The effect of sourdough (11, 17 and 33%) at given levels of tempe (0 vs 5%) and NaCl (0.5, 1.0 and 1.5%) in bread palatability score is summarized in Appendix III Table 18. No significant variance in results was observed between each treatment comparison ($p > 0.05$). However, there was a variation in the score for each comparison which represents a fixed NaCl and tempe content. Samples with 0% tempe and 0.5% NaCl scored 6.2 (slightly liked). Samples with 0%

tempe and 1% NaCl, the overall mean score was 6.4 (slightly liked).With 1.5% NaCl and 0% tempe, the average score was 6.4 (slightly liked) for three levels of sourdough. With the presence of 5% tempe and 0.5% NaCl, the average score was 4.2 (slightly disliked). When the salt level increased to 1% along with 5% tempe, the average score for the three levels of sourdough was 4.3 (slightly disliked). Similarly, 5% tempe and 1.5% NaCl, the average score was 4.2 (neither liked nor disliked) for the three levels of sourdough**.**

3.1.2 Second session

The second sensory session was conducted with treatments of NaCl 0, 0.75 and 1.5%, sourdough 0, 17 and 33% and tempe 0 and 2%.The sensory panelists judged seven parameters namely, saltiness, pasteboardiness, sourness, sourness, aroma, pasteboardy and overall palatability.

3.1.2.1 Saltiness

3.1.2.1.1 Effect of NaCl

The effect of tempe (0 and 2%) at given levels of sourdough (0, 17 and 33%) and NaCl (0, 0.75 and 1.5%) on bread saltiness scores reported in Table 4. NaCl had a significant effect on the saltiness score of bread ($p < 0.05$). When 0% sourdough and 0% tempe was present in the bread sample, treatments with 0.75 and 1.5% NaCl scored similarly (5.6 and 5.7 respectively), but their score was significantly higher than the sample treatments with 0% NaCl (4.6= neither liked nor disliked). With the samples containing 0% sourdough and 2% tempe, 0.75 and 1.5% NaCl received similar scores 5.5 and 5.3 respectively (neither liked nor disliked), and these were significantly higher than 0% NaCl (4.1). When the sourdough was 17% but did not contain tempe, 0.75 and 1.5% NaCl scored similar 5.4 and 5.7 respectively (“neither liked nor disliked” and “slightly liked”), and these are significantly higher than 0% NaCl (3.9 = slightly disliked). Finally, when bread samples were incorporated with 17% sourdough and 2% tempe, 0.75 and 1.5% NaCl obtained similar scores 5.3 for each (neither liked nor disliked), and these are significantly higher than 0% NaCl (3.8 = slightly disliked). All the treatment comparisons portray that panelists perceived similar saltiness in 0.75% and 1.5% NaCl. With the incorporation of 33% sourdough but no tempe, scores displayed that sample with 0.75 and 1.5% NaCl scored similarly, 5.1 and 5.6 respectively ("neither liked nor disliked" and "slightly liked"), but the scores were significantly higher than the sample with 0% NaCl (4.3= slightly disliked). When samples contained 33% sourdough and 2% tempe, again 0.75 and 1.5% NaCl obtained similar scores, 4.9 and 5.0 respectively (neither liked nor disliked), and these were significantly higher than 0% NaCl (3.9 = slightly disliked).

3.1.2.1.2 Effect of tempe

The effect of tempe (0 and 2%) at given levels of sourdough (0, 17 and 33%) and NaCl (0, 0.75 and 1.5%) on bread saltiness scores reported in Table 5. Tempe had no significant effect on the saltiness score of bread ($p > 0.05$). When bread samples had 0% sourdough and NaCl, the overall mean score of samples (0 and 2% tempe) was 4.3(slightly disliked). Samples with 0% sourdough and 0.75% NaCl had a mean score of 5.4 (neither liked nor disliked). When the NaCl content was 1.5% as that that of standard bread, mean score was 5.6 (slightly liked). Now when, the sourdough level was 17% in bread samples but no NaCl, the samples displayed an average score of 3.8 which was indicative of the samples being slightly disliked the panelists. For the samples with 17% sourdough and 0.75% NaCl, the mean scored received was 5.5 (neither liked nor disliked). Finally, sample containing 17% sourdough and 1.5% NaCl received an average score of 5.3 ((neither liked nor disliked) as well.With higher sourdough levels like 33% combined with 0% NaCl, the mean score was 4.1 (slightly disliked). With 33% sourdough and 075% NaCl, the mean score was 5.0 which indicated that the panelists neither liked nor disliked the saltiness in the bread samples. When samples contained 33% sourdough and 1.5% NaCl, the mean score was 5.3(neither liked nor disliked).

3.1.2.1.3 Effect of sourdough

The effect of sourdough (0, 17 and 33%) at given levels of tempe (0 vs 2%) and NaCl (0, 0.75 and 1.5%) in bread saltiness score is summarized in Table 6. The effect of sourdough on the saltiness of bread was analyzed and no significant changes in scores were observed ($p > 0.05$) (Table 24). 0% tempe and NaCl provided an average score of 4.2 which indicates the saltiness was slightly disliked by the panelists. When 0% and 0.75% NaCl was included, the mean score for the samples was 5.4 (neither liked nor disliked).Samples with 0% tempe and 1.5% NaCl displayed a mean score of 5.5 that says the saltiness perception in bread was neither liked nor disliked by the panelists. For samples with 2% tempe and no NaCl, the average score for the three sourdough levels (0,17 and 33%) was 3.9 which suggested that the saltiness in bread was slightly disliked by the panelists. Again samples containing 0.75% NaCl and 2% tempe received a mean score of 4.1, indicative that the saltiness in bread were slightly disliked by the panelists. Lastly, where 2% tempe and 1.5% NaCl were present, mean score for saltiness on the perspective as affected by sourdough was 5.3 (neither liked nor disliked).

3.1.2.2 Bitterness

3.1.2.2.1 Effect of NaCl

The effect of NaCl (0, 0.75 and 1.5%) at sourdough (0, 17 and 33%) and tempe (0 and 2%) on bread bitterness scores reported is in Table 7. Addition of NaCl increases the bitterness perception as compared to 0% NaCl in a few cases. In fact, 0.75 and 1.5% NaCl gave similar scores of bitterness (4.7 = “neither liked nor disliked” and 4.3 = slightly disliked) when 2% tempe and 33% sourdough was added which is significantly higher than 0% NaCl (3.1 = moderately disliked). When 2% tempe was added with 17% sourdough, samples containing 0.75 and 1.5% NaCl scored similarly (4.9 and 4.7, i.e. neither liked nor disliked) but was significantly higher than 0% NaCl (3.5= moderately disliked). For the sample containing 17% sourdough and 0%

tempe, similar scores were obtained by samples having 0.75 and 1.5% NaCl (5.2 and 5.3 = neither liked nor disliked) but it was significantly higher than the sample having 0% NaCl (3.8 = slightly disliked).

3.1.2.2.2 Effect of tempe

The effect of tempe (0 and 2%) at specific levels of sourdough (0, 17 and 33%) and NaCl (0, 0.75 and 1.5%) on bread bitterness scores reported in Table 8. Only two comparisons of scores were significantly different from each other ($p < 0.05$) (Table 26). First, the sample that had no sourdough and 1.5% NaCl, 0% tempe scored higher (5.6= slightly liked) than sample with 2% tempe (4.8= neither liked nor disliked). Also, 0% tempe (4.4= slightly disliked) provided higher score than 2% tempe (3.1= disliked moderately) when the samples had 33% sourdough and 0% NaCl in it. The other combinations were not significantly different from each other ($p > 0.05$). The samples which had 0% sourdough and NaCl had a mean score of 4.4, indicative that the sample was slightly disliked by the panelists. Mean score of bitterness for sample with 0% sourdough and 0.75% NaCl was 4.9 (neither liked nor disliked). When the sourdough was 17% with no NaCl, mean score was 3.6 (slightly disliked). Samples with 17% sourdough and 0.75% NaCl displayed an average bitterness score of 5 (neither liked nor disliked). 4.7 (neither liked nor disliked) was the mean score of bitterness with 33% sourdough and 0.75% NaCl. For 33% sourdough and 1.5% NaCl, mean score of bitterness for the two levels of tempe was 4.4 meaning that bitterness note in bread was slightly disliked by the panelists.

3.1.2.2.3 Effect of sourdough

The effect of sourdough (0, 17 and 33%) at given levels of tempe (0 vs 2%) and NaCl (0, 0.75 and 1.5%) in bread bitterness score is summarized in Table 9. Treatments with no tempe (0%) coupled with 1.5% NaCl produced some significant variation in results ($p < 0.05$) (Table 27). So, the bitterness associated with 17% sourdough (4.6= neither liked nor disliked) scored similarly with 0% and 33% sourdough (5.6= “slightly liked” and 4.6= “neither liked nor disliked” respectively) but scores of samples with 0% sourdough was significantly higher than 33% sourdough. The rest of the scores were not significantly different from each other ($p > 0.05$). When samples with 0% tempe and NaCl were tested the overall mean score for bitterness in bread with the three levels of sourdough (0, 17 and 33%) was 4.3 which reveals that bitterness perception was slightly disliked by the panelists. For sample with 0% tempe and 0.75% NaCl, the mean bitterness score was 5.0 (neither liked nor disliked). When tempe was included in the samples the results were not significantly different either. Samples containing 0% NaCl and 2% tempe provided a mean score of 3.5 (disliked moderately). With sample having 2% tempe and 0.75% NaCl, the mean score 4.6 was indicative that the bitterness in the bread sample was neither liked nor disliked by the panelists. Lastly, samples containing 2% tempe and 1.5% NaCl received mean score of 4.5 (slightly disliked).

3.1.2.3 Sourness

3.1.2.3.1 Effect of NaCl

The effect of variation of NaCl on the sourness score of bread was analyzed and it was seen that each block of treatment was significantly different from each other ($p < 0.05$) except one treatment when samples had 33% sourdough and 0% tempe (Appendix III Table 19). When neither sourdough nor tempe was present in the bread sample, it was seen that the score of sample with 0.75% NaCl (5.1= neither liked nor disliked) was not significantly different from 0 and 1.5% NaCl (4.5 and 5.6 respectively), however 0% NaCl was different from 1.5% NaCl. In samples having 0% sourdough and 2% tempe, 0.75 and 1.5% NaCl received similar scores of sourness 4.9= “neither liked nor disliked” and 5.5= between “neither liked nor disliked” and“slightly liked” respectively, and these were significantly higher than 0% NaCl (4.1= slightly disliked). When the sourdough content was 17% with no tempe, 0.75 and 1.5% NaCl scored similar 5.4 and

5.4 respectively (neither liked nor disliked), and these were significantly higher than 0% NaCl (4.2= slightly disliked). Finally, when bread sample contained 17% sourdough and 2% tempe, 0.75 and 1.5% NaCl obtained similar sourness scores 4.6 and 4.7 respectively (neither liked nor disliked), and these were significantly higher than 0% NaCl (3.6= slightly disliked). With the incorporation of 33% sourdough and 0% tempe, scores displayed that sample score were not significantly different from each other when the salt was varied, but the mean score of the sample was 4.2 (slightly disliked).When samples had 33% sourdough and 2% tempe, again 0.75 and 1.5% NaCl obtained similar scores 4.7 and 4.9 respectively (neither liked nor disliked), and these were significantly higher than 0% NaCl (3.2= moderately disliked).

3.1.2.3.2 Effect of tempe

When the effect of 2% tempe on sourness perception was analyzed, the scores displayed that tempe did not quite have any significant effect on the saltiness score of bread ($p > 0.05$) except for one treatment containing 33% sourdough and 0% NaCl (Appendix III Table 20). When bread samples was devoid of sourdough and NaCl, the mean sourness score of samples (0 and 2% tempe) was 4.3 (slightly disliked). Samples with 0% sourdough and 0.75% NaCl had a mean score of 5.0 (neither liked nor disliked). When the NaCl content was similar to the reference bread i.e. 1.5%, mean score of sourness was 5.5 (neither liked nor disliked). Now when, the sourdough level was 17% but no NaCl, the samples displayed an average score of 3.9 which was indicative of the sourness in the bread samples was slightly disliked by the panelists. When the samples with 17% sourdough and 0.75% NaCl, the mean sourness score received was 5.0 (neither liked nor disliked). Finally, sample containing 17% sourdough and 1.5% NaCl received a mean score of 5.0 (neither liked nor disliked) as well. With higher sourdough levels like 33% combined with 0% NaCl, the sample with 0% tempe scored significantly higher (4.3 = slightly disliked) than sample with 2% tempe (3.2 = disliked moderately). With 33% sourdough and 0.75% NaCl, the mean score of sourness parameter was 4.7 which indicated that the panelists neither liked nor disliked the sourness in the samples. When samples contained 33% sourdough and 1.5% NaCl, the mean score was 5.1(neither liked nor disliked).

3.1.2.3.3 Effect of sourdough

The effect of sourdough on the sourness of bread was analyzed and no significant changes in scores were observed ($p > 0.05$) (Appendix III Table 21). 0% tempe and NaCl provided an overall mean sourness score of 4.3 which indicates the sourness in bread was slightly disliked by the panelists. Next, when 0% and 0.75% NaCl was included, the mean score was 5.1 (neither liked nor disliked). Samples with 0% tempe and 1.5% NaCl displayed a mean score of 5.4 that says the sourness in bread was neither liked nor disliked by the panelists. For samples with 2% tempe and 0% NaCl, the mean score for the three sourdough levels was 3.6 suggesting that the sourness was slightly disliked by the panelists. Samples containing 0.75% NaCl and 2% tempe received a mean score of 4.7, indicative that the sourness was slightly disliked by the panelists. Lastly, where 2% tempe and 1.5% NaCl were present, mean score for sournesss on the perspective of sourdough was 5.0 (neither liked nor disliked).

3.1.2.4 Sweetness

3.1.2.4.1 Effect of NaCl

The effect of NaCl (0, 0.75 and 1.5%) at specific levels of sourdough (0, 17 and 33%) and tempe (0 and 2%) on bread sweetness scores is reported in Appendix III Table 22. Each treatment comparison was significantly different from each other ($p < 0.05$) except one when samples had 33% sourdough and 0% tempe. When 0% sourdough and 0% tempe was present in the bread sample, it was seen that the sweetness score of sample with 0.75% NaCl (5.7= slightly liked) was similar to 1.5% NaCl (5.9 = slightly liked), but significantly higher than 0% NaCl (4.8 = neither liked nor disliked). In samples containing 0% sourdough and 2% tempe, 0.75 and 1.5% NaCl received similar scores (4.9 and 5.3 = "neither liked nor disliked" respectively), and these are significantly higher than 0% NaCl (4.0 = slightly disliked). When the sourdough content was 17% and and no tempe was present, 0.75 and 1.5% NaCl scored similarly in sweetness (5.5 = between "slightly disliked" and "neither liked nor disliked" and 5.3 = "neither liked nor disliked" respectively), and these are significantly higher than 0% NaCl (4.4 = slightly disliked). Finally, when bread samples contained 17% sourdough and 2% tempe, sweetness scores of samples with1.5% NaCl (4.5= between "slightly disliked" and "neither liked nor disliked") were not significantly different from 0.75% and 0% NaCl (4.8 and 3.8= "slightly disliked" respectively). But, samples with 0 and 0.75% NaCl scores significantly different from each other. With the incorporation of 33% sourdough and 0% tempe, scores revealed that sweetness score were not significantly different from each other when the salt was varied, but the overall mean score of the sample was 4.8 (neither liked nor disliked).When samples contained 33% sourdough and 2% tempe, again 0.75 and 1.5% NaCl obtained similar scores (4.6 and 4.9 = neither liked nor disliked and 4.9, respectively), and these are significantly higher than 0% NaCl (3.7= slightly disliked) (Appendix III Table 22).

3.1.2.4.2 Effect of tempe

When the effect of 2% tempe on sweetness perception was analyzed, the scores displayed that for the most part tempe did not have significant effect on the sweetness score of bread ($p > 0.05$) except for two treatments containing 33% sourdough and 0% NaCl; 17% sourdough and 1.5% NaCl (Appendix III Table 23). When bread samples were devoid of sourdough and NaCl, the overall mean sweetness score of samples with 0 and 2% tempe was 4.3(slightly disliked). Samples with 0% sourdough and 0.75% NaCl had a mean sweetness score of 5.3 (neither liked nor disliked). When the NaCl content was similar to the reference containing 1.5%, average score of sweetness was 5.5 (neither liked nor disliked). For the sourdough level was 17% and combined with 0% NaCl, the samples displayed a mean score of 4.0 which was indicative of the samples being slightly disliked the panelists. When the samples with 17% sourdough and 0.75% NaCl, the mean score was 5.1 (neither liked nor disliked). Finally, sample containing 17% sourdough and 1.5% NaCl, received a higher sweetness score with 0% tempe (5.3= neither liked nor disliked) than 2% tempe (4.5= between “slightly disliked” and “neither liked nor disliked”).With higher sourdough levels like 33% combined with 0% NaCl, the sample with 0% tempe scored significantly higher (4.5= slightly disliked) than sample with 2% tempe (3.7= slightly disliked). With 33% sourdough and 0.75% NaCl, the overall mean score was 4.7 which indicated that the panelists neither liked nor disliked the sweetness in the samples. When samples contained 33% sourdough and 1.5% NaCl, the mean score of sweetness was 5.0(neither liked nor disliked).

3.1.2.4.3 Effect of sourdough

The effect of sourdough on the sweetness of bread was analyzed and no significant changes in scores were observed ($p > 0.05$) (Appendix III Table 24). Samples without tempe and NaCl provided an overall mean sweetness score of 4.5 which indicated the sweetness was between “slightly disliked” and “neither liked nor disliked”. Next, when 0% and 0.75% NaCl was included, the mean score for sweetness was 5.3 (neither liked nor disliked). Samples with 0% tempe and 1.5% NaCl displayed a mean sweetness score 5.4 meaning that the sweetness was neither liked nor disliked by the panelists. For samples with 2% tempe and 0% NaCl, the average score for the three sourdough levels was 3.8 indicating that the sweetness was slightly disliked by the panelists. Samples containing 0.75% NaCl and 2% tempe received a mean score of 4.7, indicative that the sweetness was neither liked nor disliked by the panelists. Lastly, where 2% tempe and 1.5% NaCl was present, the mean score for sweetness as affected by sourdough was 4.8 (neither liked nor disliked).

3.1.2.5 Pasteboardy

3.1.2.5.1 Effect of NaCl

When the effect of NaCl on the pasteboardiness score of bread samples was analyzed there were mixed results (Appendix III Table 25). First, when samples had 0% tempe and sourdough, score of samples with 0.75% NaCl (4.9 = neither likes nor disliked) was not significantly different from 0 and 1.5% NaCl (4.3 and 5.5 respectively) but 0 and 1.5% NaCl scores were significantly different from each other. Samples containing 0% sourdough and 2% tempe explains that pasteboardy scores of sample with 0.75 and 1.5% NaCl (4.8 and 4.9 = neither likes nor disliked) were similar but significantly higher than 0% NaCl (3.4 = moderately disliked). When the sourdough content was 17% and 0% tempe, the mean score was 4.2 (slightly disliked). When the bread samples had both 17% sourdough and 2% tempe, the mean score was 3.9 (slightly disliked) ($p > 0.05$) When 33% sourdough was incorporated in the sample coupled with 0% tempe, scores reflected that sample with 0 and 0.75% NaCl (3.6 and 3.9 = respectively) scored significantly lower than 1.5% NaCl (5.1 = neither likes nor disliked) ($p < 0.05$). With samples having 33% sourdough and 2% tempe, the pasteboardy scores were not significantly different for each other, however the overall mean of the samples was 4.3, which tells that the pasteboardy in bread samples was slightly disliked by the panelists.

3.1.2.5.2 Effect of tempe

When the effect of 2% tempe on pasteboardy perception score was analyzed, tempe did not have any significant differences in the scores ($p > 0.05$) (Appendix III Table 26). Although no significant effect of tempe on the pasteboardy perception of bread was observed few not significant highlights can be mentioned. When bread samples had 0% sourdough and NaCl, the average score of samples (0 and 2% tempe) was 3.8(slightly disliked). Samples with 0% sourdough and 0.75% NaCl had a mean score of 4.8 (neither liked nor disliked). When the NaCl content was 1.5%, average scores was 5.2 (neither liked nor disliked). Samples with 17% sourdough and no NaCl, mean score of 3.4 was seen which was indicative that the pasteboardy perception was moderately disliked the panelists. When the samples with 17% sourdough and 0.75% NaCl, the mean pasteboardy score received was 4.4 (slightly disliked). Finally, sample containing 17% sourdough and 1.5% NaCl received an average score of 4.4 (slightly disliked) as well. For samples containing higher sourdough levels like 33% without NaCl, the mean pasteboardy score was 3.7 (slightly disliked). With 33% sourdough and 0.75% NaCl, the mean score was 4.1 which indicated that the panelists neither liked nor disliked the pastebordy perception in the bread samples. When samples contained 33% sourdough and 1.5% NaCl, the mean score was 4.9 (neither liked nor disliked).

3.1.2.5.3 Effect of sourdough

The effect of sourdough on the pasteboardy mouth feel of bread was analyzed and no significant difference in scores were observed ($p > 0.05$) (Appendix III Table 27). Samples without tempe and NaCl provided an overall mean pasteboardy score 3.8 which indicates the pasteboardy perception in the bread samples was slightly disliked by the panelists. Next, when 0% and 0.75% NaCl was included, the mean score for the samples was 4.4 (neither liked nor disliked). Samples with 0% tempe and 1.5% NaCl displayed a mean score of 5.0 that says the pasteboardy perception was neither liked nor disliked by the panelists. For samples with 2% tempe and 0% NaCl, the average score for the three sourdough levels was 3.5 which suggests that the pasteboardy mouth feel was moderately disliked by the panelists. Samples containing 0.75% NaCl and 2% tempe received a mean score of 4.5, indicating that the pasteboardy perception in bread samples was neither liked nor disliked by the panelists. Lastly, where 2% tempe and 1.5% NaCl was present, mean score for pasteboardy as a function of sourdough was 4.6 (neither liked nor disliked).

3.1.2.6 Aroma

3.1.2.6.1 Effect of NaCl

When the effect of NaCl on the aroma scores of bread was analyzed, none of the values were significantly different from each other ($p > 0.05$) (Appendix III Table 28). Thus, NaCl has no effect on the aroma of bread. Few non-significant highlights can be mentioned as follows. First starting with the samples devoid of tempe and sourdough, the mean score of aroma was 5.9 (slightly liked).In samples containing 0% sourdough and 2% tempe, the mean score for aroma was 5.1 (neither liked nor disliked). When sourdough was 17% but tempe was absent, the mean score was 5.8, suggesting that the aroma in bread samples was slightly liked by the panelists. Finally, when the sample had 17% sourdough and 2% tempe, the mean score of aroma for three levels of salt was 5.1 (neither liked nor disliked). When 33% sourdough was included with 0% tempe, the average score received was 5.5, indicative that the aroma of bread was slightly liked by the panelists. When samples had 33% sourdough and 2% tempe, overall mean score of aroma was 4.8 (neither liked nor disliked).

3.1.2.6.2 Effect of tempe

When the effect of 2% tempe on aroma of bread was analyzed, the scores displayed that overall tempe did not have a significant effect on the aroma score of bread ($p > 0.05$) (Appendix III Table 29), except for one treatment comparison. Samples with 0% sourdough and 0.75% NaCl had a significant difference in score, where 0% tempe had higher score (6.0) than 2% tempe (5.0) ($p = 0.01$). When bread samples did not have sourdough and NaCl, the average score of samples (0 and 2% tempe) was 5.3(neither liked nor disliked).When the NaCl content was similar to the standard 1.5%, mean score was 5.8 (slightly liked). When, the sourdough level was 17% and had no NaCl, the samples displayed an average score of 5.4 which was indicative that the aroma was neither liked nor disliked by the panelists. When samples contained 17% sourdough and 0.75%

NaCl, the mean score of aroma was 5.7 (slightly liked). Finally, samples containing 17% sourdough and 1.5% NaCl received a mean score of 5.3 (neither liked nor disliked) as well. With higher sourdough levels like 33% combined with 0% NaCl, the mean score of aroma was 4.7 (neither liked nor disliked). With 33% sourdough and 0.75% NaCl, the average score was 5.4 which indicated that the panelists neither liked nor disliked the aroma of the bread samples. When samples contained 33% sourdough and 1.5% NaCl, the mean score of aroma was 5.3(neither liked nor disliked).

3.1.2.6.3 Effect of sourdough

The effect of sourdough on the aroma score of bread was analyzed and no significant changes in scores were observed ($p > 0.05$) (Appendix III Table 30). 0% tempe and NaCl provided a mean score of 5.5 which indicated the aroma in bread was neither liked nor disliked by the panelists. Next, when 0% tempe and 0.75% NaCl was included, the mean score of aroma for the samples was 5.9 (slightly liked). Samples with 0% tempe and 1.5% NaCl displayed a mean score of 5.8 that says the aroma was slightly liked by the panelists. For samples with 2% tempe and 0% NaCl, the mean aroma score for the three sourdough levels was 4.7 which directs that the samples were neither liked nor disliked by the panelists. Samples containing 0.75% NaCl and 2% tempe received a mean score of 5.1, indicative of the fact that the aroma was neither liked nor disliked by the panelists. Lastly, where 2% tempe and 1.5% NaCl was present, mean score for aroma on the perspective of sourdough was 5.1 (neither liked nor disliked).

3.1.2.7 Overall palatability

3.1.2.7.1 Effect of NaCl

The effect of variation of NaCl on the overall palatability scores of bread was analyzed and it was seen that each treatment comparison was significantly different from each other ($p < 0.05$) (Appendix III Table 30). Thus, NaCl has a significant effect on overall palatability of bread.

When 0% sourdough and 0% tempe was present in the bread sample, it was seen that samples with 0.75 and 1.5% NaCl had similar scores 6.1 and 5.7, slightly liked, respectively, but these scores were significantly higher than the sample with 0% NaCl (4.6= neither liked nor disliked). With the samples having 0% sourdough and 2% tempe, 0.75% NaCl (4.6= neither liked nor disliked) scores were not significantly different from 0 and 1.5% NaCl (3.8= slightly disliked and 5.3= neither liked nor disliked respectively) but sample with 1.5% NaCl received higher scores than 0% NaCl. When the sourdough content was reduced to 17% and coupled with 0% tempe, 0.75 and 1.5% NaCl had similar overall palatability scores , 6.0 (slightly liked) and 5.5 (between "neither liked nor disliked" and "slightly liked"), respectively, and these were significantly higher than 0% NaCl (3.6= slightly disliked). Finally, when bread samples had 17% sourdough and 2% tempe, 0.75 and 1.5% NaCl obtained similar scores 4.7 and 4.5 (neither liked nor disliked), respectively, and these are significantly higher than 0% NaCl (3.1= moderately liked). All the treatment comparisons portrayed that panelists perceived similar overall palatability with 0.75% NaCl and 1.5% NaCl. With the incorporation of 33% sourdough and 0% tempe, scores displayed that samples with 0.75 and 1.5% NaCl scored similarly 4.8 and 5.2 (neither liked nor disliked) respectively, and these scores were significantly higher than the sample with 0% NaCl (3.5). When samples had 33% sourdough and 2% tempe, again 0.75 and 1.5% NaCl obtained similar scores of 4.6 (neither liked nor disliked) and these scores were significantly higher than 0% NaCl (3.2= moderately disliked).

3.1.2.7 .2 Effect of tempe

When the effect of 2% tempe on overall palatability perception was analyzed, half of the treatment comparisons (four out of eight) showed a significant effect and half did not ($p > 0.05$) (Table 11). When bread samples did not have sourdough and NaCl, sample `with 0% tempe (6.1) scored higher than 2% tempe (4.6). When samples with 0% sourdough and 0.75% NaCl were analyzed, 0% tempe (6.1) scored higher than 2% tempe (4.6). When the NaCl content was similar to the standard 1.5%, average scores was 5.5 (between "neither liked nor disliked" and "slightly liked"). When, the sourdough level was 17% and combined with 0% NaCl, the samples displayed an average score of 3.3 which was indicative of the overall palatability of the bread was slightly disliked by the panelists. When the samples with 17% sourdough and 0.75% NaCl were analyzed for overall palatability, 0% tempe (6.0) scored significantly higher than 2% tempe (4.7). Finally, sample containing 17% sourdough and 1.5% NaCl displayed a higher score with 0% tempe (5.5) than 2% tempe (4.5). With higher sourdough levels like 33% combined with 0% NaCl, the mean overall palatability score was 3.3 (disliked moderately). With 33% sourdough and 0.75% NaCl, the mean score was 4.7 which indicated that the panelists neither liked nor disliked the overall palatability perceived from the samples. When samples contained 33% sourdough and 1.5% NaCl, the mean score of overall palatability was 4.9 (neither liked nor disliked).

3.1.2.7 .3 Effect of sourdough

When the effect of sourdough on overall palatability of bread was analyzed, the majority of the treatments comparisons did not have a significant effect except for two (two out of six) (Table 12). The samples containing 0% NaCl and tempe, 0% sourdough (4.6) scored significantly higher than 17and 33% sourdough (3.5 and 3.6). When 0% and 0.75% NaCl was included, 33% sourdough (4.9) scored significantly lower than 0% and 17% sourdough (6.1 and 6.0) , respectively. Samples with 0% tempe and 1.5% NaCl displayed a mean score of 5.5 that says the overall palatability was neither liked nor disliked by the panelists. For samples with 2% tempe and 0% NaCl, the average score for the three sourdough levels was 3.3 which directs that the overall palatability of bread was moderately disliked by the panelists. Samples containing 0.75% NaCl and 2% tempe received a mean score of 4.6, indicative of the fact that overall palatability of bread were neither liked nor disliked by the panelists. Lastly, where 2% tempe and 1.5% NaCl was present, mean score for overall palatability of bread as influenced by sourdough levels was 4.8 (neither liked nor disliked).

3.1.3 Third session

The third sensory session was conducted with NaCl 0, 0.75 and 1.5%, sourdough 0, 17 and 33% and tempe 0 and 3.5%. From the second session, it was learned that 2% tempe did not have any significant effect on the saltiness perception of bread. Therefore, an increased level of 3.5% tempe was used (keeping the sourdough and NaCl at same level as second baking session) and further sensory analysis was done to analyze the seven parameters of taste.

3.1.3.1 Saltiness

3.1.3.1 .1 Effect of NaCl

The effect of NaCl (0, 0.75 and 1.5%) at specific levels sourdough (0, 17 and 33%) and tempe (0 and 2%) on bread saltiness scores were reported in Table 13. When bread without any fermented products was analyzed, the results were as follows. Panelists could not detect the difference in saltiness between 0 and 0.75% NaCl (4.0 and 4.5) but sample with 1.5% NaCl (5.8 = slightly liked) scored significantly higher than the previous mentioned levels. The samples containing 17% sourdough and 0% tempe had a mean score of saltiness of 4.5 (slightly disliked).The treatment which had 17% sourdough and 3.5% tempe gives a very interesting result. The bread samples that had 0.75% NaCl scored higher than the bread containing 1.5% NaCl (6.4 = "slightly liked" and 4.9 = "slightly disliked" respectively). As expected, the lowest score was received by samples with 0% NaCl (3.6 = slightly disliked) ($p < 0.05$).When 3.5% tempe and 0% sourdough was added to the bread, a striking difference was observed in the score, sample containing 0.75% NaCl and 1.5% NaCl gave the similar saltiness perception score 5.7 and 5.5 (slightly liked) respectively and these were significantly higher from 0% NaCl (4.6= neither liked nor disliked). Therefore, tempe played an important role here in modulating the saltiness perception. When only 33% sourdough and 0% tempe was present, panelists scored significantly higher saltiness for 0.75% NaCl compared to 1.5% NaCl (4.3 and 5.6 respectively), and no significant differences in score were observed in samples with 0 and 0.75% NaCl (3.9 and 4.3 respectively).Three samples containing 33% sourdough and 3.5% tempe showed that the saltiness scores were not significantly different from each other and had mean score of saltiness of 5.2 (neither liked nor disliked).

3.1.3.1 .2 Effect of tempe

The effect of tempe (0 and 3.5%) at specific levels of sourdough (0, 17 and 33%) and NaCl (0, 0.75 and 1.5%) on bread saltiness scores was reported in Table 14.When the analysis was done comparing the presence of tempe had any effect on saltiness perception score, the results were mixed. Samples having 0% sourdough and NaCl, the scores were not significantly different from each other and the overall mean score was 4.3 (slightly disliked). In samples containing no sourdough and 0.75% NaCl, 3.5% tempe (5.7 = slightly liked) scored significantly higher than 0% tempe (4.5 = between "slightly disliked" and "neither liked nor disliked"). Also, saltiness scores were not significantly different from each other containing 0% sourdough and 1.5% NaCl, with a mean score of 5.6 (slightly liked). In 17% sourdough and 0% NaCl , 0% tempe (4.6) scored higher than 3.5% tempe (3.6). When 17% sourdough was combined with 0.75% NaCl, 3.5% tempe (6.4) scored higher than 0% tempe (4.2). Finally, when 17% sourdough was coupled with 1.5% NaCl, the scores were not significantly different from each other and the means of saltiness score was 4.6 (neither liked nor disliked). In 33% sourdough combined with 0% NaCl, 3.5% tempe (5.1 = neither liked nor disliked) scored higher than 0% tempe (3.9 = slightly disliked). 33% sourdough and 0.75% NaCl showed that 3.5% tempe (5.2 = neither liked nor disliked) scored significantly higher than 0% tempe (4.3 = slightly disliked). For samples containing 33% sourdough and 1.5% NaCl, tempe scores for saltiness (0vs 3.5%) were not significantly different from each other; however the mean score was 5.5 (neither liked nor disliked) (Table 14).

3.1.3.1 .3 Effect of sourdough

The effect of sourdough (0, 17 and 33%) at given levels of tempe (0 vs 2%) and NaCl (0, 0.75 and 1.5%) in bread saltiness score was summarized in Table 15. In samples with had 0% tempe and NaCl, the saltiness scores were similar with a mean of 4.1 (slightly disliked).Sample containing 0% tempe and 0.75% NaCl also had similar saltiness scores 4.3, slightly disliked. Samples without tempe and 1.5% tempe had similar scores for bread saltiness, 5.4 ($p > 0.05$). When 3.5% tempe was included in the sample, there was a change in the score pattern. When samples had 3.5% tempe and 0% NaCl, scores of samples with 0and 33% sourdough (4.6 and 5.1 respectively) was significantly higher than 17% sourdough (3.6). When 3.5% tempe and 0.75% NaCl were in the samples, 0% sourdough (5.7) had similar saltiness scores to 17 and 33% sourdough (6.4 and 5.2, respectively), while17% sourdough had higher score than 33% sourdough (6.4 vs. 5.2). Finally in samples containing 3.5% tempe and 1.5% tempe, scores of 0 and 33% sourdough (5.5 and 5.4 respectively) were similar and these were significantly higher than 17% sourdough (4.6). These observations suggested that the effect was not linear and it might be a threshold level of sourdough that passing it decreased the perception of saltiness. This area requires further investigation.

3.1.3.2 Bitterness

3.1.3.2.1 Effect of NaCl

The effect of NaCl on bitterness perception score of bread overall was significant except for one treatment (Table 16). In the bread sample where no fermented products (0% sourdough and tempe) were present, 0.75% NaCl received the highest score (5.8= slightly liked), 1.5% NaCl being next (4.8= neither liked nor disliked) and 0% NaCl (4.0= slightly disliked) being the least. Higher score in the 9-point hedonic scale means the panelists ranked higher the bread when asked to consider bitter notes in the bread, thus they liked more the flavor profile when analyzed for bitterness compared to a lower score. When 3.5% tempe was added along with 0% sourdough, no significant difference was observed between the scores which had mean bitterness score of 4.1 (slightly dislike) ($p > 0.05$). Similar pattern was seen when 33% and 17% sourdough was added (0% tempe). Here, samples with 1.5% NaCl have a higher score for bitterness than the lower salt levels. For sample with 33% sourdough and 0% tempe, bitterness score for 1.5% NaCl was 5.4 (neither liked nor disliked) which is significantly higher than 0and 0.75% NaCl (3.8 and 4.1 respectively). Also for sample containing 17% sourdough and 0% tempe, sample score for 1.5% NaCl was 5.3 which was significantly higher than the scores for 0 and 0.75% NaCl (4.4 and 4.5 respectively). But when 3.5% tempe was added along with the sourdough, samples with 0.75% NaCl scored higher for bitterness (they were liked more) than 0% or 1.5% NaCl. Samples with 33% sourdough and 3.5% tempe scores display that 0.75% NaCl (4.5) had significantly higher than 1.5% NaCl (3.2), In the same comparison of sourdough and tempe (33%-3.5%), 0% NaCl (3.7) bitterness scores were similar for 0.75 and 1.5% NaCl. Similarly when 17% sourdough and 3.5% tempe was present, 0.75% NaCl (5.0) scored higher than 0 and 1.5% NaCl (3.3 and 3.4 respectively). This suggested that with the specific combinations of sourdough and tempe 0.75% NaCl will be more appropriate to use since received a higher score of bitterness, meaning they were liked more.

3.1.3.2.2 Effect of tempe

The effect of tempe on bitterness scores of bread was significant on 4 out of 9 treatment comaprisons. In each of the four cases, 3.5% tempe significantly decreased the bitterness scores as compared to 0% tempe. For example, treatments with 0% sourdough and 0.75% NaCl showed that bread samples with 3.5% tempe scored 4.4 (slightlydisliked) which was significantly lower than the treatment with 0% tempe which scored 5.8 (slightl liked). In treatment comparison containing 17% sourdough and 1.5% NaCl, bread sample with 3.5% tempe scored 3.4 which is significanrtly lower than 5.3 (0% tempe). In treatment containing 33% sourdough and 1.5%

NaCl, samples with 3.5% tempe (3.2 = moderately disliked) scored significantly lower than 0% tempe (5.4 = neither liked nor disliked).Tempe did not have a significant effect on any other treatments.

3.1.3.2.3 Effect of sourdough

The effect of sourdough on bitterness scores of bread was for the most part not significant except for two treatment comparisons (Table 18). In the samples with 0% tempe and NaCl, the scores were similar for all three sourdough levels with a mean of 4.0 (slightly disliked). Sample scores having 0% tempe and 0.75% NaCl showed similar scores for 33 and 17% sourdough (4.1 and 4.5, respectively) and these scores were significantly lower than 0% sourdough (5.8). Samples containing 0% tempe and 1.5% tempe had similar scores of bitterness for all three sourdough levels with a mean value of 5.1 (neither liked nor disliked). When samples had 3.5% tempe and 0% NaCl, there was no effect of sourdough levels on the mean score of bitterness with an overall mean of 3.5 (disliked moderately). When 3.5% tempe and 0.75% NaCl was in the samples, 0, 17 and 33% sourdough has similar bitterness scores with a mean of 4.6 (neither liked nor disliked). Finally in samples containing 3.5% tempe and 1.5% tempe, bitterness scores of 17 and 33% sourdough were similar (average 3.3, disliked moderately) and these were significantly lower than 0% sourdough (4.4= slightly disliked).

3.1.3.3 Sourness

3.1.3.3 .1 Effect of NaCl

A significant effect of NaCl was observed on the sourness score of bread in most of the treatment comparisons except for two (Appendix III Table 31). In the breads with no fermented products (0% sourdough and 0% tempe), 0.75 and 1.5% NaCl (5.5 and 5.6, respectively) received similar sourness score and these scores were higher than 0% NaCl (3.9) ($p< 0.05$).This suggests that NaCl improved the scores of likeness of bread samples when analyzed for sourness. When 3.5%

tempe with 0% sourdough were added, there was no significant difference in the sourness scores (4.6, neither liked nor disliked) ($p > 0.05$) in the three levels of NaCl. This suggests that NaCl does not affect sourness perception in bread with 3.5% tempe and no sourdough. Similar scores of sourness were observed with 33% sourdough and 3.5% tempe with the three levels of NaCl (4.0 slightly disliked). It was interesting to observe that when the bread contained 17% sourdough in combination with 3.5% tempe, 0.75% NaCl had a significantly higher score of sourness (5.8= slightly liked) than 1.5% NaCl (3.4= moderately disliked) and 0% NaCl (3.2= moderately disliked). On the contrary, when 17% sourdough was coupled with 0% tempe, sourness scores of samples with 0.75 and 1.5% NaCl (5.2 and 5.4, neither liked nor disliked, respectively) were significantly higher than 0% NaCl (4.0) ($p < 0.05$).

3.1.3.3 .2 Effect of tempe

Tempe had a significant effect on sourness in only two out of nine comparison treatments (Appendix III Table 32).In the treatment comparison with 0% sourdough and 1.5% NaCl, 3.5% tempe (4.7= neither liked nor disliked)had a significantly lower score than 0% tempe (5.6 = slightly liked). Also, in treatment combination with 17% sourdough and 0% NaCl, 3.5% tempe (3.2 = moderately disliked) had a significantly lower score than 0% tempe (4.0 = slightly disliked). These two comparison treatment suggested that inclusion of tempe was not liked by the panelists in terms of sourness perception.

3.1.3.3 .3 Effect of sourdough

The effect of sourdough on sourness score of bread was significant in the majority of the treatment comparisons (four out of six), except for two (Appendix III Table 33). In the samples which had 0% tempe and NaCl, the scores were similar (3.8, slightly disliked). Sample scores having 0% tempe and 0.75% NaCl showed that 0 and 17% sourdough (5.5 and 5.2, respectively) scored significantly higher than 33% sourdough (4.1). Samples containing 0% tempe and 1.5%

tempe had similar sourness score which averaged 5.2 ($p > 0.05$). When 3.5% tempe was included in the sample, there was a change in the score pattern. When samples had 3.5% tempe and 0% NaCl, scores of samples with 17 and 33% sourdough (3.2 and 3.5, respectively) was significantly lower than 0% sourdough (4.4= slightly liked). When 3.5% tempe and 0.75% NaCl was in the samples, 17% sourdough (5.8) scored significantly higher than 0 and 33% sourdough (4.9= neither liked nor disliked and 4.1= slightly disliked, respectively). Finally in samples containing 3.5% tempe and 1.5% tempe, scores of sourness for 0 and 33% sourdough (4.7 and 4.4, respectively) were similar but significantly higher than 17% sourdough (3.4= moderately liked).

3.1.3.4. Sweetness

3.1.3.4.1 Effect of NaCl

The effect of NaCl on sweetness perception score in bread was significant except for one treatment comparison (17% sourdough and 0% tempe) in which the three NaCl levels did not affect the sweetness scores (Appendix III Table 34). In the bread sample where no fermented products (0% sourdough and tempe) were present, 0.75 and 1.5% NaCl (5.1= neither liked nor disliked) received significantly higher scores than 0% NaCl (4.1 = slightly disliked). When 3.5% tempe was added along with 0% sourdough, significant differences were observed between the sweetness scores, 0 and 1.5% NaCl (4.0 = slightly disliked) scored significantly lower than 0.75% NaCl (4.9 = neither liked nor disliked). For samples containing 17% sourdough and 0% tempe, sample sweetness scores were similar (4.8 = neither liked nor disliked). But when 3.5% tempe was added along with the 17% sourdough, samples with 0.75% NaCl (5.5) scored higher than 0% or 1.5% NaCl (3.5). With 33% sourdough and 0% tempe, sample scores were significantly different from each other, 0.75 and 1.5% NaCl (4.9 and 4.8 respectively) received significantly higher scores than 0% NaCl (3.7 = slightly disliked). Samples with 33% sourdough and 3.5%

tempe, score of sweetness for 0.75% NaCl (4.5) was significantly higher than 0 and 1.5% NaCl (3.7 = slightly disliked).

3.1.3.4.2 Effect of tempe

There was a significant effect of tempe on sweetness perception score of bread; in half (four out of eight) of the treatment comparisons the score decreased with 3.5% tempe while in the other half of the comparisons there was no significant effect (Appendix III Table 35). In samples having 0% sourdough and NaCl, sweetness scores were not significantly different from each other (4.1= slightly disliked). In samples having 0% sourdough and 0.75% NaCl, the sweetness scores were similar to each other with a mean of 5.1, indicating that the sweetness in bread as affected by tempe was neither liked nor disliked by the panelists. In sample breads containing 0% sourdough and 1.5% NaCl, 0% tempe (5.3 = neither liked nor disliked) scored higher than 3.5% tempe (4.0 = slightly disliked). Sample was tested for 17% sourdough and 0% NaCl and observed that 0% tempe (4.8 = neither liked nor disliked) scored higher than 3.5% tempe (3.7= slightly disliked). When 17% sourdough was combined with 0.75% NaCl, similar scores were observed for sweetness with mean score of 5.2, which explains that the sweetness was neither liked nor disliked by the panelists. Finally, when 17% sourdough was coupled with 1.5% NaCl, it was observed that 0% tempe (5.1) scored higher in sweetness than 3.5% tempe (3.5). 33% sourdough combined with 0% NaCl displayed that the scores were not significantly different from each other (mean 3.7 = slightly disliked). Similarly, 33% sourdough and 0.75% NaCl showed that scores were not significantly different from each other (mean 4.7 = neither liked nor disliked). Sample containing 33% sourdough and 1.5% NaCl reflected that the scores were significantly different from each other; 0% tempe (4.8= neither liked nor disliked) scored significantly higher than 3.5% tempe (3.7 = slightly disliked).

3.1.3.4.3 Effect of sourdough

The effect of sourdough on the sweetness of bread was analyzed and no significant differences were observed ($p > 0.05$) (Appendix III Table 36). 0% tempe and NaCl provided an mean score of 4.1 which indicates the sweetness was slightly disliked by the panelists. When 0% tempe and 0.75% NaCl was included, the mean score for the samples was 5.0 (neither liked nor disliked). Samples with 0% tempe and 1.5% NaCl displayed a mean score of 5.0 (neither liked nor disliked). For samples with 3.5% tempe and 0% NaCl, the mean score for the three sourdough levels was 3.8 suggesting that the sweetness was slightly disliked by the panelists. Samples containing 0.75% NaCl and 3.5% tempe received a mean score of 4.9, indicative of the fact that the sweetness was neither liked nor disliked by the panelists. Lastly, where 3.5% tempe and 1.5% NaCl were present, mean score for sweetness on the perspective of sourdough was 3.8 (slightly disliked).

3.1.3.5. Pasteboardiness

3.1.3.5.1 Effect of NaCl

Overall, there was a significant effect of NaCl levels on the pasteboardiness perception score in bread, except for two treatment comparison (0% sourdough - 0% tempe and 33% sourdough - 0% tempe) in which the three levels of NaCl did not affect pasteboardiness scores (Appendix III Table 37). In the bread sample where no fermented product (0% sourdough and tempe) was present, all the NaCl levels received similar scores (mean 4.4 = slightly disliked) ($p > 0.05$). When 3.5% tempe was added along with 0% sourdough, 0.75 and 1.5% NaCl (5.7 and 4.9, respectively) scored significantly higher than 0% NaCl (3.7= slightly disliked). For samples containing 17% sourdough and 0% tempe, pasteboardiness score for 1.5% NaCl was 5.8 which is significantly higher than 0 and 0.75% NaCl (4.0). But when 3.5% tempe was added along with the 17% sourdough, samples with 0.75% NaCl (5.5) scored higher than 0 and 1.5% NaCl (4.5 and

3.8, respectively). With 33% sourdough and 0% tempe, sample scores were not significantly different from each other (mean 4.0 = slightly disliked). Samples with 33% sourdough and 3.5% tempe, pasteboardiness scores of 0.75% NaCl (4.8 = neither liked nor disliked) were significantly higher than 0 and 1.5% NaCl (3.5 and 3.0, respectively).

3.1.3.5.2 Effect of tempe

There was a significant effect of tempe on pasteboardy perception scores of bread; in four out of nine treatment combinations the pasteboardy scores were affected by tempe (Appendix III Table 38). Samples having 0% sourdough and NaCl, the scores were not significantly different from each other (mean 3.8 = slightly disliked). In samples having 0% sourdough and 0.75% NaCl, 3.5% tempe (5.7= slightly liked) scored significantly higher pasteboardy perception than 0% tempe (4.8= neither liked nor disliked). Sample scores weren't significantly different from each other when containing 0% sourdough and 1.5% NaCl (mean 4.7). Comparison of samples with 17% sourdough and 0% NaCl resulted in pasteboardy scores that were not significantly different from each other (mean 4.2 = slightly disliked). When 17% sourdough was combined with 0.75% NaCl, scores reflected that 3.5% tempe (5.5) scored higher than 0% tempe (4.0). Finally, when 17% sourdough was coupled with 1.5% NaCl, it was observed that 0% tempe (5.8) scored higher than 3.5% tempe (3.8). For samples containing 33% sourdough combined with 0% NaCl, tempe levels displayed scores not significantly different from each other (mean 3.6 = slightly disliked). Similarly, 33% sourdough and 0.75% NaCl showed that scores were not significantly different from each other (mean 4.5 = slightly disliked). For samples containing 33% sourdough and 1.5% NaCl, pasteboardy scores were significantly different from each other; 0% tempe (4.1) scored higher than 3.5% tempe (3.0).

3.1.3.5.3 Effect of sourdough

There was a significant effect of sourdough on pasteboardiness score of bread; in half of the treatment comparisons pasteboardiness scores were affected by tempe and in half were not (Appendix III Table 39). In the samples which had 0% tempe and NaCl, the scores were similar at the three sourdough levels (mean 3.9 = slightly disliked). Samples having 0% tempe and 0.75% NaCl also showed that the scores of pasteboardiness were similar (mean 3.9 = slightly disliked). Samples containing 0% tempe and 1.5% tempe displayed that 17% sourdough (5.8) scored higher than 0 and 33% sourdough. When samples had 3.5% tempe and 0% NaCl, scores of samples with 0 and 33% sourdough (3.7 and 3.5, respectively) were significantly lower than 17% sourdough (4.5). When 3.5% tempe and 0.75% NaCl were in the samples, the scores were not significantly different from each other (mean score 5.3). Samples containing 3.5% tempe and 1.5% tempe, pasteboardiness scores of sample with 0% sourdough (4.9) were higher than 17% sourdough (3.8) and 33% sourdough (3.0).

3.1.3.6 Aroma

3.1.3.6.1 Effect of NaCl

There was a significant effect of NaCl on aroma scores of white bread; in most of the treatment comparisons, aroma scores were significantly affected by NaCl, except for 0% sourdough - 3.5% tempe and 17% sourdough - 0% tempe (Appendix III Table 40). In the bread sample where no fermented product (0% sourdough and tempe) were present, 0 and 0.75% NaCl (4.6 and 5.4, respectively) received significantly lower aroma scores than 1.5% NaCl (6.4 = slightly liked). When 3.5% tempe was added along with 0% sourdough, no significant differences in aroma scores were observed (mean 5.0), indicating that the aroma was neither liked nor disliked by the panelists. In sample containing 17% sourdough and 0% tempe, aroma scores were similar (mean 5.5 = neither liked nor disliked). When 3.5% tempe was added along with the 17% sourdough, samples with 0.75% NaCl (6.2) scored highest followed by 0% NaCl (5.0 = neither liked nor disliked) and the least scored was 1.5% NaCl (3.9 = slightly disliked). For sample with 33% sourdough and 0% tempe, aroma scores were significantly different from each other, 0 and 0.75% NaCl (4.1 = slightly disliked) received significantly lower scores than 1.5% NaCl (5.6 = slightly liked). Samples with 33% sourdough and 3.5% tempe aroma scores displayed that 1.5% NaCl (3.0 = moderately liked) was significantly lower than 0 and 0.75% NaCl (4.5 and 5.1, respectively).

3.1.3.6.2 Effect of tempe

The majority of treatment comparisons revealed a significant effect on aroma perception score of bread due to tempe (Appendix III Table 41). In the samples having 0% sourdough and NaCl, the scores were not significantly different from each other (mean 4.7 = neither liked nor disliked). In samples having 0% sourdough and 0.75% NaCl, the scores were not significantly different from each other (mean 5.2 = neither liked nor disliked) ($p > 0.05$). Sample scores were significantly different from each other containing 0% sourdough and 1.5% NaCl, where 0% tempe (6.4) scored higher than 3.5% tempe (5.1). Samples were compared for 17% sourdough and 0% NaCl and observed that scores were not significantly different from each other (mean 5.1 = slightly disliked). When 17% sourdough was combined with 0.75% NaCl, scores reflected that 3.5% tempe (6.2) scored higher than 0% tempe (5.3). When 17% sourdough was coupled with 1.5% NaCl, it was observed that 0% tempe (5.9) scored higher than 3.5% tempe (3.9). For samples containing 33% sourdough combined with 0% NaCl displayed that the scores were not significantly different from each other (mean 4.3 = slightly disliked). But, sample with 33% sourdough and 0.75% NaCl showed that scores were significantly different from each other, 3.5% tempe (5.1) scored significantly higher than 0% tempe (4.1). In contrast, samples containing 33% sourdough and 1.5% NaCl, 0% tempe (5.6) scored higher than 3.5% tempe (3.0).

3.1.3.6.3 Effect of sourdough

Overall, there was a significant effect of sourdough on aroma score of bread, except for two treatment comparisons (Appendix III Table 42). Comparing the samples which had 0% tempe and NaCl, samples with 0 and 33% sourdough (4.6 and 4.1 respectively) had significantly lower aroma scores than 17% sourdough (5.3). In the comparison of sample scores having 0% tempe and 0.75% NaCl, 0 and 17% sourdough (mean 5.35) had higher scores than 33% sourdough (4.1). Samples containing 0% tempe and 1.5% tempe displayed that the scores were not significantly different from each other (mean score 5.9 = slightly liked). When samples had 3.5% tempe and 0% NaCl, aroma scores of samples were similar to each other (mean 4.7). When 3.5% tempe and 0.75% NaCl were in the samples, the scores were different, samples with 0 and 33% sourdough (5.1) was significantly lower than 17% sourdough (6.2). Finally, in samples containing 3.5% tempe and 1.5% NaCl, aroma scores of samples with 0% sourdough (5.1) were highest, followed by 17% and 33% sourdough (3.9 and 3.0, respectively).

3.1.3.7 Overall palatability

3.1.3.7.1 Effect of NaCl

Consumers would actually look at a product's overall palatability and therefore this parameter is very important. There was a significant effect of NaCl on overall palability scores of white bread, except for one treatment combination with the highest percentage of sourdough and tempe of this study (33% sourdough and 3.5% tempe) (Table 19). In the bread samples where no fermented products (0% sourdough and tempe) were present, 0.75 and 1.5% NaCl (5.7 and 5.3, respectively) received significantly higher palatability scores than 0% NaCl (4.5). When 3.5% tempe was added along with 0% sourdough, significant differences were observed between the palatability scores; 0.75 and 1.5% NaCl (mean 4.75) received significantl y higher scores than 0% NaCl (3.7 = slightly disliked). For 33% sourdough and 0% tempe, sample palatability scores were significantly different from each other; score of 0.75% NaCl (4.4 = slightly disliked) was similar to 0 and 1.5% NaCl but 1.5% NaCl (5.0 = neither liked nor disliked) had significantly higher overall palatability scores than 0% NaCl (3.8 = slightly disliked). Samples with 33% sourdough and 3.5% tempe had similar overall palatability scores (mean 3.8 = slightly disliked). For samples containing 17% sourdough and 0% tempe, score of 0.75% NaCl (4.8 = neither liked nor disliked) was similar to 0 and 1.5% NaCl but 1.5% NaCl (5.4) scored significantly higher than 0% NaCl (4.2 = slightly disliked). But when 3.5% tempe was added along with the 17% sourdough, samples with 0.75% NaCl (5.5) scored the highest followed by 1.5% NaCl (4.0 = slightly disliked) and the least being 0% NaCl (3.2= moderately disliked).

3.1.3.7.2 Effect of tempe

There was a significant effect of tempe on overall palatability of bread with 3.5% tempe scoring lower than samples without tempe (Table 20). Samples containing 0% sourdough and NaCl had similar scores (mean 4.1= slightly disliked). Comparing samples with 0% sourdough and 0.75% NaCl displayed that 0% tempe (5.7) scored higher than 3.5% tempe (4.7 = neither liked nor disliked). 0% sourdough and 1.5% NaCl showed similar results for 0 and 3.5% tempe (mean 5.0 = neither liked nor disliked). 0% tempe (4.2 = slightly disliked) scored higher overall palatability than 3.5% tempe (3.2) in samples with 17% sourdough and 0% NaCl. Samples having 17% sourdough and 0.75% NaCl reflected that scores were similar for 1 and 3.5% tempe (mean 5.1 = neither liked nor disliked). In contrast, samples having 17% sourdough and 1.5% NaCl showed that 0% (5.4 = neither liked nor disliked) tempe scored higher than 3.5% tempe (4.0 = slightly disliked). 33% sourdough and 0% NaCl also showed similar overall palatability scores for 0 and 3.5% tempe (mean 3.6 = slightly disliked). Samples with 33% sourdough and 0.75% NaCl also had similar scores for 1 and 3.5% tempe (mean 4.3 = slightly disliked). Comparing samples containing 33% sourdough and 1.5% NaCl, 0% tempe (5.0) scored higher overall palatability than 3.5% tempe (3.7 = slightly disliked).

3.1.3.7.3 Effect of sourdough

There was a highly significant effect of sourdough on the overall palatability score of bread, except for three treatment comparisons consisting of 0% tempe - 0% NaCl, 0% tempe – 1.5% NaCl, and 3.5% tempe – 0% NaCl in which no effect of sourdough level was observed (Table 21). Comparing the samples which had 0% tempe and NaCl, there was no significant effect of sourdough in overall palatability scores (mean 4.1 = slightly disliked). Sample scores having 0% tempe and 0.75% NaCl showed that 17 and 33% sourdough (4.8 and 4.4, respectively) scored significantly lower than 0% sourdough (5.7). Samples containing 0% tempe and 1.5% tempe had similar overall palatability with the three levels of sourdough studied (mean 5.2) ($p > 0.05$). When 3.5% tempe was included in the sample, there was a change in the score pattern. When samples had 3.5% tempe and 0% NaCl, they had similar palatability scores with the three sourdough levels (mean 3.4 = disliked moderately) ($p > 0.05$). When 3.5% tempe and 0.75% NaCl was in the samples, 17% sourdough (5.5) scored significantly higher than 0 and 33% sourdough (4.7 and 4.2, respectively). Finally, in samples containing 3.5% tempe and 1.5% NaCl, scores of 17 and 33% sourdough (3.7 and 4.0, respectively) were similar but significantly lower than 0% sourdough (4.8 = neither liked nor disliked).

4. Discussion

In the first session of sensory analysis sodium chloride (0.5, 1.5 and 2%) and sourdough (11, 17 and 33%) did not make any significant effect on scores of seven parameters of white bread flavor profile. Tempe at 5% decreased the scores of flavor profile significantly ($p< 0.05$). Since 5% tempe had an intense flavor, panelists disliked the flavor profile of white bead. According to (Shogren et al., 2003) bitter taste was prominent in bread samples baked with no yeast and bread samples containing 40% soy flour. Soy flour masked the sweet taste of bread samples. In another study no significant effect in flavor profile was recorded with the addition of up to 15% of defatted soy flour (Klein et al., 1995). Also, the addition of 12% soy flour in hot dog buns were found with no significant effect in flavor profile (Tsen and Hoover, 1973). Wheat bread containing up to 20% soy flour had a very strong beany flavor compared to wheat bread with no soy flour added (Buck et al., 1987). Soybean flour substitution up to 40% resulted in lower scores in flavor profile of wheat bread, as panelists detected strong beany flavor and aroma (Ndife et al., 2011). When wheat flour is substituted by soy flour by more than 15%, it imparts soybean roasted flavor upon baking; during baking auto or enzymatic oxidation of lipids present in soybean releases ketones and aldehydes. These aldehydes and ketones make soybean flour consumption undesirable (Serrem et al., 2011). Whole wheat bread with 5% soy flour substitution were not preferred from all aspects of sensory analysis compared to whole wheat bread (Olaoye et al., 2006). Sourdough at 11% was too diluted and did not make significant effects on flavor profile so in the second sensory evaluation session the sourdough levels were increased to 17 and 33%.

In the second sensory session different levels of sodium chloride, tempe and sourdough were used. Tempe level was decreased from 5 to 2% because panelists disliked the flavor. Sodium chloride at 0.75 and 1.5% gave similar flavor perception which was significantly higher than 0% sodium chloride level in most of the parameters except aroma. It was reported that wheat breads containing 1.33 and 1.36% sodium chloride were preferred over the bread samples containing higher salt levels. At these levels of sodium chloride panelists could not differentiate other flavor profiles like sourness, sweetness, etc. (Salovaara et al., 1982). It was concluded in a study that panelists prefer bread samples containing 1.25% of sodium chloride compared to 0% NaCl (Collyer, 1966). Bread samples with 0% sodium chloride resulted in lower palatability scores as well as dominant pasteboardy flavor (Salovaara et al., 1982). Tempe at 2% did not affect flavor profile except overall palatability significantly. Sourdough levels of 0, 17 and 33% did not affect sensory parameters significantly ($p > 0.05$). Sodium chloride at higher levels (0.75, 1.5%)

increased overall palatability score compared to 0% sodium chloride whereas; tempe at 2% decreased the scores of overall palatability significantly.

In the experimental design for the third sensory analysis the only change was tempe level, as it was increased from 2 to 3.5%. Tempe at 2% in previous baking session did not give significant effect on any of the flavor parameters. In this sensory session, saltiness perception was similar for 0.75 and 1.5% sodium chloride level. (Konitzer et al., 2013) suggested that sodium chloride at 2% in bread samples gave lower saltiness perception compared to 2% sodium chloride solution. Bread consumption releases sodium chloride at a lower rate in the oral cavity and results in lower saltiness perception compared to a solution. Inhomogeneous distribution of 1.5% sodium chloride in bread gave same saltiness perception as of bread samples containing 1.9% sodium chloride. In few treatment combinations, 0.75% sodium chloride gave higher scores of saltiness perception compared to 0 and 1.5% level. It is important to understand how salt perception occurs in oral space. Typical salt perception in the oral space is based on an ion canal called 'ENaC' (epithelial sodium canal), which is permeable for sodium ions. Due to a concentration slope on the tongue, the sodium ions flow through the ENaC and reach a depolarisation of the membrane. Through this, Na^+ / K^+ canals are opened and an action potential is caused. The action potential leads to an emission of Ca^{2+} ions which releases neurotransmitters and activates primary sensory neurons which pass the signals on to the brain. They are processed in the gustatory cortex, are compared to other impulses, and then the taste impression is interpreted as 'salty' (Despopoulos et al., 2003). Sourdough at 33% in the presence of tempe gave similar saltiness perception among three levels of sodium chloride with the scores ranging from "neither like nor dislike" to "slightly like". Fermentation time affects flavor profile of sourdough bread. Samples baked with sourdough fermented with combination of starters increased the overall flavor (Katina et al., 2006). Tempe at 3.5% in the presence of 17% sourdough and 0.75% sodium chloride gave saltiness perception with range of "moderately like". Sourdough made with fermented wheat germ gave high scores for acidic flavor, saltiness perception was also higher with score range of 6.8 (Rizzello et al., 2010). Tempe had a significant effect on saltiness perception and other sensory parameters. Overall palatability had higher scores with 0.75 and 1.5% sodium chloride compared to 0% sodium chloride. Sourdough (17 and 33%) and sodium chloride (0.75, 1.5%) levels showed higher scores for aroma whereas, lower scores of aroma were recorded with increase in tempe levels. Tempe and sourdough gave significantly lower scores for sourness perception at higher levels.

5. Conclusion

In first sensory session bread samples with 0% tempe scored significantly higher (approx. 6) on flavor profile compared to 5% tempe (approx. 4-5) on the 9-point hedonic scale. The effect of sourdough and NaCl on the scores was not significant. In second sensory session it was concluded that 0.75 and 1.5% NaCl received similar scores for saltiness perception. Sourdough at 17 and 33% levels did not have a significant impact on the saltiness perception. Tempe at 2% decreased the scores of overall palatability significantly. During the third sensory evaluation session it was concluded that 3.5% tempe resulted in significantly lower scores in all flavor parameters except saltiness with some treatment combinations. Samples with 3.5% scored higher than 0% tempe only in a three treatment combinations of saltiness parameter. In a few combinations, 17% sourdough scored higher than 0 and 33% sourdough. The highest score (6.4) for saltiness parameter was observed in the combination where 17% sourdough, 3.5% and 0.75% NaCl was present. Here, panelists did not detect the 50% reduction in salt from 1.5% to 0.75%. This observation can be explained in part by the fact that the intensity of the saltiness perception is in direct combination with the rate of solubility of salt in the food medium. A fast solubility can strengthen the salty taste. Therefore, when a lower concentration of salt is added, if it is increased solubility a high salty perception can be perceived. In this case, 17% sourdough was added into the treatment combination along with 2.5% tempe and 0.75% NaCl. The sourdough most likely lead to an increase in solubility of the bread in the mouth, this in turn caused a higher perception of salt. Also, at 1.5% NaCl with the same treatment combination the scores are significantly lower (4.4) than 0.75% NaCl. According to the explanation given above, 1.5% NaCl might have retained an amount of salt which was too high for the panelists. Therefore, the bread with 1.5% NaCl might have tasted too salty which the panelists did not like and gave lower scores.

Table 1. Effect of tempe (0 and 5%) on saltiness score of white bread at different levels of sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%).

Soudough (%)	**NaCl (%)**	**Tempe (%)**	**Salty**			**P-value**
11	0.5	0	6.2	±	0.27	0.0008
11	0.5	5	4.8	±	0.23	
11	1.0	0	6.1	±	0.27	0.0014
11	1.0	5	4.7	±	0.30	
11	1.5	0	6.1	±	0.21	0.0496
11	1.5	5	5.3	±	0.32	
17	0.5	0	6.1	±	0.31	0.0052
17	0.5	5	4.9	±	0.28	
17	1.0	0	6.4	±	0.34	0.0090
17	1.0	5	5.1	±	0.25	
17	1.5	0	6.6	±	0.38	<0.0001
17	1.5	5	4.5	±	0.38	
33	0.5	0	6.3	±	0.32	0.0029
33	0.5	5	4.8	±	0.50	
33	1.0	0	6.8	±	0.33	0.0043
33	1.0	5	5.4	±	0.43	
33	1.5	0	6.9	±	0.29	0.0049
33	1.5	5	5.5	±	0.40	

[a]Mean (n=3) ± standard error.

Table 2. Effect of tempe (0 and 5%) on bitterness score of white bread at different levels of sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Bitter**	**P-value**
11	0.5	0	5.7 ± 0.26	<0.0001
11	0.5	5	3.8 ± 0.28	
11	1.0	0	5.9 ± 0.26	<0.0001
11	1.0	5	3.9 ± 0.29	
11	1.5	0	5.8 ± 0.26	0.0030
11	1.5	5	4.5 ± 0.31	
17	0.5	0	6.0 ± 0.29	<0.0001
17	0.5	5	4.1 ± 0.25	
17	1.0	0	6.1 ± 0.34	<0.0001
17	1.0	5	3.9 ± 0.27	
17	1.5	0	6.1 ± 0.37	<0.0001
17	1.5	5	3.8 ± 0.32	
33	0.5	0	6.1 ± 0.32	<0.0001
33	0.5	5	3.8 ± 0.43	
33	1.0	0	6.1 ± 0.31	0.0002
33	1.0	5	4.3 ± 0.45	
33	1.5	0	5.9 ± 0.29	<0.0001
33	1.5	5	3.9 ± 0.42	

[a]Mean (n=3) ± standard error.

Table 3. Effect of tempe (0 and 5%) on overall palatability score of white bread at different levels of sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Overall Palatability	P-value
11	0.5	0	6.2 ± 0.23	<0.0001
11	0.5	5	4.0 ± 0.27	
11	1.0	0	6.4 ± 0.29	<0.0001
11	1.0	5	4.5 ± 0.32	
11	1.5	0	6.0 ± 0.21	<0.0001
11	1.5	5	4.4 ± 0.36	
17	0.5	0	6.4 ± 0.28	<0.0001
17	0.5	5	4.4 ± 0.29	
17	1.0	0	6.5 ± 0.36	<0.0001
17	1.0	5	4.2 ± 0.26	
17	1.5	0	6.8 ± 0.30	<0.0001
17	1.5	5	4.3 ± 0.30	
33	0.5	0	6.4 ± 0.28	<0.0001
33	0.5	5	4.2 ± 0.34	
33	1.0	0	6.6 ± 0.27	<0.0001
33	1.0	5	4.7 ± 0.43	
33	1.5	0	6.7 ± 0.24	<0.0001
33	1.5	5	4.2 ± 0.37	

[a]Mean (n=3) ± standard error.

Table 4. Effect of NaCl (0.0, 0.75 and 1.5%) on saltiness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 2%).

Sourdough (%)	**Tempe (%)**	**NaCl (%)**	**Salty**				**P-value**
0	0	0.0	4.6	±	0.25	b	0.0097
0	0	0.75	5.6	±	0.24	a	
0	0	1.5	5.7	±	0.28	a	
0	2	0.0	4.1	±	0.31	b	0.0008
0	2	0.75	5.3	±	0.30	a	
0	2	1.5	5.5	±	0.32	a	
17	0	0.0	3.9	±	0.29	b	<0.0001
17	0	0.75	5.7	±	0.24	a	
17	0	1.5	5.4	±	0.30	a	
17	2	0.0	3.8	±	0.30	b	0.0002
17	2	0.75	5.3	±	0.27	a	
17	2	1.5	5.3	±	0.29	a	
33	0	0.0	4.3	±	0.28	b	0.0053
33	0	0.75	5.1	±	0.25	a	
33	0	1.5	5.6	±	0.25	a	
33	2	0.0	3.9	±	0.33	b	0.0115
33	2	0.75	4.9	±	0.29	a	
33	2	1.5	5.0	±	0.26	a	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 5. Effect of tempe (0 and 2%) on saltiness score of white bread at different levels of sourdough (0, 17 and 33%) and NaCl (0.0, 0.75 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Salty**	**P-value**
0	0.0	0	4.6 ± 0.25	0.2664
0	0.0	2	4.2 ± 0.31	
0	0.75	0	5.6 ± 0.25	0.4379
0	0.75	2	5.3 ± 0.30	
0	1.5	0	5.7 ± 0.28	0.8049
0	1.5	2	5.6 ± 0.31	
17	0.0	0	4.0 ± 0.30	0.7574
17	0.0	2	3.9 ± 0.30	
17	0.75	0	5.7 ± 0.25	0.2939
17	0.75	2	5.3 ± 0.27	
17	1.5	0	5.4 ± 0.31	0.7574
17	1.5	2	5.3 ± 0.29	
33	0.0	0	4.4 ± 0.29	0.3232
33	0.0	2	4.0 ± 0.34	
33	0.75	0	5.2 ± 0.26	0.6212
33	0.75	2	5.0 ± 0.30	
33	1.5	0	5.7 ± 0.25	0.1228
33	1.5	2	5.0 ± 0.27	

[a]Mean (n=3) ± standard error.

Table 6. Effect of sourdough (0, 17 and 33%) on saltiness score of white bread at different levels of tempe (0 and 2%) and NaCl (0.0, 0.75 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Salty	P-value
0	0.00	0	4.6 ± 0.25	0.2991
0	0.00	17	4.0 ± 0.3	
0	0.00	33	4.4 ± 0.29	
0	0.75	0	5.6 ± 0.25	0.3435
0	0.75	17	5.7 ± 0.25	
0	0.75	33	5.2 ± 0.26	
0	1.50	0	5.7 ± 0.28	0.7694
0	1.50	17	5.4 ± 0.31	
0	1.50	33	5.7 ± 0.25	
2	0.00	0	4.2 ± 0.31	0.7520
2	0.00	17	3.9 ± 0.30	
2	0.00	33	4.0 ± 0.34	
2	0.75	0	5.3 ± 0.3	0.6278
2	0.75	17	5.3 ± 0.27	
2	0.75	33	.05 ± 0.3	
2	1.5	0	5.6 ± 0.31	0.3645
2	1.5	17	5.3 ± 0.29	
2	1.5	33	5.0 ± 0.27	

[a]Mean (n=3) ± standard error.

Table 7. Effect of NaCl (0.0, 0.75 and 1.5%) on bitterness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 2%).

Sourdough (%)	Tempe (%)	NaCl (%)	Bitter				P-value
0	0	0.0	4.8	±	0.28		0.0696
0	0	0.75	5.4	±	0.26		
0	0	1.5	5.7	±	0.30		
0	2	0.0	4.1	±	0.29		0.2186
0	2	0.75	4.6	±	0.30		
0	2	1.5	4.8	±	0.31		
17	0	0.0	3.9	±	0.27	b	0.0002
17	0	0.75	5.3	±	0.22	a	
17	0	1.5	5.4	±	0.25	a	
17	2	0.0	3.5	±	0.33	b	0.0013
17	2	0.75	4.9	±	0.23	a	
17	2	1.5	4.7	±	0.31	a	
33	0	0.0	4.4	±	0.29		0.6497
33	0	0.75	4.8	±	0.23		
33	0	1.50	4.6	±	0.34		
33	2	0.0	3.2	±	0.33	b	0.0004
33	2	0.75	4.7	±	0.29	a	
33	2	1.5	4.3	±	0.31	a	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 8. Effect of tempe (0 and 2%) on bitterness score of white bread at different levels of sourdough (0, 17 and 33%) and NaCl (0.0, 0.75 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Bitter**			**P-value**
0	0.0	0	4.8	±	0.28	0.1245
0	0.0	2	4.1	±	0.29	
0	0.75	0	5.4	±	0.26	0.0556
0	0.75	2	4.6	±	0.3	
0	1.5	0	5.7	±	0.3	0.0368
0	1.5	2	4.8	±	0.31	
17	0.0	0	3.9	±	0.27	0.3564
17	0.0	2	3.5	±	0.33	
17	0.75	0	5.2	±	0.21	0.3253
17	0.75	2	4.8	±	0.22	
17	1.5	0	5.3	±	0.25	0.0748
17	1.5	2	4.6	±	0.3	
33	0.0	2	4.4	±	0.29	0.0022
33	0.0	0	3.2	±	0.33	
33	0.75	2	4.8	±	0.23	0.8536
33	0.75	0	4.7	±	0.29	
33	1.5	2	4.6	±	0.34	0.4241
33	1.5	0	4.3	±	0.31	

[a]Mean (n=3) ± standard error.

Table 9. Effect of sourdough (0, 17 and 33%) on bitterness score of white bread at different levels of tempe (0 and 2%) and NaCl (0.0, 0.75 and 1.5%).

Tempe (%)	**NaCl (%)**	**Sourdough (%)**	**Bitter**				**P-value**
0	0	0	4.8	±	0.28		0.0834
0	0	17	3.9	±	0.27		
0	0	33	4.4	±	0.29		
0	0.75	0	5.4	±	0.26		0.3142
0	0.75	17	5.3	±	0.22		
0	0.75	33	4.8	±	0.23		
0	1.5	0	5.7	±	0.3	a	0.0295
0	1.5	17	5.4	±	0.25	ab	
0	1.5	33	4.6	±	0.34	b	
2	0	0	4.1	±	0.29		0.0512
2	0	17	3.5	±	0.33		
2	0	33	3.2	±	0.33		
2	0.75	0	4.6	±	0.3		0.7949
2	0.75	17	4.9	±	0.23		
2	0.75	33	4.7	±	0.29		
2	1.5	0	4.8	±	0.31		0.4213
2	1.5	17	4.7	±	0.31		
2	1.5	33	4.3	±	0.31		

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 10. Effect of NaCl (0.0, 0.75 and 1.5%) on overall palatability score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 2%).

Sourdough (%)	**Tempe (%)**	**NaCl (%)**	**Overall Palatability**				**P-value**
0	0	0.0	4.7	±	0.28	b	0.0020
0	0	0.75	6.1	±	0.28	a	
0	0	1.5	5.8	±	0.31	a	
0	2	0.0	3.8	±	0.27	b	0.0013
0	2	0.75	4.7	±	0.34	ab	
0	2	1.5	5.4	±	0.31	a	
17	0	0.0	3.6	±	0.27	b	<0.0001
17	0	0.75	6.0	±	0.28	a	
17	0	1.5	5.6	±	0.29	a	
17	2	0.0	3.1	±	0.32	b	0.0003
17	2	0.75	4.7	±	0.27	a	
17	2	1.5	4.5	±	0.31	a	
33	0	0.0	3.5	±	0.3	b	<0.0001
33	0	0.75	5.0	±	0.32	a	
33	0	1.5	5.2	±	0.37	a	
33	2	0.0	3.2	±	0.28	b	0.0009
33	2	0.75	4.6	±	0.30	a	
33	2	1.5	4.6	±	0.29	a	

[a]Mean (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

Table 11. Effect of tempe (0 and 2%) on overall palatability score of white bread at different levels of sourdough (0, 17 and 33%) and NaCl (0.0, 0.75 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Overall Palatability			P-value
0	0.0	0	4.7	±	0.28	0.0454
0	0.0	2	3.8	±	0.27	
0	0.75	0	6.1	±	0.28	0.0006
0	0.75	2	4.7	±	0.34	
0	1.5	0	5.8	±	0.31	0.3769
0	1.5	2	5.4	±	0.31	
17	0.0	0	3.6	±	0.27	0.2631
17	0.0	2	3.1	±	0.32	
17	0.75	0	6.0	±	0.28	0.0027
17	0.75	2	4.7	±	0.27	
17	1.5	0	5.6	±	0.29	0.0115
17	1.5	2	4.5	±	0.31	
33	0.0	0	3.5	±	0.30	0.5169
33	0.0	2	3.2	±	0.28	
33	0.75	0	5.0	±	0.32	0.4437
33	0.75	2	4.6	±	0.30	
33	1.5	0	5.2	±	0.37	0.1410
33	1.5	2	4.6	±	0.29	

[a]Mean (n=3) ± standard error.

Table 12. Effect of sourdough (0, 17 and 33%) on overall palatability score of white bread at different levels of tempe (0 and 2%) and NaCl (0.0, 0.75 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Overall Palatability				P-value
0	0.0	0	4.7	±	0.28	a	0.0092
0	0.0	17	3.6	±	0.27	b	
0	0.0	33	3.5	±	0.30	b	
0	0.75	0	6.1	±	0.28	a	0.0102
0	0.75	17	6.0	±	0.28	a	
0	0.75	33	5.0	±	0.32	b	
0	1.5	0	5.8	±	0.31		0.4521
0	1.5	17	5.6	±	0.29		
0	1.5	33	5.2	±	0.37		
2	0.0	0	3.8	±	0.27		0.2039
2	0.0	17	3.1	±	0.32		
2	0.0	33	3.2	±	0.28		
2	0.75	0	4.7	±	0.34		0.9703
2	0.75	17	4.7	±	0.27		
2	0.75	33	4.6	±	0.30		
2	1.5	0	5.4	±	0.31		0.0787
0	1.5	17	4.5	±	0.31		
2	1.5	33	4.6	±	0.29		

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 13. Effect of NaCl (0, 0.75 and 1.5%) on saltiness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 3.5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Salty				P-value
0	0.0	0.0	4.0	±	0.34	b	<0.0001
0	0.0	0.75	4.5	±	0.34	b	
0	0.0	1.5	5.8	±	0.25	a	
0	3.5	0.0	4.6	±	0.30	b	0.0224
0	3.5	0.75	5.7	±	0.27	a	
0	3.5	1.5	5.5	±	0.32	a	
17	0.0	0.0	4.6	±	0.30	a	0.2209
17	0.0	0.75	4.2	±	0.32	a	
17	0.0	1.5	4.9	±	0.32	a	
17	3.5	0.0	3.6	±	0.28	c	<0.0001
17	3.5	0.75	6.4	±	0.19	a	
17	3.5	1.5	4.4	±	0.26	b	
33	0.0	0.0	3.9	±	0.30	b	<0.0001
33	0.0	0.75	4.3	±	0.30	b	
33	0.0	1.5	5.6	±	0.29	a	
33	3.5	0.0	5.1	±	0.28	a	0.7277
33	3.5	0.75	5.2	±	0.24	a	
33	3.5	1.5	5.4	±	0.29	a	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 14. Effect of tempe (0 and 3.5%) on saltiness scores of white bread at different levels of sourdough (0, 17 and 33) and NaCl (0, 0.75 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Salty	P-value
0	0.0	0.0	4 ± 0.34	0.1688
0	0.0	3.5	4.6 ± 0.30	
0	0.75	0.0	4.5 ± 0.34	0.0072
0	0.75	3.5	5.7 ± 0.27	
0	1.5	0.0	5.8 ± 0.25	0.4021
0	1.5	3.5	5.5 ± 0.32	
17	0.0	0.0	4.6 ± 0.30	0.0121
17	0.0	3.5	3.6 ± 0.28	
17	0.75	0.0	4.2 ± 0.32	<0.0001
17	0.75	3.5	6.4 ± 0.19	
17	1.5	0.0	4.9 ± 0.32	0.1881
17	1.5	3.5	4.4 ± 0.26	
33	0.0	0.0	3.9 ± 0.30	0.0023
33	0.0	3.5	5.1 ± 0.28	
33	0.75	0.0	4.3 ± 0.30	0.0485
33	0.75	3.5	5.2 ± 0.24	
33	1.5	0.0	5.6 ± 0.29	0.6752
33	1.5	3.5	5.4 ± 0.29	

Mean (n=3) ± standard error.

Table 15. Effect of sourdough (0, 17 and 33%) on saltiness scores of white bread at different levels of tempe (0 and 3.5%) and sodium chloride (0, 0.75 and 1.5%)

Tempe (%)	**NaCl (%)**	**Sourdough (%)**	**Salty**	**P-value**
0.0	0.0	0	4.0 ± 0.34 a	0.1648
0.0	0.0	17	4.6 ± 0.30 a	
0.0	0.0	33	3.9 ± 0.30 a	
0.0	0.75	0	4.5 ± 0.34 a	0.7347
0.0	0.75	17	4.2 ± 0.32 a	
0.0	0.75	33	4.3 ± 0.30 a	
0.0	1.5	0	5.8 ± 0.25 a	0.0814
0.0	1.5	17	4.9 ± 0.32 a	
0.0	1.5	33	5.6 ± 0.29 a	
3.5	0.0	0	4.6 ± 0.30 a	0.0007
3.5	0.0	17	3.6 ± 0.28 b	
3.5	0.0	33	5.1 ± 0.28 a	
3.5	0.75	0	5.7 ± 0.27 ab	0.0132
3.5	0.75	17	6.4 ± 0.19 a	
3.5	0.75	33	5.2 ± 0.24 b	
3.5	1.5	0	5.5 ± 0.32 a	0.0123
3.5	1.5	17	4.4 ± 0.26 b	
3.5	1.5	33	5.4 ± 0.29 a	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 16. Effect of NaCl (0, 0.75 and 1.5%) on bitterness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 3.5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Bitter				P-value
0	0.0	0.0	4.0	±	0.34	c	<0.0001
0	0.0	0.75	5.8	±	0.22	a	
0	0.0	1.5	4.8	±	0.30	b	
0	3.5	0.0	3.6	±	0.26	a	0.0621
0	3.5	0.75	4.4	±	0.26	a	
0	3.5	1.5	4.4	±	0.31	a	
17	0.0	0.0	4.4	±	0.32	b	0.048
17	0.0	0.75	4.5	±	0.26	b	
17	0.0	1.5	5.3	±	0.28	a	
17	3.5	0.0	3.3	±	0.29	b	<0.0001
17	3.5	0.75	5.0	±	0.31	a	
17	3.5	1.5	3.4	±	0.25	b	
33	0.0	0.0	3.8	±	0.31	b	0.0002
33	0.0	0.75	4.1	±	0.29	b	
33	0.0	1.5	5.4	±	0.27	a	
33	3.5	0.0	3.7	±	0.29	ab	0.0043
33	3.5	0.75	4.5	±	0.30	a	
33	3.5	1.5	3.2	±	0.24	b	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 17. Effect of tempe (0 and 3.5%) on bitterness scores of white bread at different levels of sourdough (0, 17 and 33) and sodium chloride (0, 0.75 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Bitter**	**P-value**
0	0.0	0.0	4.0 ± 0.34	0.3291
0	0.0	3.5	3.6 ± 0.26	
0	0.75	0.0	5.8 ± 0.22	0.001
0	0.75	3.5	4.4 ± 0.26	
0	1.5	0.0	4.8 ± 0.30	0.3291
0	1.5	3.5	4.4 ± 0.31	
17	0.0	0.0	4.4 ± 0.32	0.0074
17	0.0	3.5	3.3 ± 0.29	
17	0.75	0.0	4.5 ± 0.26	0.2003
17	0.75	3.5	5.0 ± 0.31	
17	1.5	0.0	5.3 ± 0.28	<0.0001
17	1.5	3.5	3.4 ± 0.25	
33	0.0	0.0	3.8 ± 0.31	0.8548
33	0.0	3.5	3.7 ± 0.29	
33	0.75	0.0	4.1 ± 0.29	0.2723
33	0.75	3.5	4.5 ± 0.30	
33	1.5	0.0	5.4 ± 0.27	<0.0001
33	1.5	3.5	3.2 ± 0.24	

[a]Mean (n=3) ± standard error.

Table 18. Effect of sourdough (0, 17 and 33%) on bitterness scores of white bread at different levels of tempe (0 and 3.5%) and sodium chloride (0, 0.75 and 1.5%)

Tempe (%)	**NaCl (%)**	**Sourdough (%)**	**Bitter**				**P-value**
0.0	0.0	0	4.0	±	0.34	a	0.322
0.0	0.0	17	4.4	±	0.32	a	
0.0	0.0	33	3.8	±	0.31	a	
0.0	0.75	0	5.8	±	0.22	a	0.0001
0.0	0.75	17	4.5	±	0.26	b	
0.0	0.75	33	4.1	±	0.29	b	
0.0	1.5	0	4.8	±	0.30	a	0.3252
0.0	1.5	17	5.3	±	0.28	a	
0.0	1.5	33	5.4	±	0.27	a	
3.5	0.0	0	3.6	±	0.26	a	0.5749
3.5	0.0	17	3.3	±	0.29	a	
3.5	0.0	33	3.7	±	0.29	a	
3.5	0.75	0	4.4	±	0.26	a	0.3366
3.5	0.75	17	5.0	±	0.31	a	
3.5	0.75	33	4.5	±	0.30	a	
3.5	1.5	0	4.4	±	0.31	a	0.0056
3.5	1.5	17	3.4	±	0.25	b	
3.5	1.5	33	3.2	±	0.24	b	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 19. Effect of NaCl (0, 0.75 and 1.5%) on overall palatability score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 3.5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Overall Palatability	P-value
0	0.0	0.0	4.5 ± 0.33 b	0.0056
0	0.0	0.75	5.7 ± 0.21 a	
0	0.0	1.5	5.3 ± 0.30 a	
0	3.5	0.0	3.7 ± 0.25 b	0.0097
0	3.5	0.75	4.7 ± 0.24 a	
0	3.5	1.5	4.8 ± 0.30 a	
17	0.0	0.0	4.2 ± 0.30 b	0.0099
17	0.0	0.75	4.8 ± 0.32 ab	
17	0.0	1.5	5.4 ± 0.24 a	
17	3.5	0.0	3.2 ± 0.24 c	<0.0001
17	3.5	0.75	5.5 ± 0.29 a	
17	3.5	1.5	4.0 ± 0.32 b	
33	0.0	0.0	3.8 ± 0.30 b	0.0168
33	0.0	0.75	4.4 ± 0.32 ab	
33	0.0	1.5	5.0 ± 0.24 a	
33	3.5	0.0	3.5 ± 0.26 a	0.2004
33	3.5	0.75	4.2 ± 0.29 a	
33	3.5	1.5	3.7 ± 0.23 a	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 20. Effect of tempe (0 and 3.5%) on overall palatability scores of white bread at different levels of sourdough (0, 17 and 33) and sodium chloride (0, 0.75 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Overall Palatability**	**P-value**
0	0.0	0.0	4.5 ± 0.33	0.0623
0	0.0	3.5	3.7 ± 0.25	
0	0.75	0.0	5.7 ± 0.21	0.0109
0	0.75	3.5	4.7 ± 0.24	
0	1.5	0.0	5.3 ± 0.30	0.2373
0	1.5	3.5	4.8 ± 0.30	
17	0.0	0.0	4.2 ± 0.30	0.0155
17	0.0	3.5	3.2 ± 0.24	
17	0.75	0.0	4.8 ± 0.32	0.0819
17	0.75	3.5	5.5 ± 0.29	
17	1.5	0.0	5.4 ± 0.24	0.0005
17	1.5	3.5	4.0 ± 0.32	
33	0.0	0.0	3.8 ± 0.30	0.3839
33	0.0	3.5	3.5 ± 0.26	
33	0.75	0.0	4.4 ± 0.32	0.4939
33	0.75	3.5	4.2 ± 0.29	
33	1.5	0.0	5.0 ± 0.24	0.0013
33	1.5	3.5	3.7 ± 0.23	

[a]Mean (n=3) ± standard error.

Table 21. Effect of sourdough (0, 17 and 33%) on overall palatability scores of white bread at different levels of tempe (0 and 3.5%) and sodium chloride (0, 0.75 and 1.5%)

Tempe (%)	NaCl (%)	Sourdough (%)	Overall Palatability	P-value
0.0	0.0	0	4.5 ± 0.33 a	0.268
0.0	0.0	17	4.2 ± 0.30 a	
0.0	0.0	33	3.8 ± 0.30 a	
0.0	0.75	0	5.7 ± 0.21 a	0.0041
0.0	0.75	17	4.8 ± 0.32 b	
0.0	0.75	33	4.4 ± 0.32 b	
0.0	1.5	0	5.3 ± 0.3 a	0.5009
0.0	1.5	17	5.4 ± 0.24 a	
0.0	1.5	33	5.0 ± 0.24 a	
3.5	0.0	0	3.7 ± 0.25 a	0.4613
3.5	0.0	17	3.2 ± 0.24 a	
3.5	0.0	33	3.5 ± 0.26 a	
3.5	0.75	0	4.7 ± 0.24 b	0.0035
3.5	0.75	17	5.5 ± 0.29 a	
3.5	0.75	33	4.2 ± 0.29 b	
3.5	1.5	0	4.8 ± 0.30 A	0.0124
3.5	1.5	17	4.0 ± 0.32 B	
3.5	1.5	33	3.7 ± 0.23 B	

Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

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CHAPTER IV

EFFECT OF WHOLE WHEAT SOURDOUGH AND WHEAT-SOYBEAN TEMPE FLOUR ON DOUGH MIXING AND EXTENSION PROPERTIES

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Abstract

The aim of this study was to analyze the effect of different levels of sodium chloride, wheat-soybean tempe flour and sourdough on the rheological properties of dough. Commercial wheat flour with protein content 11.8% was treated with different levels sodium chloride (0.75, 1.5 and 2.0%), wheat-soybean tempe flour (2 and 3.5%) and sourdough (17 and 33%) following a Randomized Complete Block Design with 3 replicates. Sourdough was made by a five day procedure with a feeding schedule of 16 h and 6-8 h. Tempe was made from wheat kernels and soybean, dried at 60℃ for 12 h, milled, sieved and stored at 4˚C until used. Dough mixing (water absorption, dough development time, stability time and breakdown time) and extension (maximum resistance to extension R_{max}, maximum extensibility E_{max}, total area and R_{max}/E_{max})

properties were determined. Water absorption was not affected by the treatments ($p > 0.05$). Increase in development time, stability time and breakdown time was observed with elevation of NaCl levels. Development time and breakdown time decreased with increase in sourdough (17 vs 33%). NaCl and tempe did not show a pattern of changes in resistance and extensibility with the variation in their levels. However, sourdough at 33% resulted in a significantly higher resistance and R_{max} value than 17% in all the treatments that contained the fermented products.

Keywords: Rheological properties, dough, sodium chloride, tempe, sourdough.

Introduction

Tempe is an Indonesian traditional fermented food which is made by fungi fermentation of soybeans and other legumes (Astuti et al., 2000). Tempe is known for its attractive flavor, texture and good digestibility (Nout and Kiers, 2005). The desirable taste, flavor, texture, acidity and aroma are produced by the hydrolysis of substrates by enzymes (Hachmeister and Fung, 1993).There is a modification of chemical compounds which goes on in the fermentation stage of tempe and is contributed by mold activity which mostly ceases after 46 hours of incubation (Bisping et al., 1993). The pH of tempe rises from 4.6 (0 h) to 6.6 at mature tempe (46 h) and then to 7.1 at ageing stage (72 h), all these is due to ammonia production (Sparringa and Owens, 1999). Bioactive peptides, liberated from protein during tempe formation have a wide range of benefits such as antimicrobial, cholesterol-lowering agent and increase in the bioavailability and absorption of minerals (Hartmann and Meisel, 2007). Substitution of soy flour into bread formulation can be a good proposal since it decreases carbohydrate content (calories) (Mohamed et al., 2006) and it increases the mineral and fiber content (Serrem et al., 2011), isoflavones (Shao et al., 2009) protein and lysine content (Serrem et al., 2011; Shogren et al., 2003). The tempe flour has some negative effects on gluten network due to soy in it since it decreases loaf volume and increases bread weight (Islam et al., 2007).

Sourdough process is very simple and is based on naturally occurring yeasts in the cereal grains; it was predominant until the nineteenth century when baker's yeast came into existence (Pederson, 1971). In wheat flour a myriad species of lactic acid bacteria occur which includes members of genera Lactobacillus, Lactococcus, Pediococcus, Enterococcus and Leuconostoc (Hammes and Vogel, 1997). When the mixing properties of wheat dough were studied, the water absorption increased with the addition of organic acids and absence of salt in the dough (Galal et al., 1978; Tanaka et al., 1967).The mixing time was also reduced with the addition of organic acids which weakened the dough (Galal et al., 1978; Wehrle et al., 1997). The empirical measurements of dough properties using the extensograph revealed that the addition of organic acid in the presence of salt produced doughs with increased resistance and decreased extensibility (Clarke et al., 2002; Tanaka et al., 1967; Tsen, 1966). (Masi et al., 2001) suggested that when a piece of dough is subjected to elongation, it will tear when the network between two entangled region reaches its full extension; it was suggested that gluten protein entanglement could be positively correlated to resistance to deformation.

Rheological studies have been conducted on different types of breads such as wheat flour (WFB), raw wheat germ (RWGB) and sourdough fermented wheat germ (SFWGB) flours as determined by the farinograph (Rizzello et al., 2010). There was no significant difference in the absorption capacity of the WFB, RWGB and SFWGB flours. The dough development time was higher for RWGB and SFWGB dough than WFB dough. Texture profile analysis (TPA) of bread revealed that SFWGB had the lowest values and WFB the highest values of resilience. Fracturability of breads increased after 4-8 days of storage, WFB was lowest and SFWGB was highest (Rizzello et al., 2010)

The objective of the study was to analyze the effect of different levels of NaCl (0.75, 1.5 and 2%), tempe (2 and 3.5%) and sourdough (17 and 33%) on the mixing and micro-extension properties of wheat dough.

2. Materials and Methods

2.1 Materials

Commercial all- purpose and whole wheat flour, and soybeans were purchased from local supermarket. Billing hard red winter wheat grain was donated by Oklahoma Seed Improvement Association (Stillwater, OK) and tempe mix culture inoculum (LIPI, Indonesian Institute of Science, Bandung, Indonesia) was donated by Dr. Erni Murtini (Oklahoma State University, Stillwater OK).

2.2 Experimental

2.2.1 Sourdough preparation

Sourdough culture was prepared as described by (Suas, 2008) . The method consisted of five day feeding schedule. On Day 1, 0.5 kg of whole wheat flour and 0.5 kg all-purpose flour was mixed with 1kg of tap water and incubated for 24 h. On Day 2, 0.5 kg of bread flour, 0.5 kg of H_2O and 0.5 kg of the previous day starter was mixed and fermented for 6-8 h, and the same procedure was repeated after 16 h on Day 2. A similar schedule and formula was applied after every 6-8 h and 16 h from Day 3 through Day 5. The fermentation temperature was about 27℃. A mature sourdough is also known as levain and it is defined as the natural preferment used to ferment the sourdough.

2.2.2 Tempe preparation

Wheat-soy bean tempe was prepared as described by Murtni (2014). Briefly, soy beans and wheat grain were used at 1:1 ratio (w/w) and soaked overnight. Wheat and soy beans were boiled separately for 15-20 minutes and cooled at room temperature by rinsing independently. The seed coat of the soy beans was peeled off manually. The soy and wheat were mixed and the inoculum (0.1% mix cultures tempe starter) added. The mixture was packed in zip locked type of bags forming a slab. The bags were perforated to provide aeration, incubated in a damp and slightly warm environment at 30±2^{o}C for 36-48 h. The fermented mixture was dried in the oven at 60˚C (Fisher Scientific Company LLC., Grand Prairie, TX), milled in Kitchen Mill (Blendtec, West Orem, UT) and sifted through 40 mesh sieve. Tempe flour was packed in a closed tight plastic jar and stored at -4℃ until it was needed.

2.2.3 Protein, Moisture and Ash Analysis

The protein, moisture and ash contents were determined using near infrared reflectance with a NIR System Model 8300 (FOSS NIR Systems Inc, Laurel, MD 20723) following manufacturer's instructions. Analyses were performed in duplicate.

2.2.4 Mixing properties

The mixing properties were analyzed using a Farinograph according to approved AACCI Method 54-21.02 (Ambardekar, 2009). The flour was mixed in Farinograph-E which is equipped with a 10g bowl at a speed of 63 rpm and 30^{o}C temperature (C.W. Brabender Instruments, Hackensack, NJ). The following parameters were obtained to evaluate the mixing properties: a) Development Time b) Stability Time, c) Time to Breakdown, and d) Water Absorption corrected to 14% moisture. Definitions of these parameters were included in Appendix I Table 2.

2.2.5 Dough Extensibility

Dough for extensibility test was prepared following the method of (Kieffer et al., 1998). The flour was mixed with a Farinograph until a dough consistency of 600 Brabender Units (BU) was reached. At the peak consistency of 600 BU, the dough was retrieved and gently rolled. It was then transferred into a Teflon form of the Kieffer rig (TA.XTPlus, Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK).The dough was clamped between two resting plates for 40 minutes to relax in a constant humid environment at room temperature. Mineral oil was added to avoid excessive sticking of the dough to the resting plates. After resting, the dough was unclamped and the mold was removed gently to avoid deformation of the dough. The dough strips were carefully removed from the mold and placed on the Texture analyzer plate. Test speed of 4.0 mm/s and trigger force of 1g was used for the measurement of extensibility. The parameters evaluated were R_{max} (maximum resistance to extension), E_{max} (extensibility at maximum resistance), Area to R_{max} (work required to reach R_{max}) and Total area. This test was performed in triplicates and the values were within a coefficient of variation of 10%.

2.2.6 Statistical Analysis

Statistical analysis was done using SAS 9.3 (SAS Institute, Cary, NC) version. Analysis of Variance (ANOVA) was done in a factorial arrangement of 2*2*3+1 corresponding to 3 NaCl treatments (0.75, 1.5 and 2%); 2 sourdough treatments (17 and 33%) and 2 tempe treatments (2 and 3.5%) and 1 reference control treatment (2% NaCl, 0% sourdough and 0% tempe). The experimental design is randomized complete block.

3. Results

3.1 *Mixing properties*

3.1.1 Water absorption (%) (Corrected to 14% moisture)

No treatment was significantly different from each other or control with respect to water absorption ($p > 0.05$). Neither NaCl, tempe nor sourdough had any significant effect on the water absorption (Table 2, 3 and 4)

3.1.2 Development time (min)

3.1.2.1 Effect of NaCl

The treatments produced a significant effect on dough development time ($p< 0.05$) as referred in Table 5. A general trend observed in each comparison block was that development time increased as the NaCl level increased, except for treatment with 33% sourdough and 3.5% tempe in which no effect of NaCl was observed. Treatment with 33% sourdough, 2% tempe showed the highest increase (48.4%) in development time with 1.5% NaCl ($p< 0.0001$). In the three comparison blocks with significant effect of NaCl, the 1.5% level showed the highest increase in development time compared to 2% NaCl (Table 5). Therefore, NaCl had a positive influence in the dough development time.

3.1.2.2 Effect of tempe

There was no significant effect of tempe on dough development time ($p > 0.05$) except the treatment with 33% sourdough and 2% NaCl where 3.5% tempe (7.2 min) decreased development time by 33.3% compared to 2% tempe (10.8 min) ($p = 0.0004$) (Table 6).

3.1.2.3 Effect of sourdough

In contrast to the above results, the effect of sourdough on the development time of dough was significant ($p < 0.05$) except in 0.75% NaCl and 3.5% tempe ($p > 0.05$) (Table 7). The increase in sourdough led to decrease in development time. Two comparisons revealed highest decrease: first, in treatments with 0.75% NaCl and 2% tempe 33% sourdough (6.1 min) resulted in 39.7% lower value than 17% sourdough (10.2 min). Second, in treatments with 2% NaCl and 3.5% tempe, 33% sourdough (7.2 min) led to 41.0% lower development time than 17% sourdough (12.2 min) ($p< 0.0001$). This suggests that sourdough weakens the gluten protein network and therefore leads to decrease in dough development time.

3.1.3 Stability time (min)

The stability time indicates the time the dough maintains a consistency of 500 Brabender Units and is considered a good indication of dough strength.

3.1.3.1 Effect of NaCl

NaCl provided highly significant effect on stability time in all the treatment comparisons ($p< 0.05$) (Table 8). A general trend was observed where increase of salt leads to a higher stability time with the exception of 2 treatments. 2% NaCl provided 1.6% and 27.6% lower stability time than 1.5% NaCl, respectively, in treatments having 17and 33% sourdough and 2% tempe. The highest percent change was observed in treatments having 33% sourdough and 3.5% tempe. Here, 1.5 and 2% NaCl resulted in 50.6 and 56.3% higher stability time than 0.75 and 1.5% NaCl ($p < 0.0001$). This suggests that NaCl is important to maintain a good stability time in terms of bread-making perspective (Table 8).

3.1.3.2 Effect of tempe

The effect of tempe resulted in a significant difference on the stability time of dough ($p < 0.05$) except for the treatment with 17% sourdough and 2% NaCl ($p > 0.05$) (Table 9). Results showed that 3.5% tempe lead to a lower stability time than 2% tempe. The highest change was observed by treatments with 33% sourdough and 1.5% NaCl where 3.5% tempe (11.9 min) resulted in 27.4% lower stability time than 2% tempe (16.4 min) ($p = 0.0002$). A contradictory result was observed in the last block where 3.5% tempe provided a 56.7% higher stability time than 2% tempe (treatments contained 33% sourdough and 2% NaCl). The reason for this exception might be because the effect of 3.5% tempe and 2% NaCl is strong enough to outlaw the effect of 33% sourdough which tends to decrease dough stability time ($p < 0.0001$).

3.1.3.3 Effect of sourdough

Most of the treatment combinations comparing sourdough resulted in non significant effects on dough stability except for one treatment combination which showed an inverse relationship (Table 10). The treatments were 2% NaCl combined with 2 and 3.5% tempe.When treatments had 2% NaCl and tempe, 33% sourdough (11.9 min) resulted in 18.7% lower stability time than 17% sourdough (14.6) ($p < 0.05$) whereas, 33% sourdough (18.6 min) provided 35.1% higher stability time than 17% sourdough (13.8 min) when treatments contained 2% NaCl and 3.5% tempe ($p < 0.0001$). This suggests that in an acidic environment the protein solubility is increased and it leads to softening of dough leading to a lower stability time (Table 10).

3.1.4 Time to breakdown (min)

Time to breakdown (TBD) is 20.0 min for the control sample which had only 2% NaCl. It is higher than the majority of other treatments that had fermented products which means fermented products led to softening in dough.

3.1.4.1 Effect of NaCl

NaCl had a significant effect on the breakdown time of dough (Table 11). In general, 1.5% NaCl had higher value than 0.75% NaCl and 2% NaCl had higher TBD value than 1.5% although the comparison few treatments were not significant. The percentage change of TBD ranged from 10.3- 32.9%. A highly significant change ($p < 0.0001$) was observed in treatments containing 17% sourdough and 2% tempe where 1.5% NaCl (17.4 min) provided 24.3% higher TBD value than 0.75% NaCl (14.0 min). Also, when treatments contained 33% sourdough and 2% tempe, 1.5 and 2% NaCl led to 32.9 and 23.4% higher TBD value than 0.75 and 1.5% NaCl (Table 11).

3.1.4.2 Effect of tempe

The effect of tempe on time to breakdown value of dough was mostly not significant ($p > 0.05$) except two treatments as shown in Table 12. First, where 17% sourdough and 1.5% NaCl was present, 3.5% tempe had 11.6% lower value than 2% tempe. Also, when the dough samples had 17% sourdough along with 2% NaCl, 3.5% tempe (17.2 min) had a 10.2% lower TBD value than 2% tempe (19.2 min). This suggests that in only two treatments tempe decreased the dough consistency and breakdown occurs faster with increase in tempe ($p < 0.05$) but in the majority of the treatment comparisons the effect of tempe on time to breakdown was not significant.

3.1.4.3 Effect of sourdough

In contrast to the above results, the effect of sourdough on the TBD value showed a significant difference in all the treatments ($p < 0.05$) (Table 13). TBD value was decreased with 33% sourdough than 17% sourdough, the percentage change ranging from 19.4-32.6% and the TBD values ranged from 9.4 – 19.2 min.

3.2 Dough Extensibility

3.2.1 Rmax (mN)

3.2.1.1 Effect of NaCl

Except the comparison group with 33% sourdough and 3.5% tempe ($p > 0.05$), all the other blocks of treatments had a significant effect on R_{max} ($p < 0.05$) (Table 14). Overall, as salt level increased, the R_{max} value increased as well, except one treatment when dough strip contained 17% sourdough and 3.5% tempe. In this treatment combination, resistance to extension of 1.5% NaCl (238.6 mN) decreased by 15.5% compared to 0.75% NaCl (282.3 mN). Among the other significant treatments the percentage change ranged from 3.3 to 27.1%. Salt leads to a stronger gluten protein network so more resistance to extension would be observed with increase in NaCl.

3.2.1.2 Effect of tempe

Overall, the effect of tempe on resistance to extension of the dough was significant (Table 15). Samples having 17% sourdough and 0.75% NaCl with 3.5% tempe (282.3m N) had 29.2% higher resistance than 2% tempe (218.6 mN) (highest percentage change) ($p < 0.05$). No specific conclusion can be drawn from the table since two treatment comparisons suggest a decrease and two an increasing effect on resistance to extension results. Samples with 33% sourdough combined with 1.5 and 2% NaCl, did not give a significant effect ($p > 0.05$).

3.2.1.3 Effect of sourdough

The effect of sourdough on the maximum resistance to extension recorded that an increase in sourdough level led to increased R_{max} ranging from 14.0 to 41.8% (Table 16). A general trend showed that 33% sourdough led to higher resistance than 17% sourdough. Four treatment comparisons provided strikingly significant results ($p < 0.0001$) where 33% sourdough led to 40.2, 41.7, 33.7 and 41.8% higher resistance than 17% sourdough.

3.2.2 Emax (cm)

3.2.2.1 Effect of NaCl

Except the combination of treatment with 17% sourdough and 2% tempe ($p > 0.05$), NaCl had a significant effect on maximum extensibility ($p < 0.05$) which is shown in Table 17. An increase of NaCl led to increase in extension in most of the treatments except a treatment with 17% sourdough and 2% tempe. Here, 1.5% NaCl (2.5 cm) resulted in 11.8% lower extension than 0.75% NaCl (2.8 cm). The most strikingly significant difference in result ($p < 0.0001$) was observed when dough treatments contained 17% sourdough and 3.5% tempe. In this case, 1.5% NaCl led to 18.9% more extensibility than 0.75% NaCl and 2% NaCl resulted in 12.1% increase in E_{max} value than 1.5% NaCl.

3.2.2.2 Effect of tempe

Treatment with 17% sourdough and 0.75% NaCl resulted significant decrease ($p < 0.0001$) where 3.5% tempe (2.1 cm) reduced maximum extensibility by 25.7% compared to 2% tempe (2.8 cm) (Table 18). On the contrary, 3.5% tempe (2.2 cm) increased maximum dough extensibility by 18.4% compared to 2% tempe (1.9 cm) when the treatments included 33% sourdough and 2% NaCl ($p = 0.0049$). The other treatments did not show a significant effect on maximum extensibility ($p > 0.05$).

3.2.2.3 Effect of sourdough

The effect of sourdough on maximum extensibility of dough led to a significant decrease except one treatment (Table 19). Sourdough at 33% sourdough led to a significantly lower extension than 17% sourdough. Four out of six treatment comparisons resulted in a highly significant difference ($p < 0.0001$) and the dough pieces containing 0.75% NaCl and 3.5% tempe did not provide significant difference ($p > 0.05$). The decrease of maximum extensibility calculated as percentage change ranged from 11.9 to 32.5%.

3.2.3 Area to R_{max} (mN-cm)

The area to R_{max} (work required to reach R_{max}) from the dough extensibility curve for the reference control with 2% NaCl was 839.4 mN-cm. A trend was observed to lower values with all the other treatments with NaCl and fermented products in it, which indicates that reference control (2% NaCl) required more work to reach R_{max} during the extensibility tests compared to the other treatments. Therefore, addition of the fermented products increases the viscosity of the dough which leads to a lower area under the curve to reach the maximum resistance to extension.

3.2.3.1 Effect of NaCl

When area to R_{max} was judged on the basis of whether NaCl has an effect on it, only one treatment combination which has 17% sourdough and 3.5% tempe had significantly increased the area (Table 20). Here, 2% NaCl (551.9 mN-cm) resulted in an increase of 20.0% area compared to 1.5% NaCl (459.8 mN-cm) ($p < 0.05$). The rest of the treatments did not have significant effect ($p > 0.05$).

3.2.3.2 Effect of tempe

The effect of tempe on the area to R_{max} showed that only one treatment had a significant effect ($p = 0.0005$) (Table 21). Here, treatments containing 33% sourdough and 2% NaCl revealed that

3.5% tempe (564.7 mN-cm) resulted in 32. 7% increased area to R_{max} compared to 2% tempe (425.5 mN-cm) ($p < 0.05$). The other treatments did not have a significant effect on the area to R_{max} ($p > 0.05$).

3.2.3.3 Effect of sourdough

Sourdough had a significant effect on two out of six comparison treatments (Table 22). The two treatments consisted of 0.75% NaCl and 2% tempe which showed that 33% sourdough (411.3 mN-cm) had decreased by 16.3% the area to R_{max} compared 17% sourdough (491.2 mN-cm) ($p = 0.0324$). Also, treatment combination containing 2% NaCl and tempe showed that area to R_{max} of 33% sourdough (425.5 mN-cm) decreased by 23.5% compared to 17% sourdough (556.0 mN-cm) ($p = 0.0010$). The other treatments did not have any significant effect ($p > 0.05$).

3.2.4 Total area under the curve (mN-cm)

The total area under the curve (mN/cm) or total work of the reference control treatment (only 2% NaCl) was 1480.3 N/mm. A trend to decreased total area (mN-cm) was observed with all the treatment combination of NaCl and fermented products since fermented products tend to weaken the gluten protein network.

3.2.4.1 Effect of NaCl

No significant effect of NaCl on total area (mN-cm) was observed ($p > 0.05$) except the treatment containing 17% sourdough and 3.5% tempe. In this treatment combination, 2% NaCl had 19.8% higher in area under the curve than 0.75% NaCl (Table 23).

3.2.4.2 Effect of tempe

Tempe produced significant difference in results on the samples which contained 33% sourdough and 2% NaCl. 3.5% tempe (926.9 mN-cm) had 41.9% higher total area under the curve than 2%

tempe (653.4 mN-cm) ($p < 0.05$). The other blocks of treatments did not have any significant difference in area value ($p > 0.05$) (Table 24).

3.2.4.3 Effect sourdough

The effect of sourdough on the total area (mN-cm) under the curve led to significant difference in results in four treatment combinations out of six ($p< 0.05$) (Table 25). A trend of result was observed where 33% sourdough resulted in less work done than 17% sourdough. A strikingly high significant difference in result was observed in treatment which contained 2% NaCl and tempe where 33% sourdough (653.4 mN-cm) resulted in 41.0% lower area than 17% sourdough (1107.2 mN-cm) ($p< 0.0001$).

3.2.5 R_{max}/E_{max} (mN/cm)

3.2.5.1 Effect of NaCl

The effect of NaCl showed no specific trend, although 3 out of 4 treatment combinations had a significant difference ($p< 0.05$) as shown in table 26. The treatment combination with 33% sourdough and 2% tempe provided a remarkably high significant difference ($p< 0.0001$). Here, dough strips with 33% sourdough, 2% tempe and 2% NaCl (204.3 mN/cm) led to 30.3% higher value than 1.5% NaCl (156.7 mN/cm).

3.2.5.2 Effect of tempe

Only the first treatment combination provided significant difference in result ($p< 0.0001$) (Table 27). Here, 3.5% tempe (134.7 mN/cm) led to 72.7% higher value than 2% tempe (78.0 mN/cm). The rest of the treatments did not give significantly different result ($p> 0.05$).

3.2.5.3 Effect of sourdough

All the treatments provided high significant effect in R_{max}/E_{max} ($p < 0.0001$ to $p = 0.0004$) (Table 28). 33% sourdough led to higher value than 17% sourdough, the percentage change ranging from 28.8 to 108.0%.

4. Discussion

The interactive effects amongst different levels of NaCl, sourdough and tempe had effects on dough mixing and extensibility properties. According to (Gocmen et al., 2007) the sourdough application resulted in softer dough with lower water absorption but data in this research does not support the findings where NaCl, tempe and sourdough did not have any significant effect on water absorption. On the other hand, suggested that water absorption increases in wheat flour as the level of incorporated soy increases (Basman et al., 2003).The fermented products therefore resulted in a non-significant effect on water absorption. Development time of the control dough with just 2% NaCl (no fermented products) was significantly higher than all other treatments. (Galal et al., 1978) put forward that in a flour-water system, the gluten protein has a net positive charge. These positive charges repulse each other and this enables faster hydration of gluten (shorter mixing time) and keeps the protein chains from interacting with each other, resulting in weaker dough. Low levels of salt cancel the charges that allow the protein chains to approach each other. This allows the flour to hydrate more slowly, thus a longer development time as illustrated in a selected group of samples (Fig 1a and 1b) and Table 5. The authors also stated that in an acidic environment the protein solubility is increased. The increase in the intra molecular electrostatic repulsion leads to an unfolding of gluten proteins, and an increased exposure of hydrophobic groups while the presence of strong intermolecular electrostatic repulsive forces prevents the formation of new bonds (Galal et al., 1978). The net effect results in the increase of viscosity in dough. This hypothesis has been supported by (Osborne, 1907) and

(Takeda et al., 2001) who reported increased solubility of constituent gluten proteins at acidic values. Sourdough at 33% led to higher maximum resistance to extension than 17% sourdough in all the treatment combination with NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%). Similar results were also obtained which reported that the maximum resistance to extension was directly proportional to the amount of sourdough added (Esteve et al., 1994). Results showed that extensibility is inversely proportional to sourdough. Treatments with 33% sourdough led to lower extensibility that 17% sourdough. The control dough (only 2% NaCl) had the extensibility of 3.7cm and when the dough became acidic (sourdough treatment), the extensibility decreased Fig 2a and 2b and Table 19. (Tsen, 1966) and (Tanaka et al., 1967) determined that the addition of acid, in the presence of salt resulted in doughs with decreased extensibility. The explanation for this phenomenon is given in terms of entangled protein network model. When a piece of dough is subjected to elongation, it tears when the network between the two entangled regions reaches the greatest extent of extension. Therefore, the more entangled network leads to higher resistance to deformation. Addition of acids weakens the dough and therefore extensibility decreases (Masi et al., 2001).

5. Conclusion

An overall effect to increase in development time, stability time and breakdown time was observed in most of the treatment combinations. There was only one exception to these observations in treatment combinations containing 33% sourdough and 2% tempe where 2% NaCl resulted in 38% lower stability time than 1.5% NaCl. A possible explanation of these observations could be that 33% sourdough level overpowered the effect of NaCl and tempe together. 33% sourdough might have weakened the gluten structure by protein hydrolysis resulting in retarding the formation of new bonds. Therefore, even with the increase in NaCl from 1.5 to 2%, a decrease in stability time was observed. It was also observed that the development time of the reference dough with no fermented products (only 2% NaCl) was 16.8 min which was higher compared to all the treatments with fermented products ranging from 6.1 -12.9 min. NaCl results in delay of hydration and consequently a longer time is required for the dough to develop. Whereas, addition of fermented products like sourdough results in dilution of the gluten structure and therefore, a faster hydration resulting in a lower development time. The effect of tempe on development time was non-significant in all the treatments except the treatments with 33% sourdough and 2% NaCl. Here, 3.5% tempe showed 33% lower development time than 2% tempe. A general trend of a decrease in stability time and breakdown time was observed with an increase in tempe level from 2 to 3.5%. The effect of sourdough revealed that values of development time, stability time and breakdown were inversely proportional to the level of sourdough added. NaCl and tempe showed different pattern of changes in resistance and extensibility with the variation in their levels. However, the effect of sourdough displayed that inclusion of 33% resulted in a significantly higher resistance and R_{max} value than 17% sourdough in all the treatment combinations that contained the fermented products. Whereas, in case of maximum extensibility (E_{max}) the increase in sourdough level decreased the E_{max} valueBut when compared to the control, it was seen that E_{max}, Area to R_{max} and Total area (mN/cm) under the curve of dough with fermented products was decreased compared to the dough with just 2% NaCl (no fermented products). Thus, the inclusion of sourdough and tempe poses a negative impact on the gluten network as proposed by (Islam et al., 2007).

Table 1 Partial proximate analysis of flour

Wheat type	Protein (%)	Moisture (%)	Ash (%)
Hard red winter	11.5±0.07	13.8±0.03	0.48±0.00

Mean (n=3) ± standard error.

Table 2. Effect of NaCl (0.75, 1.5 and 2.0%) on water absorption of wheat dough at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Water Absorption (14 %)	Percentage change (%)	P-value
17	2.0	0.75	57.8 ± 0.07 a		0.7422
17	2.0	1.5	58.0 ± 0.13 a		
17	2.0	2.0	57.9 ± 0.18 a		
17	3.5	0.75	57.7 ± 0.12 a		0.3029
17	3.5	1.5	58.0 ± 0.15 a		
17	3.5	2.0	58.1 ± 0.20 a		
33	2.0	0.75	58.0 ± 0.23 a		0.7586
33	2.0	1.5	58.0 ± 0.23 a		
33	2.0	2.0	58.2 ± 0.23 a		
33	3.5	0.75	58.1 ± 0.22 a		0.624
33	3.5	1.5	57.9 ± 0.15 a		
33	3.5	2.0	57.9 ± 0.17 a		

[a]Mean (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) water absorption= 57.9 ± 0.21; mean (n=3) ± standard error.

Table 3. Effect of tempe (2.0 and 3.5%) on water absorption of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and sourdough (17 and 33%) [ab].

Sourdough (%)	NaCl (%)	Tempe (%)	Water Absorption (14 %)	Percentage change (%)	P-value
17	0.75	2.0	57.8 ± 0.07		0.7978
17	0.75	3.5	57.7 ± 0.12	-0.1	
17	1.5	2.0	58.0 ± 0.13		1.0000
17	1.5	3.5	58.0 ± 0.15	0.0	
17	2.0	2.0	57.9 ± 0.18		0.3732
17	2.0	3.5	58.1 ± 0.20	0.4	
33	0.75	2.0	58.0 ± 0.23		0.6090
33	0.75	3.5	58.1 ± 0.22	0.2	
33	1.5	2.0	58.0 ± 0.23		0.7978
33	1.5	3.5	57.9 ± 0.15	-0.1	
33	2.0	2.0	58.2 ± 0.23		0.3100
33	2.0	3.5	57.9 ± 0.17	-0.5	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) water absorption= 57.9 ± 0.21; mean (n=3) ± standard error.

Table 4. Effect of sourdough (17 and 33%) on water absorption of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and tempe (2.0 and 3.5%)[ab].

NaCl (%)	**Tempe (%)**	**Sourdough (%)**	**Water Absorption (14%)**	**Percentage change (%)**	**P-value**
0.75	2.0	17	57.8 ± 0.07		0.3732
0.75	2.0	33	58.0 ± 0.23	0.4	
0.75	3.5	17	57.7 ± 0.12		0.1044
0.75	3.5	33	58.1 ± 0.22	0.8	
1.5	2.0	17	58.0 ± 0.13		0.8980
1.5	2.0	33	58.0 ± 0.23	0.1	
1.5	3.5	17	58.0 ± 0.15		0.8980
1.5	3.5	33	57.9 ± 0.15	-0.1	
2.0	2.0	17	57.9 ± 0.18		0.2546
2.0	2.0	33	58.2 ± 0.23	0.5	
2.0	3.5	17	58.1 ± 0.20		0.4444
2.0	3.5	33	57.9 ± 0.17	-0.3	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) water absorption= 57.9 ± 0.21; mean (n=3) ± standard error.

Table 5. Effect of NaCl (0.75, 1.5 and 2.0%) on development time of wheat dough at different levels of sourdough (17 and 33%) and tempe (2.0 and 3.5%)[ab].

Sourdough (%)	**Tempe (%)**	**NaCl (%)**	**Development time (min)**		**Percentage change (%)**	**P-value**
17	2.0	0.75	10.2 ± 0.09	b		0.0176
17	2.0	1.5	11.6 ± 0.58	ab		
17	2.0	2.0	12.9 ± 1.01	a		
17	3.5	0.75	9.0 ± 0.15	b		0.003
17	3.5	1.5	11.4 ± 0.23	a	26.8	
17	3.5	2.0	12.2 ± 0.51	a		
33	2.0	0.75	6.1 ± 0.34	b		<.0001
33	2.0	1.5	9.1 ± 0.44	a	48.4	
33	2.0	2.0	10.8 ± 1.02	a		
33	3.5	0.75	7.2 ± 0.18	a		0.0534
33	3.5	1.5	9.2 ± 0.93	a		
33	3.5	2.0	7.2 ± 0.67	a		

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) development time = 16.8 ± 0.79; mean (n=3) ± standard error.

Table 6. Effect of tempe (2.0 and 3.5%) on development time of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and sourdough (17 and 33%) [ab].

Sourdough (%)	NaCl (%)	Tempe (%)	Development time (min)	Percentage change (%)	P-value
16	0.75	2.0	10.2 ± 0.09		0.1835
16	0.75	3.5	9.0 ± 0.15		
16	1.5	2.0	11.6 ± 0.58		0.7638
16	1.5	3.5	11.4 ± 0.23		
16	2.0	2.0	12.9 ± 1.01		0.4546
16	2.0	3.5	12.2 ± 0.51		
33	0.75	2.0	6.1 ± 0.34		0.2215
33	0.75	3.5	7.2 ± 0.18		
33	1.5	2.0	9.1 ± 0.44		0.9401
33	1.5	3.5	9.2 ± 0.93		
33	2.0	2.0	10.8 ± 1.02		0.0004
33	2.0	3.5	7.2 ± 0.67	-33.3	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) development time = 16.8 ± 0.79; mean (n=3) ± standard error.

Table 7. Effect of sourdough (17 and 33%) on development time of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and tempe (2.0 and 3.5%)[ab].

NaCl (%)	Tempe (%)	Sourdough (%)	Development time (min)	Percentage change (%)	P-value
0.75	2.0	17	10.2 ± 0.09		<.0001
0.75	2.0	33	6.1 ± 0.34	-39.7	
0.75	3.5	17	9.0 ± 0.15		0.0591
0.75	3.5	33	7.2 ± 0.18		
1.5	2.0	17	11.6 ± 0.58		0.0078
1.5	2.0	33	9.1 ± 0.44	-21.8	
1.5	3.5	17	11.4 ± 0.23		0.0188
1.5	3.5	33	9.2 ± 0.93	-19.4	
2.0	2.0	17	12.9 ± 1.01		0.0265
2.0	2.0	33	10.8 ± 1.02	-16.1	
2.0	3.5	17	12.2 ± 0.51		<.0001
2.0	3.5	33	7.2 ± 0.67	-41.0	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) development time = 16.8 ± 0.79; mean (n=3) ± standard error.

Table 8. Effect of NaCl (0.75, 1.5 and 2.0%) on stability time of wheat dough at different levels of sourdough (17 and 33%) and tempe (2.0 and 3.5%) [ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Stability time (min)				Percentage change (%)	P-value
17	2.0	0.75	11.27	±	0.33	b		0.003
17	2.0	1.5	14.83	±	0.28	a	31.7	
17	2.0	2.0	14.60	±	0.53	a		
17	3.5	0.75	9.17	±	0.35	b		0.0007
17	3.5	1.5	11.27	±	0.15	b		
17	3.5	2.0	13.77	±	0.17	a	22.2	
33	2.0	0.75	11.23	±	0.73	b		<.0001
33	2.0	1.5	16.40	±	0.47	a	46.0	
33	2.0	2.0	11.87	±	1.83	b	-27.6	
33	3.5	0.75	7.90	±	0.46	c		<.0001
33	3.5	1.5	11.90	±	1.42	b	50.6	
33	3.5	2.0	18.60	±	0.17	a	56.3	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) stability time =14.8 ± 0.25;

mean (n=3) ± standard error.

Table 9. Effect of tempe (2.0 and 3.5%) on stability time of wheat dough at different levels of NaCl (0.75, 1.5, 2.0%) and sourdough (17 and 33%) [ab].

Sourdough (%)	NaCl (%)	Tempe (%)	Stability time (min)	Percentage change (%)	P-value
17	0.75	2.0	11.3 ± 0.33		0.0543
17	0.75	3.5	9.2 ± 0.35		
17	1.5	2.0	14.8 ± 0.28		0.0021
17	1.5	3.5	11.3 ± 0.15	-24.0	
17	2.0	2.0	14.6 ± 0.53		0.4311
17	2.0	3.5	13.8 ± 0.17		
33	0.75	2.0	11.2 ± 0.73		0.0036
33	0.75	3.5	7.9 ± 0.46	-29.7	
33	1.5	2.0	16.4 ± 0.47		0.0002
33	1.5	3.5	11.9 ± 1.42	-27.4	
33	2.0	2.0	11.9 ± 1.83		<.0001
33	2.0	3.5	18.6 ± 0.17	56.7	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) stability time =14.8 ± 0.25; mean (n=3) ± standard error.

Table 10. Effect of sourdough (17 and 33%) on stability time of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and tempe (2.0 and 3.5%) [ab].

NaCl (%)	**Tempe (%)**	**Sourdough (%)**	**Stability time (min)**	**Percentage change (%)**	**P-value**
0.75	2.0	17	11.3 ± 0.33		0.9747
0.75	2.0	33	11.2 ± 0.73		
0.75	3.5	17	9.2 ± 0.35		0.2351
0.75	3.5	33	7.9 ± 0.46		
1.5	2.0	17	14.8 ± 0.28		0.1448
1.5	2.0	33	16.4 ± 0.47		
1.5	3.5	17	11.3 ± 0.15		0.5486
1.5	3.5	33	11.9 ± 1.42		
2.0	2.0	17	14.6 ± 0.53		0.0144
2.0	2.0	33	11.9 ± 1.83	-18.7	
2.0	3.5	17	13.8 ± 0.17		<.0001
2.0	3.5	33	18.6 ± 0.17	35.1	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) stability time =14.8 ± 0.25; mean (n=3) ± standard error.

Table 11. Effect of NaCl (0.75, 1.5 and 2.0%) on breakdown time of wheat dough at different levels of sourdough (17 and 33%) and tempe (2.0 and 3.5%) [ab].

Sourdough (%)	Tempe (%)	NaCl (%)	TBD (min)				Percentage change (%)	P-value
17	2.0	0.75	14.0	±	0.40	b		<.0001
17	2.0	1.5	17.4	±	1.04	a	24.3	
17	2.0	2.0	19.2	±	0.70	a		
17	3.5	0.75	13.9	±	0.26	b		0.0043
17	3.5	1.5	15.4	±	0.41	b		
17	3.5	2.0	17.2	±	0.47	a	12.1	
33	2.0	0.75	9.4	±	0.48	c		<.0001
33	2.0	1.5	12.5	±	0.35	b	32.9	
33	2.0	2.0	15.5	±	1.57	a	23.4	
33	3.5	0.75	11.0	±	0.57	b		0.0153
33	3.5	1.5	12.2	±	0.20	ab		
33	3.5	2.0	13.8	±	0.61	a	25.5	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) breakdown time = 20.0 ± 0.00; mean (n=3) ± standard error.

Table 12. Effect of tempe (2.0 and 3.5%) on breakdown time of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and sourdough (17 and 33%) [ab].

Sourdough (%)	NaCl (%)	Tempe (%)	TBD (min)	Percentage change (%)	P-value
17	0.75	2.0	14.0 ± 0.40		0.9125
17	0.75	3.5	13.9 ± 0.26		
17	1.5	2.0	17.4 ± 1.04		0.0333
17	1.5	3.5	15.4 ± 0.41	-11.7	
17	2.0	2.0	19.2 ± 0.70		0.0390
17	2.0	3.5	17.2 ± 0.47	-10.2	
33	0.75	2.0	9.4 ± 0.48		0.0947
33	0.75	3.5	11.0 ± 0.57		
33	1.5	2.0	12.5 ± 0.35		0.6875
33	1.5	3.5	12.2 ± 0.20		
33	2.0	2.0	15.5 ± 1.57		0.0822
33	2.0	3.5	13.8 ± 0.61		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) breakdown time = 20.0 ± 0.00; mean (n=3) ± standard error.

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Table 13. Effect of sourdough (17 and 33%) on breakdown time of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and tempe (2.0 and 3.5%) [ab].

NaCl (%)	Tempe (%)	Sourdough (%)	TBD (min)	Percentage change (%)	P-value
0.75	2.0	17	14.0 ± 0.40		<.0001
0.75	2.0	33	9.4 ± 0.48	-32.6	
0.75	3.5	17	13.9 ± 0.26		0.0037
0.75	3.5	33	11.0 ± 0.57	-20.9	
1.5	2.0	17	17.4 ± 1.04		<.0001
1.5	2.0	33	12.5 ± 0.35	-28.0	
1.5	3.5	17	15.4 ± 0.41		0.0016
1.5	3.5	33	12.2 ± 0.20	-20.8	
2.0	2.0	17	19.2 ± 0.70		0.0004
2.0	2.0	33	15.5 ± 1.57	-19.4	
2.0	3.5	17	17.2 ± 0.47		0.0009
2.0	3.5	33	13.8 ± 0.61	-19.7	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) breakdown time = 20.0 ± 0.00; mean (n=3) ± standard error.

Table 14. Effect of NaCl (0.75, 1.5 and 2.0%) on maximum resistance to extension (R_{max}) of wheat dough at different levels of sourdough (17 and 33%) and tempe (2.0 and 3.5%) [ab]

Sourdough (%)	**Tempe (%)**	**NaCl (%)**	**Rmax (mN)**				**Percentage change (%)**	**P-value**
17	2.0	0.75	218.6	±	11.04	b		0.0005
17	2.0	1.5	277.8	±	17.57	a	27.1	
17	2.0	2.0	286.3	±	7.62	a		
17	3.5	0.75	282.3	±	2.61	a		0.0361
17	3.5	1.5	238.6	±	11.23	b	-15.5	
17	3.5	2.0	253.0	±	4.02	ab		
33	2.0	0.75	306.5	±	12.50	b		0.0001
33	2.0	1.5	316.7	±	16.58	b		
33	2.0	2.0	382.8	±	5.89	a	20.9	
33	3.5	0.75	340.4	±	6.95	a		0.3813
33	3.5	1.5	338.0	±	12.69	a		
33	3.5	2.0	358.9	±	14.99	a		

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[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) maximum resistance to extension (R_{max}) = 286.95 ± 15.39; mean (n=3) ± standard error.

Table 15. Effect of tempe (2.0 and 3.5%) on maximum resistance to extension (R_{max}) of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and sourdough (17 and 33%) [ab].

Sourdough (%)	NaCl (%)	Tempe (%)	Rmax (mN)	Percentage change (%)	P-value
17	0.75	2.0	218.6 ± 11.04		0.0006
17	0.75	3.5	282.3 ± 2.61	29.2	
17	1.5	2.0	277.8 ± 17.57		0.0228
17	1.5	3.5	238.6 ± 11.23	-14.1	
17	2.0	2.0	286.3 ± 7.62		0.0504
17	2.0	3.5	253.0 ± 4.02	-11.6	
33	0.75	2.0	306.5 ± 12.50		0.0460
33	0.75	3.5	340.4 ± 6.95	11.1	
33	1.5	2.0	316.7 ± 16.58		0.1978
33	1.5	3.5	338.0 ± 12.69		
33	2.0	2.0	382.8 ± 5.89		0.1506
33	2.0	3.5	358.9 ± 14.99		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) maximum resistance to extension (R_{max}) = 286.95 ± 15.39; mean (n=3) ± standard error.

Table 16. Effect of sourdough (17 and 33%) on maximum resistance to extension (R_{max}) of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and tempe (2.0 and 3.5%) [ab].

NaCl (%)	Tempe (%)	Sourdough (%)	Rmax (mN)	Percentage change (%)	P-value
0.75	2	17	218.6 ± 11.04		<.0001
0.75	2.0	33	306.5 ± 12.50	40.2	
0.75	3.5	17	282.3 ± 2.61		0.0239
0.75	3.5	33	340.4 ± 6.95	20.6	
1.5	2.0	17	277.8 ± 17.57		0.0014
1.5	2.0	33	316.7 ± 16.58	14.0	
1.5	3.5	17	238.6 ± 11.23		<.0001
1.5	3.5	33	338.0 ± 12.69	41.7	
2.0	2.0	17	286.3 ± 7.62		<.0001
2.0	2.0	33	382.8 ± 5.89	33.7	
2.0	3.5	17	253.0 ± 4.02		<.0001
2.0	3.5	33	358.9 ± 14.99	41.8	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) maximum resistance to extension (R_{max}) = 286.95 ± 15.39; mean (n=3) ± standard error.

Table 17. Effect of NaCl (0.75, 1.5 and 2.0%) on maximum extensibility (E_{max}) of wheat dough at different levels of sourdough (17 and 33%) and tempe (2.0 and 3.5%) [ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Emax (cm)				Percentage change (%)	P-value
17	2.0	0.75	2.8	±	0.12	b		0.0202
17	2.0	1.5	2.5	±	0.09	a	-11.8	
17	2.0	2.0	2.6	±	0.07	ab		
17	3.5	0.75	2.1	±	0.01	a		<.0001
17	3.5	1.5	2.5	±	0.08	b	18.9	
17	3.5	2.0	2.8	±	0.15	c	12.1	
33	2.0	0.75	1.9	±	0.09	a		0.4100
33	2.0	1.5	2.0	±	0.03	a		
33	2.0	2.0	1.9	±	0.02	a		
33	3.5	0.75	2.0	±	0.06	a		0.0624
33	3.5	1.5	2.2	±	0.06	a		
33	3.5	2.0	2.2	±	0.02	a		

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) maximum extensibility (E_{max}) = 3.69 ± 0.12; mean (n=3) ± standard error.

Table 18. Effect of tempe (2.0 and 3.5%) on maximum extensibility (E_{max}) of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and sourdough (17 and 33%) [ab].

Sourdough (%)	NaCl (%)	Tempe (%)	Emax (cm)	Percentage change (%)	P-value
17	0.75	2.0	2.8 ± 0.12		<.0001
17	0.75	3.5	2.1 ± 0.01	-25.7	
17	1.5	2.0	2.5 ± 0.09		0.9788
17	1.5	3.5	2.5 ± 0.08		
17	2.0	2.0	2.6 ± 0.07		0.094
17	2.0	3.5	2.8 ± 0.15		
33	0.75	2.0	1.9 ± 0.09		0.5719
33	0.75	3.5	2.0 ± 0.06		
33	1.5	2.0	2.0 ± 0.03		0.1254
33	1.5	3.5	2.2 ± 0.06		
33	2.0	2.0	1.9 ± 0.02		0.0049
33	2.0	3.5	2.2 ± 0.02	18.4	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) maximum extensibility (E_{max}) = 3.69 ± 0.12; mean (n=3) ± standard error.

Table 19. Effect of sourdough (17 and 33%) on maximum extensibility (E_{max}) of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and tempe (2.0 and 3.5%) [ab].

NaCl (%)	Tempe (%)	Sourdough (%)	Emax (cm)	Percentage change (%)	P-value
0.75	2.0	17	2.8 ± 0.12		<.0001
0.75	2.0	33	1.9 ± 0.09	-24.3	
0.75	3.5	17	2.1 ± 0.01		0.2597
0.75	3.5	33	2.0 ± 0.06		
1.5	2.0	17	2.5 ± 0.09		0.0003
1.5	2.0	33	2.0 ± 0.03	-60.1	
1.5	3.5	17	2.5 ± 0.08		0.0139
1.5	3.5	33	2.2 ± 0.06	-20.5	
2.0	2.0	17	2.6 ± 0.07		<.0001
2.0	2.0	33	1.9 ± 0.02	-74.8	
2.0	3.5	17	2.8 ± 0.15		<.0001
2.0	3.5	33	2.2 ± 0.02	-88.2	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) maximum extensibility (E_{max}) = 3.69 ± 0.12; mean (n=3) ± standard error.

Table 20. Effect of NaCl (0.75, 1.5 and 2.0%) on area to Rmax of wheat dough at different levels of sourdough (17 and 33%) and tempe (2.0 and 3.5%) [ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Area to Rmax (mN-cm)				Percentage change (%)	P-value
17	2.0	0.75	491.2	±	12.48	a		0.2059
17	2.0	1.5	522.5	±	14.04	a		
17	2.0	2.0	556.0	±	5.98	a		
17	3.5	0.75	442.3	±	2.96	b		0.0098
17	3.5	1.5	459.8	±	22.69	b		
17	3.5	2.0	551.9	±	31.03	a	20.0	
33	2.0	0.75	411.3	±	6.39	a		0.4945
33	2.0	1.5	453.1	±	27.51	a		
33	2.0	2.0	425.5	±	58.31	a		
33	3.5	0.75	474.4	±	10.25	a		0.0543
33	3.5	1.5	520.5	±	30.58	a		
33	3.5	2.0	564.7	±	15.45	a		

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) area to Rmax = 839.43 ± 27.66; mean (n=3) ± standard error.

Table 21. Effect of tempe (2.0 and 3.5%) on area to Rmax of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and sourdough (17 and 33%) [ab].

Sourdough (%)	NaCl (%)	Tempe (%)	Area to Rmax (mN-cm)	Percentage change (%)	P-value
17	0.75	2.0	491.2 ± 12.48		0.178
17	0.75	3.5	442.3 ± 2.96		
17	1.5	2.0	522.5 ± 14.04		0.0877
17	1.5	3.5	459.8 ± 22.69		
17	2.0	2.0	556.0 ± 5.98		0.9092
17	2.0	3.5	551.9 ± 31.03		
33	0.75	2.0	411.3 ± 6.39		0.086
33	0.75	3.5	474.4 ± 10.25		
33	1.5	2.0	453.1 ± 27.51		0.0678
33	1.5	3.5	520.5 ± 30.58		
33	2.0	2.0	425.5 ± 58.31		0.0005
33	2.0	3.5	564.7 ± 15.45	32.7	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) area to Rmax = 839.43 ± 27.66; mean (n=3) ± standard error.

Table 22. Effect of sourdough (17 and 33%) on area to Rmax of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and tempe (2.0 and 3.5%) [ab].

NaCl (%)	Tempe (%)	Sourdough (%)	Area to Rmax (mN-cm)	Percentage change (%)	P-value
0.75	2.0	17	491.2 ± 12.48		0.0324
0.75	2.0	33	411.3 ± 6.39	-16.3	
0.75	3.5	17	442.3 ± 2.96		0.3722
0.75	3.5	33	474.4 ± 10.25		
1.5	2.0	17	522.5 ± 14.04		0.0603
1.5	2.0	33	453.1 ± 27.51		
1.5	3.5	17	459.8 ± 22.69		0.0980
1.5	3.5	33	520.5 ± 30.58		
2.0	2.0	17	556.0 ± 5.98		0.0010
2.0	2.0	33	425.5 ± 58.31	-23.5	
2.0	3.5	17	551.9 ± 31.03		0.7207
2.0	3.5	33	564.7 ± 15.45		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) area to Rmax = 839.43 ± 27.66; mean (n=3) ± standard error.

Table 23. Effect of NaCl (0.75, 1.5 and 2.0%) on Total area (mN-cm)of wheat dough at different levels of sourdough (17 and 33%) and tempe (2.0 and 3.5%) [ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Total area (mN-cm)				Percentage change (%)	P-value
17	2.0	0.75	995.8	±	33.40	a		0.2918
17	2.0	1.5	1069.9	±	74.68	a		
17	2.0	2.0	1107.2	±	9.40	a		
17	3.5	0.75	922.9	±	51.14	b		0.0446
17	3.5	1.5	977.8	±	44.24	ab		
17	3.5	2.0	1105.2	±	15.40	a	19.8	
33	2.0	0.75	761.4	±	21.55	a		0.1183
33	2.0	1.5	799.9	±	30.10	a		
33	2.0	2.0	653.4	±	96.99	a		
33	3.5	0.75	778.6	±	18.78	a		0.0897
33	3.5	1.5	909.9	±	53.40	a		
33	3.5	2.0	926.9	±	50.97	a		

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) Total area (mN-cm)= 1480.27 ± 64.69; mean (n=3) ± standard error.

Table 24. Effect of tempe (2.0 and 3.5%) on Total area (mN-cm)of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and sourdough (17 and 33%) [ab].

Sourdough (%)	NaCl (%)	Tempe (%)	Total area (mN-cm)	Percentage change (%)	P-value
17	0.75	2.0	995.8 ± 33.40		0.3111
17	0.75	3.5	922.9 ± 51.14		
17	1.5	2.0	1069.9 ± 74.68		0.2035
17	1.5	3.5	977.8 ± 44.24		
17	2.0	2.0	1107.2 ± 9.40		0.9777
17	2.0	3.5	1105.2 ± 15.40		
33	0.75	2.0	761.4 ± 21.55		0.8096
33	0.75	3.5	778.6 ± 18.78		
33	1.5	2.0	799.9 ± 30.10		0.131
33	1.5	3.5	909.9 ± 53.40		
33	2.0	2.0	653.4 ± 96.99		0.0006
33	2.0	3.5	926.9 ± 50.97	41.9	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) Total area (mN/cm)= 1480.27 ± 64.69; mean (n=3) ± standard error.

Table 25. Effect of sourdough (17 and 33%) on Total area (mN-cm)of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and tempe (2.0 and 3.5%) [ab].

NaCl (%)	Tempe (%)	Sourdough (%)	Total area (mN-cm)	Percentage change (%)	P-value
0.75	2.0	17	995.8 ± 33.4		0.0027
0.75	2.0	33	761.4 ± 21.6	-23.5	
0.75	3.5	17	922.9 ± 51.1		0.0510
0.75	3.5	33	778.6 ± 18.8		
1.5	2.0	17	1069.9 ± 74.7		0.0007
1.5	2.0	33	799.9 ± 30.1	-25.2	
1.5	3.5	17	977.8 ± 44.2		0.3448
1.5	3.5	33	909.9 ± 53.4		
2	2.0	17	1107.2 ± 9.4		<.0001
2	2.0	33	653.36 ± 97.0	-41.0	
2	3.5	17	1105.24 ± 15.4		0.0179
2	3.5	33	926.92 ± 51.0	-16.1	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) Total area (mN-cm)= 1480.27 ± 64.69; mean (n=3) ± standard error.

Table 26. Effect of NaCl (0.75, 1.5 and 2.0%) on R_{max}/E_{max} of wheat dough at different levels of sourdough (17 and 33%) and tempe (2.0 and 3.5%) [ab].

Sourdough (%)	Tempe (%)	NaCl (%)	R_{max}/E_{max} (mN/cm)		Percentage change (%)	P-value
17	2.0	0.75	78.0 ± 6.62	b		0.0018
17	2.0	1.5	112.3 ± 10.37	a	44.0	
17	2.0	2.0	110.5 ± 6.06	a		
17	3.5	0.75	134.7 ± 1.36	a		0.0002
17	3.5	1.5	96.0 ± 5.26	b	-28.8	
17	3.5	2.0	91.2 ± 5.24	b		
33	2.0	0.75	162.3 ± 13.87	b		<.0001
33	2.0	1.5	156.7 ± 5.85	b		
33	2.0	2.0	204.3 ± 4.80	a	30.3	
33	3.5	0.75	173.5 ± 8.54	a		0.1350
33	3.5	1.5	153.9 ± 1.19	a		
33	3.5	2.0	161.8 ± 7.75	a		

[a]Mean (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) R_{max}/E_{max} = 78.22 ± 6.42; mean (n=3) ± standard error.

Table 27. Effect of tempe (2.0 and 3.5%) on R_{max}/E_{max} of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and sourdough (17 and 33%) [ab].

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**R_{max}/E_{max} (mN/cm)**	**Percentage change (%)**	**P-value**
17	0.75	2.00	78.0 ± 6.62		<.0001
17	0.75	3.50	134.7 ± 1.36	72.7	
17	1.5	2.00	112.3 ± 10.37		0.0963
17	1.5	3.50	96.0 ± 5.26		
17	2.0	2.00	110.5 ± 6.06		0.0517
17	2.0	3.50	91.2 ± 5.24		
33	0.75	2.00	162.3 ± 13.87		0.2462
33	0.75	3.50	173.5 ± 8.54		
33	1.5	2.00	156.7 ± 5.85		0.7675
33	1.5	3.50	153.9 ± 1.19		
33	2.0	2.00	204.3 ± 4.80		0.7675
33	2.0	3.50	161.8 ± 7.75		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) R_{max}/E_{max} = 78.22 ± 6.42; mean (n=3) ± standard error.

Table 28. Effect of sourdough (17 and 33%) on R_{max}/E_{max} of wheat dough at different levels of NaCl (0.75, 1.5 and 2.0%) and tempe (2.0 and 3.5%) [ab].

NaCl (%)	Tempe (%)	Sourdough (%)	R_{max}/E_{max} (mN/cm)	Percentage change (%)	P-value
0.75	2.0	17	78.0 ± 6.62		<.0001
0.75	2.0	33	162.3 ± 13.87	108.0	
0.75	3.5	17	134.7 ± 1.36		0.0004
0.75	3.5	33	173.5 ± 8.54	28.8	
1.5	2.0	17	112.3 ± 10.37		<.0001
1.5	2.0	33	156.7 ± 5.85	39.5	
1.5	3.5	17	96.0 ± 5.26		<.0001
1.5	3.5	33	153.9 ± 1.19	60.4	
2.0	2.0	17	110.5 ± 6.06		<.0001
2.0	2.0	33	204.3 ± 4.80	84.8	
2.0	3.5	17	91.2 ± 5.24		<.0001
2.0	3.5	33	161.8 ± 7.75	77.5	

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe and sourdough) R_{max}/E_{max} = 78.22 ± 6.42; mean (n=3) ± standard error.

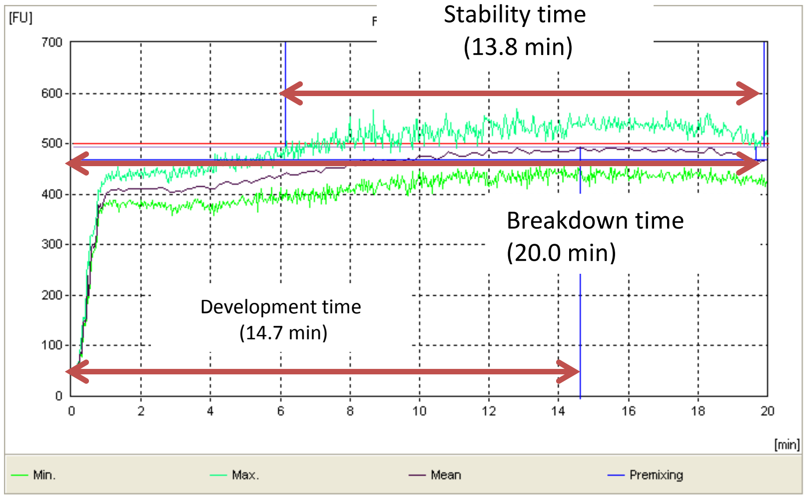

Fig 1a. Effect of mixing properties when lower level of fermented products are present along with 2% NaCl (2% tempe and 17% sourdough).

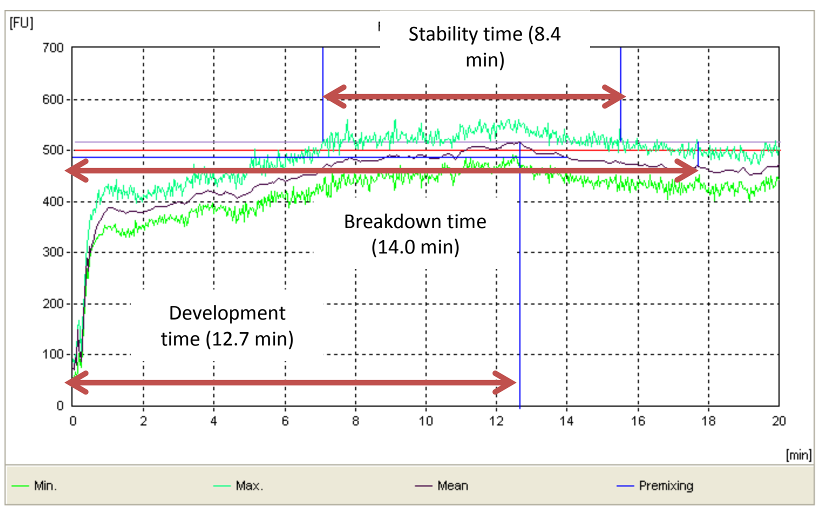

Fig 1b . Effect of mixing properties when higher level of fermented products are present along with 2% NaCl (3.5% tempe and 33% sourdough).

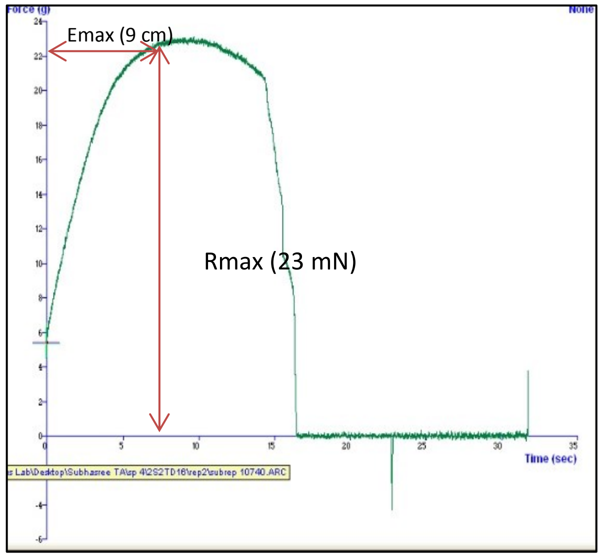

Fig 2a. Effect of extension properties when lower level of fermented products are present along with 2% NaCl (2% tempe and 17% sourdough).

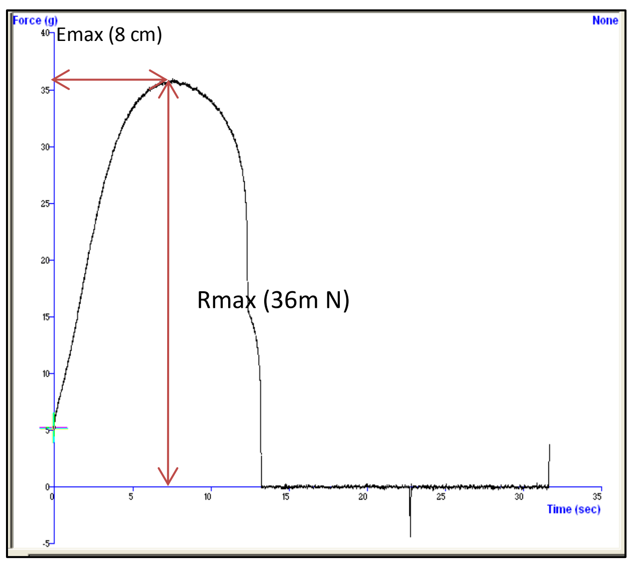

Fig 2b. Effect of extension properties when higher level of fermented products are present along with 2% NaCl (2% tempe and 17% sourdough).

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CHAPTER V

EFFECT OF COMMERCIAL SODIUM CHLORIDE SUBSTITUTES ON MIXING AND EXTENSION PROPERTIES OF WHEAT DOUGH

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Abstract

This study is aimed to determine the effect of sodium chloride substitutes on rheological (mixing and extension) properties of wheat dough. A set of three commercial wheat flours with protein content 9.8, 10.9 and 13.4% was treated with sodium chloride (control) as well as five commercial sodium chloride (NaCl) substitutes following a Randomized Complete Block Design with 3 replicates. Dough mixing (water absorption, dough development time, stability time and breakdown time) and extension (maximum resistance to extension R_{max}, maximum extensibility E_{max}, are covered to each the peak of extension, Total area and R_{max}/E_{max} properties were determined. Data were analyzed using ANOVA.

Mixing properties showed that development time and stability time was directly proportional to the level of salt. Analysis also showed that soft red winter wheat (protein= 9.8%) had significantly higher ($p< 0.05$) development and stability time when treated with 2% commercial sodium chloride (NaCl) substitutes as compared to 2% sodium chloride (NaCl The hard red winter wheat (protein= 10.9%) determined that stability time of 1% commercial sodium chloride (NaCl) substitutes was significantly higher ($p< 0.05$) than 1% sodium chloride (NaCl). NaCl and

NaCl substitutes did not show any significant effect on water absorption and breakdown time did not provide any significant trend in result. In case of extension properties, maximum resistance to extension (R_{max}) and area to R_{max} increased with an elevation in level of NaCl. Also, NaCl resulted in a higher area than commercial sodium chloride (NaCl) substitutes when each level of salt was analyzed.

Key words: dough, mixing property, extension property, sodium chloride, commercial sodium chloride substitutes.

1. Introduction

The body of evidence relating dietary sodium chloride intake and hypertension and cardiovascular diseases continues to grow (Elliott et al., 2007) (du Cailar et al., 2002). Bread is a staple food worldwide and it accounts for 30% of the daily salt intake (Girgis et al., 2003). Sodium chloride has contributions to more than saltiness in bread including functionality of gluten and yeast.

Among the alternative products to substitute sodium chloride is potassium chloride. It has been reported that potassium chloride does not affect dough handling properties, but when substituted above 10%, an adverse effect on the flavor of bread is observed as a metallic taste prevails (Kilcast and Angus, 2007b). A replacement of sodium up to 32% was achieved with a mixture of magnesium chloride (six hydrate), potassium chloride (dry), magnesium sulphate (dry) and calcium carbonate without affecting flavor and texture of breads when compared to control (Charlton et al., 2007). Sodium gluconate (Na-gluconate) and potassium gluconate (K-gluconate) were used as NaCl substitutes. Replacement of 75% of NaCl by Na-gluconate and of 50% NaCl by K-gluconate had no effect on the rheological properties of dough, loaf volume, bread quality and shelf-life of white bread (Takano and Kondou, 2002). It was reported that decreasing NaCl concentration (4.0- 0%) led to increasing water absorption. However, the effect was significant ($p < 0.05$) only at 3.5% NaCl. Also, 2% NaCl in dough resulted in 181.5% increased stability time compared to 0% NaCl (Beck et al., 2011). The addition of 0.3% (w/w) calcium-gluconate to wheat flour significantly increased the loaf volume of bread by 10.8%. With regards to mixing properties, the dough development time was shortened by 0.3% Ca-gluconate when compared to that of control by 15.4% (Morita et al., 1994). A significantly lower dough consistency (16.7%) was obtained in dough with 2% NaCl compared to 0% NaCl (Wehrle et al., 1997). 1 and 2% NaCl resulted in 2.3% and 3.0% decrease in water absorption (Hlynka, 1962a). (Calvel, 2001) suggested that salt reduction leads to a decrease in dough development time. NaCl has ionic nature which results in extensive interaction with water as well as macromolecules. It is responsible for restricted water availability in the dough and therefore a gluten network development. As a result, salt reduction leads to a decreased dough development time. (Grausgruber et al., 2002) reported significant ($p< 0.0001$) relationship between micro-extensograph (SMS/Kieffer rig) and standard extensograph (Brabender). High correlation was observed for maximum resistance to extension (0.92-0.93), area under curve (0.93-0.96) and a comparatively medium coefficient was observed in extensibility (0.57-0.63). Empirical rheology showed that 0% NaCl resulted in 21% to 26% reduction in resistance to extension (R_{max}) and extensibility (E') respectively compared to 1.2% NaCl when measured in extensograph (Lynch et al., 2009a). Dough with 3% salt resulted in threefold increase in resistance to extension compared to 0% salt (Tanaka et al., 1967). (Beck et al., 2011) reported that increase in NaCl caused higher resistance to extension and extensibility. 2% NaCl led to 32 and 27.5% higher resistance to extension and extensibility than 0% NaCl. This was due to the fact that dough without salt lacks stability resulting in viscous dough that doesn't retain its shape completely. NaCl addition leads to improved gluten network formed by less shielding of charged gluten molecules. Therefore, the interaction between the polymer crosslinks become stronger resulting in increased dough resistance to extension and extensibility (Bushuk and Hlynka, 1964).

The objective of this study is to analyze the effect of effect of commercial sodium chloride substitutes on mixing and extension properties of wheat dough.

2. Materials and methods

2.1 Materials

Three commercial wheat flours, one soft red winter wheat (F1) and wheat two hard red winter wheat (F2 and F3) were obtained from Shawnee Milling (Shawnee, OK) and used to study the rheological properties of commercial sodium chloride (NaCl) substitutes at two levels (1 and 2%).

The other materials were sodium chloride (Fisher Scientific, Fair Lawn, NJ), five commercial sodium chloride (NaCl) substitutes (Nu-Tek Food Science, LLC, Minnetonka, MN) and instant dry yeast (Lesaffre Yeast Corporation, Milwaukee, WI). Five commercial sodium chloride (NaCl) substitutes were identified as S1, S2, S3, S4 and S5.

2.2. Experimental

2.2.1 Protein, Moisture and Ash Analysis

The protein, moisture and ash contents were determined using near infrared reflectance with a NIR System Model 8300 (FOSS NIR Systems Inc, Laurel, MD 20723) following manufacturer's instructions. Analyses were performed in triplicate.

2.2.2 Mixing Properties

Mixing properties of the dough were determined in a Farinograph. The three flours were analyzed for the consistency (CS) , optimal dough development time (DT), stability time(ST), time to breakdown (TBD), water absorption corrected to 14% moisture, mixing tolerance index (MTI) and farinograph quality number (FQN) at 63 rpm and 30°C in a 10-g bowl Farinograph-E (C.W. Brabender Instruments, Hackensack, NJ) according to approved AACCI Method 54-21.02. The parameters are explained in Appendix I Table 2.

2.2.3 Dough preparation

Dough was prepared according to the method of Kieffer et. al (1998). The flour was mixed with a Farinograph until a dough consistency of 600 Brabender Units (BU) was reached. At the peak consistency of 600BU, the dough was retrieved and rolled. It was then transferred into the Teflon form of the Kieffer rig from Texture Technologies (TA.XTPlus, Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK).The dough was clamped between two resting plates for 40 minutes to relax in a humid environment and inside an air tight plastic bag at room temperature. Mineral oil was added to avoid excessive sticking of the dough to the resting plates.

2.2.4 Dough Extensibility

After resting, the dough was unclamped and the mold was removed very gently to avoid any deformation of the dough. The dough strips were carefully removed from the mold and placed on the Texture analyzer plate. A Kieffer Dough Extensibility rig was used in the Texture Analyzer TA-XT2 (TA.XTPlus, Texture Technologies Corp., Scarsdale, NY/StableMicro Systems, Godalming, Surrey, UK). A test speed of 4.0 mm/s and trigger force of 1g were used for the measurement of extensibility of the dough strip. The parameters evaluated for obtaining the dough strength were R_{max} (maximum resistance to extension), E_{max} (extensibility at maximum resistance), area to R_{max} (work required to reach R_{max}) and total area. This test was performed in triplicates with 10% coefficient of variation (CV).

2.3 *Statistical analysis*

Statistical analysis was done using SAS 9.3version. Analysis of Variance (ANOVA) was done in an arrangement of 6*2+1 corresponding to 6 salts (C through S5), 2 levels each (1 and 2%) and 1 reference control (C0).

3. Results and discussion

3.1 Mixing properties

3.1.1 Water absorption (corrected to 14% moisture)

Within each F1, F2 and F3 any of the water absorption values were significantly different from each other. This suggests that the different salt treatments do not have any significant effect on the water absorption of dough ($p > 0.05$) as shown in Table 2, 3 and 4. These results do not support the findings of (Salovaara, 1982a) and (Lynch et al., 2009a), which tells that addition of NaCl decreases water absorption.

3.1.2 Development time (min)

The effect of all the treatments on dough development time was significant in each of the flours F1, F2 and F3 with p-values < 0.002 (Table 5-7).

3.1.2.1 Flour 1 (F1)

The development time of F1 (9.8% protein) is reported in Table 5, where NaCl is the control (C). When comparing 0, 1 and 2% of C, 1 and 2% C had a 17.4% lower development time than 0% C ($p< 0.05$). This result is in contrast to the findings of (Bartoshuk, 2000), where dough development t time increased with the increase of salt. A general trend of 2% commercial sodium chloride (NaCl) substitutes was higher development time than 1% salts .A strikingly high development time was noticed in in S3, where 2% S3 (7.5 min) resulted in 445.1% higher value than 1% S3 (1.4 min). (Hlynka, 1962a) suggested that with the addition of salt, less water is available for gluten network formation and development time is increased. The results support the theory of (Hlynka, 1962a). 2% S3 showed a drastic 445.1% higher development time than 1% S3. Salts S1, S2 and S4 did not have a significant difference in development time between 1 and 2% levels ($p> 0.05$).

When comparisons were done between 1% C (NaCl) and 1% of each commercial NaCl substitutes, no significant difference in results was seen ($p> 0.05$). But in case of comparison between 2% C (NaCl) and 2% of commercial NaCl substitutes, a specific trend was seen where, 2% commercial sodium chloride (NaCl) substitutes had a higher development time than 2% C, three of them (S3> S5> S1) being significantly higher with a range of 23.7- 488.1% increase ($p< 0.05$) and two salts were not significantly different (S2 and S4). 2% S3 (7.5 min) led to 488.1%

higher development time value than 2% C (1.3 min) may be due to the fact that salt S3 was very coarse compared to NaCl and therefore more time was required for the dough to develop.

3.1.2.2 Flour 2 (F2)

For flour 2 (10.9% protein), control treatments (0, 1 and 2% C) were not significantly different from each other with respect to development time ($p > 0.05$) (Table 6). None of the commercial NaCl substitutes had a significant difference in development time when 1 vs 2% were analyzed ($p > 0.05$) except salt S5, where 2% S5 (1.9 min) had a 78.1 % higher development time than 1% S5 (1.1 min) ($p < 0.05$) (Table 6).

Comparisons drawn between 1% control and commercial NaCl substitutes (S1 through S5) revealed that 1% commercial NaCl substitute treatments had lower values than 1% C (NaCl). Especially, 1% S4 and 1% S5 resulted in a 26.7 and 28.9% lower development time than 1% C ($p < 0.05$), however no significant change was observed in 1% S1, S2 and S3($p > 0.05$) (Table 6). The addition of salt leads to the dough strengthening which in turn leads to a higher development time. In a flour-water system, the gluten protein has a net positive charge. These positive charges repulse each other and this allows the gluten to hydrate faster (shorter mixing time) and keeps the protein chains from interacting with each other, resulting in weaker dough. Low levels of salt shield the charges allowing the protein chains to approach each other. This allows the flour to hydrate more slowly, thus a longer a mixing time and development time (Galal et al., 1978). Comparisons of all salts at 2% with C at 2% showed only two significant differences with contrasting direction of the effect on development time (Table 6). S4 had 25% lower development time than 2% C whereas S5 29.5% had higher development time than 2% C ($p > 0.05$). 2% S1, S2 and S3 were not different than 2% C (Table 6).

3.1.2.3 Flour 3 (F3)

When development time of F3 (13.4%) was analyzed 1% C (NaCl) had 8.0% higher development time than 0% C (no salt) and 2% C had 4.2% higher development time than 1% C. (Table 7). Comparing 1 vs 2% of salts showed that 2% salts S3, S4 and S5 had a 16.2, 21.3 and 17.0% higher development time value than 1% salts ($p < 0.05$). This result is in accordance with the literature provided by (Hlynka, 1962a). S1 and S2 showed no significant difference, however trend is suggested towards an increase in development time ($p > 0.05$).

Comparisons drawn between 1% C and 1% commercial NaCl substitutes showed that 1% commercial sodium chloride (NaCl) substitutes had a lower development time than 1% C, except for S1 which showed no difference (Table 7). NaCl has ionic nature which results in extensive interaction with water as well as macromolecules. It is responsible for restricted water availability in the dough and therefore a gluten network is developed. As a result, salt reduction (in this case commercial NaCl substitutes) leads to a decreased dough development time (Calvel, 2001). Only S1 had non-significant difference in result and S5 having the highest percentage change of 19.9% ($p < 0.05$). On the other hand, 2% C did not have any significant difference in development time when it was compared to 2% level of reduced salts (6.4-6.9% change) ($p > 0.05$). Refer to table 7.

3.1.3 Stability time (min)

The analysis of stability time has a highly significant difference in each of the flours F1, F2 and F3 which is shown by the p-values < 0.0001 (Table 8-10).

3.1.3.1 Flour 1 (F1)

When the stability time of F1 was analyzed, most of the treatments were significantly different from each other ($p < 0.05$) (Table 8). 1% C had 68.2% more stability time than 0% C and 2% C had 15.2% more stability time than 1% C. For commercial sodium chloride (NaCl) substitutes it was observed that 2% salts had a higher stability time than 1% salts. Improvement in stability with salt KCl and at an increasing level has been reported (Srivastava et al., 1994). 2% S4 showed the highest change in value (54.3%) than 1% S4 ($p < 0.05$). S2 gave a non-significant difference (14.9%) ($p > 0.05$).

1% commercial sodium chloride (NaCl) substitutes provided lower stability time value than 1% C (NaCl), all the treatments gave a non-significant difference ranging from 0-23.2%. At 2% level, the trend was opposite to 1% level where 2% commercial sodium chloride (NaCl) substitutes had a higher stability time than 2% C ranging from 1.3-28.6%.

3.1.3.2 Flour 2 (F2)

F2 had higher protein content than F1 andthe effect of the treatments was significant (Table 9). There is a specific trend in control as well as commercial sodium chloride (NaCl) substitute treatments which shows that 2% salt provides a higher stability time than 1% of its respective salt. 2% C (NaCl) provided a drastic 814.3% higher stability time than 1% C. In case of commercial sodium chloride (NaCl) substitutes, 2% S2 had 55.2% higher value than 1% S2, lowest among all the treatments ($p < 0.05$).

When comparison was drawn between 1% C and 1% commercial sodium chloride (NaCl) substitutes, none of the results were significantly different except S2. 1% S2 provided a 334.9% higher stability time than 1%C. The other treatments with 1% salts provided a non-significant effect ($p > 0.05$). But, when 2% salts were compared for stability time, it was observed that 2% commercial sodium chloride (NaCl) substitutes had a lower stability time than 2% C. Amongst the treatments, S5 resulted in the highest percentage change (88.2%) in value while S4 did not have a sifgnificant effect (Table 9).

3.1.3.3 Flour 3 (F3)

F3 had the highest protein content of 13.3% and had a significantly different stability time from each other ($p < 0.05$) (Table 10).There was no significant change (0.2-3.6%) in stability time between the 0, 1 and 2% C (NaCl) ($p > 0.05$). But, in case of commercial sodium chloride (NaCl) substitutes, there was an inversely proportional relationship; higher salt content gave lower stability time. 2% S1, S2, S3, S4 and S5 resulted in 21.8, 24.3, 10.6, 21.3 and 12.8% respectively lower stability time than its respective 1% salt.

1% commercial sodium chloride (NaCl) substitutes had a significantly higher stability time than 1% C ranging from 16.8- 27.7% ($p < 0.05$). Whereas, no significant change (0.7-11.4%) in value was observed between 2% C and 2% commercial sodium chloride (NaCl) substitutes except 2% S3 (11.9%) ($p > 0.05$).

3.1.4 Time to breakdown (min)

3.1.4.1 Flour 1 (F1)

The effect of salt substitutes in Flour 1 significantly affected the dough time to breakdown. The overall effect was an increase of dough time to breakdown with 2% concentration except for S4 (Table 11). Dough with 1% C resulted in 190.1% higher TBD value than without salt (0% C). Whereas, 2% C had a 0.8% lower TBD value than 1% C. For commercial sodium chloride (NaCl) substitutes, 2% salts led to a higher TBD than 1% salts but S4 was an exception; 2% S4 had a 63.9% lower TBD than 1% S4.

When comparisons were drawn between 1% C and 1% reduced salts, results showed that 1% S2, S4 and S5 had 67.3, 4.4 and 58.9% lower TBD than 1% C whereas, 1% S1 and S3 had 17.7 and 9.5% higher TBD than 1% C. A same trend of result was observed in 2% reduced salts when compared with 2% C.

3.1.4.2 Flour 2 (F2)

While determining the TBD value for control treatments, it was observed that 1% C had 18.8% lower value than 0% C ($p < 0.05$) (Table 12). This result is contradictory to the expected, since salt strengthens the dough. The dough without the salt should be less strong than the dough with it and therefore a lower TBD value as well. On the contrary, 2% C had a 28.1% higher TBD value than 1% C which is in accordance with the literature. For commercial sodium chloride (NaCl) substitutes, 2% salts led to a higher TBD value than 1% salts except S2. In general, 2% salts resulted in 15.4 - 40.2% higher TBD than 1% salts.

No conclusion can be drawn seeing the results of the commercial sodium chloride (NaCl) substitutes when they were compared with its respective level of control treatment (Table 12).

3.1.4.3 Flour (F3)

Analysis of flour F3 determined that none of the treatments were significantly different from each other when compared amongst them and with control ($p > 0.05$) (Table 13).

3.2 Extension properties

3.2.1 Rmax (mN)

The analysis of R_{max} (maximum resistance) has a highly significant difference in each of the flours F1, F2 and F3 which is shown by the p-values < 0.0001 (Table 14-17).

3.2.1.1. Flour 1

When the micro extension of dough was tested it was observed that the control treatments were significantly different from each other (Table 14). Dough sample without salt i.e., 1% C had almost 32.3% more R_{max} value than dough with 0% C. Also, 2% C resulted in a 15.2% more resistance than 1% C ($p < 0.05$). It can be seen that amount of salt is directly proportional to resistance in TA.XT2. This behavior was explained by (Tanaka et al., 1967); the high resistance brought about by salt was due to the denaturation of gluten which results in unfolding and therefore the inside polar group comes outside and results in network formation. This trend has been followed in commercial sodium chloride (NaCl) substitutes as well. The highest percent change was observed in S3; 2% S3 had a 58.1% more resistance (R_{max} value) than 1% S3. The R_{max} value for other treatments ranged from 16.8-36.0%.

Analysis of R_{max} value comparison was also done between the same level of NaCl (control) and other reduced sodium chloride salts. 1% commercial sodium chloride (NaCl) substitutes S1, S2, S3and S5, had a significantly lower resistance (25.0, 22.1, 26.9 and 19.7% respectively) than 1% C but 1% S4 did not provide a significantly lower value (8.6%) than 1% C. Similarly, dough strips with 2% C resulted in a higher resistance than 2% reduced salts ($p < 0.05$). 2% S1, S2 and S5 resulted in 11.4, 21.0 and 11.5% lower change in maximum resistance to extension values. The control salt (100% NaCl) in both and 1 and 2% level resulted in a higher resistance due to the protein crosslinking and therefore having comparatively stronger dough than the ones treated with commercial sodium chloride (NaCl) substitutes. The commercial sodium chloride (NaCl) substitutes contained KCl and magnesium and therefore the dough was less strong than the dough with NaCl. Refer to table 14.

3.2.1.2. Flour2

Flour 2 has higher protein content than F1 and results are mentioned below (Table 15). Starting with the control, 1% C had 17.7% higher R_{max} value than 0% C ($p < 0.05$) and 2% C had 7.1% more resistance to extension than 1%C. All the commercial sodium chloride (NaCl) substitutes except S1 maintained the same trend where level of salt had a directly proportional relationship (2% of each salt had a higher resistance than its respective 1% level) with resistance. 2% S2, S3, S4 and S5 resulted in 17.2, 29.4, 7.0 and 17.8% higher R_{max} value than 1% S2, S3, S4 and S5.

Similar behavior that salt increases resistance was suggested by (Birch, 2000) and (Tanaka et al., 1967). For S1, an inversely proportional relationship was seen between amount of salt in the dough and resistance, although the results were non-significant (6% change).

When comparisons were drawn between 1% C and 1% commercial sodium chloride (NaCl) substitutes each, the R_{max} value of 1% commercial sodium chloride (NaCl) substitutes was significantly lower than 1% C (11.2-14.8%) except 1% S1, change of which was non-significant (1.4). At 2% level, only S1 and S4 provided significantly lower resistance such as 11 and 13% as compared to 2% C. Refer to Table 15.

3.2.1.3. Flour3

The flour F3 has the highest protein content; the results of R_{max} are mentioned below (Table 16). When control dough strips were analyzed, it was observed that 1% C resulted in a 23.2% more resistance (R_{max} value) than 0% C. Also, 2%C had 7.2% less resistance than 1% C ($p < 0.05$). No specific trend was observed in commercial sodium chloride (NaCl) substitutes. 2% S3 and S5 resulted in 20.5 and 21.1% more resistance to extension than 1% S3 and S5. S1, S2 and S4 provided non-significant variation in results.

Analysis of comparisons led to the fact that dough strips with 1 and 2% commercial sodium chloride (NaCl) substitutes produced a higher resistance than dough strips with 1 and 2% C. In both cases S4 had the highest percent change as compared to control treatments. 1% S4 had a 26.5% lower resistance to extension than 1% C. Also, 2% S4 resulted in a 33.3% lower resistance (R_{max} value) than 2% C ($p < 0.05$). Refer to table 16.

3.2.2 Emax (cm)

3.2.2.1. Flour 1

Flour F1 had the lowest protein content of 9.8%, the results of which is mentioned below (Table 17). Initially, when control treatments were analyzed it was observed that 1% C and 2% C produced 24.4% and 13.0% higher extension (E_{max}) than 0% C and 1% C respectively ($p < 0.05$). The addition of salt leads to more protein crosslinking and therefore more extensibility was observed. No specific trend was observed in the commercial sodium chloride (NaCl) substitutes when extension between 1 and 2% level of each salt were compared.

Analysis was also done between same levels of control and reduced salt treatments. No significant variation in extensibility was observed when 1% commercial sodium chloride (NaCl) substitutes was compared to 1% C. 2% S3 and S4 resulted in 22.7 and 26.4% lower E_{max} value than 2% C ($p < 0.05$).

3.2.2.2. Flour 2

Flour F2 had a medium protein content of 10.9%; the analysis is mentioned below (Table 18). When control treatments were analyzed regarding how salt affect maximum extension, it was observed that 1and 2% C was 15.6 and 13.6% lower than 1 and 2% C ($p < 0.05$). So, the more salt led to a lower E_{max} value as compared to the dough strips with less salt. When extension was compared between 1 and 2 % level of each salt, S5 resulted in the highest change in extension. 2% S5 had a 24.9% lower extension than 1% S5 ($p < 0.05$). But, a general trend showed that as salt level increases, extension decreases.

When comparisons were drawn between 1% C and 1% commercial sodium chloride (NaCl) substitutes, 1% commercial sodium chloride (NaCl) substitutes resulted in higher extensions than 1% C ($p < 0.05$). Similar results were obtained at 2% level, although a few treatments gave non-significant results. The highest percentage change was shown by 1% S5 and 2% S4 which was significantly greater in extension than 1 and 2% C respectively. Refer to table 18.

3.2.2.3. Flour 3

Flour 3 had the highest protein content 13.3% and the results are mentioned below (Table 19). While analyzing control treatments it was observed that 1% C had 13% higher extension than 0% C but 2% C had a 0.6% lower extension than 1% C. For commercial sodium chloride (NaCl) substitutes, no specific trends were observed in terms for extensions. 2% S3 and S5 provided a significantly lower extension such as 18.8 and 24.8% than 1% S3 and S5. The other treatments led to non-significant results.

1% commercial sodium chloride (NaCl) substitutes generally produced comparatively higher E_{max} values than 1% C ($p < 0.05$). Except S2, all other salts provided significantly higher extension ranging from 18.7-28.5% when compared with 1% C. On the contrary, 2% commercial sodium chloride (NaCl) substitutes couldn't provide any trend in extension when compared to 2% C. Refer to table 19.

3.2.3 Area to R_{max} (mN-cm)

3.2.3.1 Flour 1

Dough strips with 1and 2% C resulted in 57.8 and 11% higher value than 0 and 1% C in terms of the area to R_{max} when the strips had maximum extension (Table 20). None of the treatments except S5 provided significant difference in area when comparisons were drawn between 1 and 2% of each salt; 2% S5 had a 27.9% area than 1% S5 ($p < 0.05$).

At 1 % salt level treatments (between control and commercial sodium chloride (NaCl) substitutes), a variety of significant and non-significant result was observed from which no conclusion can be drawn. Although, for 2% treatments, general behavior was seen where 2%

commercial sodium chloride (NaCl) substitutes resulted in a comparatively lower area value than 2% C; a few treatments (S5 and S1) had non-significant values still maintained the trend. Dough strips with 2% S2, S3 and S4 resulted in 19.9, 13.5 and 23.9% lower area than 1% S2, S3 and S4.

3.2.3.2 Flour 2

None of the treatments provided significant difference in results from which a trend can be observed ($p > 0.05$). Refer to Table 21.

3.2.3.3 Flour 3

Dough strips with 1% C resulted in a 343.2% remarkably higher value than 0% C in terms of the area covered while the dough strip attained the maximum extension. (Table 22) Regarding commercial sodium chloride (NaCl) substitutes it was observed that 2% salts had a greater area value (196.2- 237.6%) than 1% of its respective salt. Con the contrary, 2% S5 covered 11.6% lower area than 1% S5.

1 and 2% commercial sodium chloride (NaCl) substitutes provided a trend of having lower area to R_{max} than 1 and 2% C respectively. The only treatments which gave non-significant variation in results were 1% S5 and 2% S1 ($p > 0.05$). 1% S1, S2, S3 and S4 resulted in 64.1, 73.7, 70.4 and 71.6% lower results than 1% C. Similarly, 2% S2, S3, S4 and S5 resulted in 17.0, 11.1, 19.2 and 23.2 % lower area than 2% C ($p < 0.05$).

3.2.4 Total area (mN-cm)

The analysis of Total area (mN-cm) has a pretty significant difference in each of the flours F1 and F3 and non-significant difference in F2 which is shown by the p-values. The total area is the area under the curve on the force/ distance graph when the dough strip starts deforming to the point it either comes back or it tears apart.

3.2.4.1 Flour 1

In flour 1 which had a protein content of 9.8%, analysis of total area under the curve first showed a striking result where the dough strip without any salt covered the least area as compared to all the treatments with salt irrespective of the level ($p < 0.05$) (Table 23). This is due to the fact that salt increases the hydrophobic and hydrogen bonding reactions and therefore, more resistance is seen during extension. Dough with 1 and 2% C had 67.2 and 8.3% more area than 0 and 1% C respectively. Also, in every set of reduced salt treatment, 2% level covered a greater area than 1% level, although S2, S4 and S5 provided non-significant variation in data. In case of significantly different treatment 2% S1and S3 resulted in 17.1 and 29.9% greater Total area (mN-cm) than 1% S1 and S3.

When comparisons were made between control treatments and reduced salt treatments, it was observed that control treatments containing NaCl led to a greater area covered than the treatments with commercial sodium chloride (NaCl) substitutes ($p < 0.05$). Refer to table 23.

3.2.4.2 Flour 2

None of the results had a significant variation when total area (mN-cm) was analyzed for flour 2 with protein content 10.9% ($p > 0.05$) (Table 24). The dough strip with 1% C resulted in 3.3% greater area covered than 0% C but on the contrary, 2% C led to 3.6% lower area than 1%C. The general behavior was observed in all treatments except S3 andS5, where 2% salt led to higher area than 1% salt. The maximum change, 42% was observed in S4. No trend can be observed when several comparisons were between control treatments and commercial sodium chloride (NaCl) substitute treatments.

3.2.4.3 Flour 3

For flour 3 with a protein content of 13.3%, dough strip with 1% C resulted in 305.6% greater work was done than 0% C ($p < 0.05$) (Table 25). For commercial sodium chloride (NaCl) substitutes, the range of variation was 243.9-303.3%. Also, the trend was seen that 1 and 2% C had a higher area value than 1 and 2% reduced salts respectively.

3.2.5 R_{max}/E_{max} (mN/cm)

3.2.5.1 Flour 1

The control treatments provided non-significant results but a general behavior was seen in control as well as commercial sodium chloride (NaCl) substitutes where dough treated with 2% salts provided a higher value than 1% salts. S3 led to highest change; 2% S3 had 93.3% higher value than 1% S3 ($p < 0.05$) (Table 26).

Analysis has shown a contradictory result when 1 and 2% levels of commercial sodium chloride (NaCl) substitutes were compared with their control treatments. 1% commercial sodium chloride (NaCl) substitutes resulted in lower R_{max}/E_{max} value than 1%C except S4 (non-significant). But, 2% commercial sodium chloride (NaCl) substitutes resulted in higher R_{max}/E_{max} value than 2% C ($p < 0.05$).

3.2.5.2 Flour 2

Flour 2 gave pretty consistent trend in terms of R_{max}/E_{max} values (Table 27). For control treatments, 1 and 2% C had a 39.5 and 24.5% higher value than 0 and 1% C respectively. In commercial sodium chloride (NaCl) substitutes, 2% level produced a higher value than 1% level. 2% S2, S3, S4 and S5 provided 47.3, 47.7, 20.6 and 55.4% higher value than 1% S2, S3, S4 and S5($p < 0.05$).

When comparisons were drawn between dough treated with control salts and commercial sodium chloride (NaCl) substitutes, again a consistent trend was observed that 1 and 2% C had a higher value than 1and 2% commercial sodium chloride (NaCl) substitutes. The significant range of variation was 19.5-32.8% for 1% level of salts and 16.1-28.1% for 2% level of salts. ($p < 0.05$).

3.2.5.3 Flour 3

1 and 2% C had 9 and 7.7% higher value than 0 and 1% C respectively in terms of R_{max}/E_{max} (Table 28). For commercial sodium chloride (NaCl) substitutes, no specific trend was observed, although the highest percent change was observed by S5; 2%S5 resulted in 61.4% higher value than 1% S5.

When analysis was made between control and reduced sodium treatments, it was observed that 1 and 2% commercial sodium chloride (NaCl) substitutes had a lower value than 1 and 2% C respectively. At 1% level, the commercial sodium chloride (NaCl) substitutes ranged 27.2 - 40.7% lower value than 1% C while at 2% level, the range was 34.3 to 44.1% for treatments with significant difference (S1, S2 and S4).

4. Discussion

In Flour F1, a general trend of 2% commercial sodium chloride (NaCl) substitutes was higher development time than 1% salts. Hlynka, 1962 a suggested that with the addition of salt, less water is available for gluten network formation and development time is increased. In flour F2, comparisons drawn between 1% control and commercial NaCl substitutes (S1 through S5) revealed that 1% commercial NaCl substitute treatments had lower values than 1% C (NaCl). The addition of salt leads to the dough strengthening which in turn leads to a higher development time. In a flour-water system, the gluten protein has a net positive charge. These positive charges repulse each other and this allows the gluten to hydrate faster (shorter mixing time) and keeps the protein chains from interacting with each other, resulting in weaker dough. Low levels of salt shield the charges allowing the protein chains to approach each other. This allows the flour to hydrate more slowly, thus a longer a mixing time and development time (Galal., 1978). In flour 1, 2% S3 resulted in a remarkably high (488%) higher development time than 2% C. This can be possibly due to the fact that salt S3 is coarser than NaCl. During mixing, as the particle size increases, more time will be required to hydrate the gluten and form the dough. Therefore, an increase in the development time will be observed. In Flour F1, 1 and 2% NaCl had a significantly higher maximum resistance to extension R_{max} than their respective level of salt substitutes due to the protein crosslinking and therefore having comparatively stronger dough than the ones treated with commercial sodium chloride (NaCl) substitutes. The commercial sodium chloride (NaCl) substitutes contained KCl and magnesium and therefore the dough was less strong than the dough with NaCl. Regarding maximum extensibility to fracture in flour F1, it was observed that 2% NaCl substitutes resulted in a significantly lower extensibility than NaCl. This can be partially explained by the phenomenon of different effects of salt primarily based on the protein content of flour. In low protein content flour, NaCl results in a better alignment and close knitted gluten structure because of the changes in the secondary structure conformation i.e. more beta sheets are formed due to hydrogen and hydrophobic interactions. The β-sheets provides more viscosity to gluten under small strain because of an extensive structure. In flour F3, it was observed that 1 and 2% C had a higher total area under the curve than 1 and 2% reduced salts respectively. Since control dough contains only NaCl it is observed that the dough is stronger than the dough with NaCl substitutes and therefore more work is required to elongate the dough.

5. Conclusion

Development time and stability time increased with the increase in the salt content in dough. In case of mixing properties, water absorption did not have any significant variation in in three flours which was unexpected. In Flour F1, a general trend of 2% commercial sodium chloride (NaCl) substitutes was higher development time than 1% salts. In flour F2, 1% commercial NaCl substitute treatments had lower values than 1% C (NaCl). In flour 1, 2% S3 resulted in a remarkably high (488%) higher development time than 2% C. This can be possibly due to the fact that salt S3 is coarser than NaCl. In Flour F1, 1 and 2% NaCl had a significantly higher maximum resistance to extension R_{max} than their respective level of salt substitutes due to the protein crosslinking and therefore having comparatively stronger dough than the ones treated with commercial sodium chloride (NaCl) substitutes. In flour F3, it was observed that 1 and 2% C had a higher total area under the curve (total work done) than 1 and 2% reduced salts respectively. Analysis of micro-extension of dough tells us that the maximum resistance to extension increased with the increase in salt content. Extensibility resulted in a variety of results in F1, F2 and F3 and therefore a general trend can't be concluded. Finally, when area was analyzed, results portrayed that there was a directly proportional relationship between level of salt and area covered. Also, NaCl resulted in a higher area than commercial sodium chloride (NaCl) substitutes when each level of salt was analyzed.

Table 1. Partial proximate analysis of flours

Wheat type	Flour	Protein (%)	Moisture (%)	Ash (%)
Soft red winter	**F1**	9.8±0.00	14.5±0.05	0.4±0.00
Hard red winter	**F2**	10.9±0.01	13.6±0.05	0.4±0.00
Hard red winter	**F3**	13.3±0.01	13.5±0.07	0.4±0.01

Mean (n=3) ± standard error.

Table 2. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on water absorption of soft red winter wheat (F1) [abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Water Absorption (14%)**				**I**	**II**	**III**	**P-value**
F1	C	0	57.1	±	0.60	a				0.4179
F1	C	1	57.8	±	0.06	a	1.2			
F1	C	2	57.8	±	0.07	a	0.1			
F1	S1	1	57.7	±	0.09	a	-0.2	0.0		
F1	S1	2	58.3	±	0.15	a	1.0		0.8	
F1	S2	1	57.4	±	0.82	a	-1.5	0.0		
F1	S2	2	56.7	±	0.90	a	-1.2		-1.9	
F1	S3	1	58.0	±	0.09	a	2.3	0.0		
F1	S3	2	57.8	±	0.12	a	-0.4		-0.1	
F1	S4	1	58.0	±	0.15	a	0.3	0.0		
F1	S4	2	58.0	±	0.27	a	0.1		0.3	
F1	S5	1	57.3	±	0.49	a	-1.3	0.0		
F1	S5	2	57.9	±	0.23	a	1.0		0.1	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F1 protein content 9.8%, 14% moisture basis.

Table 3. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on water absorption of hard red winter wheat (F2) [abcde]

						Percentage change (%)			
Flour	Salt	Amount	Water Absorption (14%)			I	II	III	P-value
F2	C	0	56.0	± 0.23	a				0.7978
F2	C	1	56.3	± 0.10	a				
F2	C	2	56.1	± 0.12	a				
F2	S1	1	55.9	± 0.20	a				
F2	S1	2	56.0	± 0.18	a				
F2	S2	1	56.1	± 0.23	a				
F2	S2	2	56.2	± 0.00	a				
F2	S3	1	55.9	± 0.15	a				
F2	S3	2	56.0	± 0.15	a				
F2	S4	1	56.0	± 0.15	a				
F2	S4	2	55.9	± 0.13	a				
F2	S5	1	55.8	± 0.25	a				
F2	S5	2	56.0	± 0.15	a				

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F2 protein content 10.9%, 14% moisture basis.

Table 4. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on water absorption of hard red winter wheat (F3) [abcde]

						Percentage change (%)			
Salt	Amount	Water Absorption (14%)				I	II	III	P-value
C	0	58.1	±	0.06	a				0.1231
C	1	58.0	±	0.17	a				
C	2	57.8	±	0.06	a				
S1	1	58.0	±	0.21	a				
S1	2	57.8	±	0.15	a				
S2	1	58.1	±	0.12	a				
S2	2	57.8	±	0.15	a				
S3	1	58.2	±	0.24	a				
S3	2	57.7	±	0.09	a				
S4	1	58.4	±	0.06	a				
S4	2	58.0	±	0.23	a				
S5	1	57.9	±	0.20	a				
S5	2	57.7	±	0.06	a				

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F3 protein content 13.4%, 14% moisture basis.

Table 5. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on development time of soft red winter wheat (F1) [abcde].

				Percentage change (%)			
Flour	**Salt**	**Amount**	**Developemnt time (min)**	**I**	**II**	**III**	**P-value**
F1	C	0	1.5 ± 0.09 bcd				<.0001
F1	C	1	1.3 ± 0.07 e	-17.4			
F1	C	2	1.3 ± 0.07 e				
F1	S1	1	1.4 ± 0.03 cde				
F1	S1	2	1.6 ± 0.13 bc			23.7	
F1	S2	1	1.3 ± 0.06 de				
F1	S2	2	1.5 ± 0.15 bcde				
F1	S3	1	1.4 ± 0.09 cde				
F1	S3	2	7.5 ± 0.05 a	445.1		488.1	
F1	S4	1	1.3 ± 0.05 e				
F1	S4	2	1.4 ± 0.09 cde				
F1	S5	1	1.4 ± 0.07 cde				
F1	S5	2	1.7 ± 0.12 b	18.6		34.2	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F1 protein content 9.8%, 14% moisture basis.

Table 6. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on development time of hard red winter wheat (F2) [abcde]

				Percentage change (%)			
Flour	**Salt**	**Amount**	**Developemnt time (min)**	**I**	**II**	**III**	**P-value**
F2	C	0	1.7 ± 0.13 ab				0.0002
F2	C	1	1.5 ± 0.00 bcd				
F2	C	2	1.5 ± 0.03 bcd				
F2	S1	1	1.4 ± 0.10 cd				
F2	S1	2	1.5 ± 0.10 bcd				
F2	S2	1	1.6 ± 0.07 bc				
F2	S2	2	1.3 ± 0.09 cde				
F2	S3	1	1.4 ± 0.03 cd				
F2	S3	2	1.3 ± 0.10 def				
F2	S4	1	1.1 ± 0.10 ef		-26.7		
F2	S4	2	1.1 ± 0.10 ef				
F2	S5	1	1.1 ± 0.07 f		28.9		
F2	S5	2	1.9 ± 0.00 a	78.1			

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F2 protein content 10.9%, 14% moisture basis.

Table 7. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on development time of hard red winter wheat (F3) [abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Development time (min)**				**I**	**II**	**III**	**P-value**
F3	C	0	12.4	±	0.30	bcd				0.0012
F3	C	1	13.4	±	0.64	ab				
F3	C	2	14.0	±	0.38	a				
F3	S1	1	12.4	±	0.61	bcd				
F3	S1	2	12.6	±	0.31	abc				
F3	S2	1	11.4	±	0.21	cde		-15.1		
F3	S2	2	12.6	±	0.31	abc				
F3	S3	1	11.3	±	0.20	cde		-15.6		
F3	S3	2	13.2	±	0.24	ab	16.2			
F3	S4	1	11.1	±	0.71	de		-17.1		
F3	S4	2	13.5	±	0.40	ab	21.3			
F3	S5	1	10.8	±	0.73	e		-19.9		
F3	S5	2	12.6	±	0.78	abc	17.0			

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F3 protein content 13.4%, 14% moisture basis.

Table 8. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on stability time of soft red winter wheat (F1) [abcde].

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Stability time (min)**				**I**	**II**	**III**	**P-value**
F1	C	0	6.5	±	0.12	f				<.0001
F1	C	1	10.9	±	0.23	d	68.2			
F1	C	2	12.6	±	0.70	c	15.2			
F1	S1	1	10.9	±	0.57	d				
F1	S1	2	14.6	±	0.80	b	33.5		15.9	
F1	S2	1	8.5	±	0.26	e		-22.3		
F1	S2	2	9.8	±	0.58	de			-22.5	
F1	S3	1	10.7	±	0.23	d				
F1	S3	2	16.2	±	0.60	a	51.4		28.6	
F1	S4	1	9.8	±	0.18	de				
F1	S4	2	15.1	±	0.72	ab	54.3		19.6	
F1	S5	1	8.4	±	0.23	e		-23.2		
F1	S5	2	12.8	±	0.20	c	52.0			

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F1 protein content 9.8%, 14% moisture basis.

Table 9. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on stability time of hard red winter wheat (F2) [abcde].

							Percentage change (%)			
Flour	Salt	Amount	Stability time (min)				I	II	III	P-value
F2	C	0	2.3	±	0.05	ef				<.0001
F2	C	1	2.1	±	0.12	ef				
F2	C	2	19.2	±	0.12	a	814.3			
F2	S1	1	1.7	±	0.10	ef				
F2	S1	2	13.8	±	0.55	c	711.8		-28.1	
F2	S2	1	9.1	±	0.37	d		334.9		
F2	S2	2	14.2	±	0.90	c	55.1		-26.2	
F2	S3	1	1.8	±	0.00	ef				
F2	S3	2	16.0	±	0.10	b	788.9		-16.7	
F2	S4	1	2.0	±	0.07	ef				
F2	S4	2	17.8	±	1.20	a	775.4			
F2	S5	1	0.8	±	0.00	f				
F2	S5	2	2.3	±	0.24	e	183.3		-88.2	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F2 protein content 10.9%, 14% moisture basis.

Table 10. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (C) on stability time of hard red winter wheat (F3) [abcde].

							Percentage change (%)			
Flour	Salt	Amount	Stability time (min)				I	II	III	P-value
F3	C	0	13.8	±	0.38	d				<.0001
F3	C	1	14.3	±	0.79	d				
F3	C	2	14.3	±	0.64	cd				
F3	S1	1	16.7	±	0.59	ab		16.8		
F3	S1	2	13.1	±	0.64	d	-21.8			
F3	S2	1	17.3	±	0.81	ab		20.7		
F3	S2	2	13.1	±	0.64	d	-24.3			
F3	S3	1	17.9	±	0.47	a		25.2		
F3	S3	2	16.0	±	1.06	b	-10.6		11.9	
F3	S4	1	18.0	±	0.09	a		26.1		
F3	S4	2	14.2	±	0.25	d	-21.3			
F3	S5	1	18.3	±	0.28	a		27.7		
F3	S5	2	15.9	±	0.82	bc	-12.8			

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F3 protein content 13.4%, 14% moisture basis.

Table 11. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on breakdown time of soft red winter wheat (F1) [abcde].

				Percentage change (%)			
Flour	**Salt**	**Amount**	**Time to breakdown (min)**	**I**	**II**	**III**	**P-value**
F1	C	0	2.9 ± 0.25 d				<.0001
F1	C	1	8.3 ± 0.49 c	190.1			
F1	C	2	8.2 ± 0.70 c				
F1	S1	1	9.7 ± 0.48 b		17.7		
F1	S1	2	12.4 ± 0.48 a	27.1			
F1	S2	1	2.7 ± 0.00 d		-67.3		
F1	S2	2	3.9 ± 0.15 d			-53.0	
F1	S3	1	9.1 ± 0.05 bc				
F1	S3	2	12.7 ± 0.66 a	40.7		55.3	
F1	S4	1	7.9 ± 0.40 c				
F1	S4	2	2.9 ± 0.05 d	-63.9		-65.2	
F1	S5	1	3.4 ± 0.30 d		-58.9		
F1	S5	2	10.2 ± 0.20 b	201.0		24.8	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F1 protein content 9.8%, 14% moisture basis.

Table 12. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on breakdown time of hard red winter wheat (F2) [abcde]

							Percentage change (%)			
Flour	Salt	Amount	Time to breakdown (min)				I	II	III	P-value
F2	C	0	3.4	±	0.07	bc				<.0001
F2	C	1	2.7	±	0.07	de	-18.8			
F2	C	2	3.5	±	0.10	bc	28.1			
F2	S1	1	2.8	±	0.20	de				
F2	S1	2	3.8	±	0.10	ab	37.3			
F2	S2	1	3.7	±	0.30	b		35.4		
F2	S2	2	3.0	±	0.20	cde	-18.9			
F2	S3	1	3.1	±	0.38	cd				
F2	S3	2	4.3	±	0.26	a	40.2		22.9	
F2	S4	1	2.6	±	0.12	de				
F2	S4	2	3.0	±	0.00	cde				
F2	S5	1	2.0	±	0.15	f		-26.8		
F2	S5	2	2.4	±	0.25	ef			-32.9	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F2 protein content 10.9%, 14% moisture basis.

Table 13. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on breakdown time of hard red winter wheat (F3) [abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Time to breakdown (min)**				**I**	**II**	**III**	**P-value**
F3	C	0	17.4	±	0.32	a				0.1666
F3	C	1	17.4	±	0.73	a				
F3	C	2	18.7	±	0.64	a				
F3	S1	1	18.5	±	0.81	a				
F3	S1	2	18.6	±	0.71	a				
F3	S2	1	19.9	±	0.07	a				
F3	S2	2	18.6	±	0.71	a				
F3	S3	1	19.9	±	0.07	a				
F3	S3	2	18.7	±	1.05	a				
F3	S4	1	18.8	±	0.32	a				
F3	S4	2	19.3	±	0.70	a				
F3	S5	1	19.8	±	0.17	a				
F3	S5	2	18.7	±	1.06	a				

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F3 protein content 13.4%, 14% moisture basis.

Table 14. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on maximum resistance to extension (R_{max}) of soft red winter wheat (F1) [abcde]

							Percentage change (%)			
Flour	Salt	Amount	Rmax (mN)				I	II	III	P-value
F1	C	0	172.4	±	7.65	f				<.0001
F1	C	1	228.1	±	5.62	bcd	32.3			
F1	C	2	262.8	±	9.39	a	15.2			
F1	S1	1	171.1	±	3.25	f		-25.0		
F1	S1	2	232.7	±	6.03	bc	36.0		-11.4	
F1	S2	1	177.7	±	3.85	f		-22.1		
F1	S2	2	207.5	±	9.70	de	16.8		-21.0	
F1	S3	1	166.7	±	3.74	f		-26.9		
F1	S3	2	263.7	±	14.71	a	58.1			
F1	S4	1	208.4	±	5.09	cd				
F1	S4	2	251.5	±	13.89	ab	20.7			
F1	S5	1	183.1	±	3.09	ef		-19.7		
F1	S5	2	232.7	±	12.38	bc	27.1		-11.5	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F1 protein content 9.8%, 14% moisture basis.

Table 15. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on maximum resistance to extension (R_{max}) of hard red winter wheat (F2) [abcde]

							Percentage change (%)			
Flour	Salt	Amount	Rmax (mN)				I	II	III	P-value
F2	C	0	204.1	±	1.83	f				<.0001
F2	C	1	240.3	±	11.37	bcd	17.7			
F2	C	2	257.4	±	15.15	ab				
F2	S1	1	243.7	±	1.45	bcd				
F2	S1	2	229.0	±	5.48	cde			-11.0	
F2	S2	1	213.4	±	5.63	ef		-11.2		
F2	S2	2	250.1	±	10.94	bc	17.2			
F2	S3	1	211.9	±	3.22	ef		-11.8		
F2	S3	2	274.1	±	4.86	a	29.4			
F2	S4	1	209.0	±	1.04	ef		-13.1		
F2	S4	2	223.6	±	4.18	def			-13.1	
F2	S5	1	204.7	±	13.55	f		-14.8		
F2	S5	2	241.2	±	5.22	bcd	17.8			

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F2 protein content 10.9%, 14% moisture basis.

Table 16. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on maximum resistance to extension (R_{max}) of hard red winter wheat (F3) [abcde]

							Percentage change (%)			
Flour	Salt	Amount	Rmax (mN)				I	II	III	P-value
F3	C	0	259.9	±	4.68	de				<.0001
F3	C	1	319.8	±	11.47	ab	23.1			
F3	C	2	342.8	±	20.87	a				
F3	S1	1	295.3	±	1.72	bc				
F3	S1	2	275.3	±	3.66	cd			-19.7	
F3	S2	1	251.7	±	6.93	def		-21.3		
F3	S2	2	245.1	±	10.90	ef			-28.5	
F3	S3	1	251.9	±	3.98	def		-21.2		
F3	S3	2	303.6	±	24.44	bc	20.5			
F3	S4	1	235.1	±	4.44	ef		-26.5		
F3	S4	2	228.5	±	1.52	f			-33.3	
F3	S5	1	239.9	±	5.22	ef		-25.0		
F3	S5	2	290.5	±	6.07	bc	21.1			

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F3 protein content 13.4%, 14% moisture basis.

Table 17. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on maximum extensibility (E_{max}) of soft red winter wheat (F1) [abcde]

							Percentage change (%)			
Flour	Salt	Amount	Emax (cm)				I	II	III	P-value
F1	C	0	2.4	±	0.11	d				0.0153
F1	C	1	3.0	±	0.15	abcd				
F1	C	2	3.4	±	0.33	ab				
F1	S1	1	3.6	±	0.41	a				
F1	S1	2	2.9	±	0.12	bcd	-19.2			
F1	S2	1	3.0	±	0.18	abcd				
F1	S2	2	3.3	±	0.34	abc				
F1	S3	1	3.3	±	0.41	abc				
F1	S3	2	2.6	±	0.04	d	-20.8		-22.7	
F1	S4	1	2.6	±	0.03	d				
F1	S4	2	2.5	±	0.19	d			-26.4	
F1	S5	1	2.7	±	0.02	cd				
F1	S5	2	2.9	±	0.10	bcd				

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F1 protein content 9.8%, 14% moisture basis.

Table 18. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on maximum extensibility (E_{max}) of hard red winter wheat (F2)[abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Emax (cm)**				**I**	**II**	**III**	**P-value**
F2	C	0	4.0	±	0.07	ab				<.0001
F2	C	1	3.4	±	0.12	cd	-15.6			
F2	C	2	2.9	±	0.08	e	-13.6			
F2	S1	1	3.5	±	0.07	cd				
F2	S1	2	3.3	±	0.04	de				
F2	S2	1	4.3	±	0.05	a		29.1		
F2	S2	2	3.5	±	0.04	cd	-20.5			
F2	S3	1	3.7	±	0.09	bc				
F2	S3	2	3.2	±	0.06	de	-12.5			
F2	S4	1	4.0	±	0.28	ab		18.4		
F2	S4	2	3.5	±	0.09	cd	-12.1		20.5	
F2	S5	1	4.3	±	0.25	a		28.5		
F2	S5	2	3.2	±	0.11	de	-24.9			

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F2 protein content 10.9%, 14% moisture basis.

Table 19. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on maximum extensibility (E_{max}) of hard red winter wheat (F3)[abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Emax (cm)**				**I**	**II**	**III**	**P-value**
F3	C	0	4.61	±	0.09	f				<.0001
F3	C	1	5.23	±	0.23	e	13.6			
F3	C	2	5.20	±	0.16	e				
F3	S1	1	6.72	±	0.24	a		28.5		
F3	S1	2	6.34	±	0.24	abc			22.0	
F3	S2	1	5.63	±	0.18	de				
F3	S2	2	5.93	±	0.15	cd			14.1	
F3	S3	1	6.38	±	0.06	abc		22.1		
F3	S3	2	5.19	±	0.18	e	-18.8			
F3	S4	1	6.45	±	0.11	ab		23.4		
F3	S4	2	6.17	±	0.08	bc			18.6	
F3	S5	1	6.21	±	0.14	bc		18.7		
F3	S5	2	4.67	±	0.16	f	-24.8		-10.3	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F3 protein content 13.4%, 14% moisture basis.

Table 20. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on area to Rmax of soft red winter wheat (F1) [abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Area to Rmax (mN-cm)**				**I**	**II**	**III**	**P-value**
F1	C	0	344.2	±	15.86	f				<.0001
F1	C	1	543.2	±	48.23	abc	57.8			
F1	C	2	603.2	±	31.95	a				
F1	S1	1	579.7	±	39.51	ab				
F1	S1	2	533.0	±	7.98	abcd				
F1	S2	1	458.9	±	31.62	de		-15.5		
F1	S2	2	483.3	±	14.63	cde			-19.9	
F1	S3	1	533.3	±	26.40	abcd				
F1	S3	2	521.9	±	36.41	bcd			-13.5	
F1	S4	1	427.6	±	14.11	e		-21.3		
F1	S4	2	459.1	±	18.49	de			-23.9	
F1	S5	1	412.3	±	7.21	ef		-24.1		
F1	S5	2	527.1	±	10.45	abcd	27.9			

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F1 protein content 9.8%, 14% moisture basis.

Table 21. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on area to Rmax (mN-cm) of hard red winter wheat (F2) [abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Area to Rmax (mN-cm)**				**I**	**II**	**III**	**P-value**
F2	C	0	203.4	±	5.46	a				0.4076
F2	C	1	191.5	±	15.42	a				
F2	C	2	173.5	±	5.09	a				
F2	S1	1	207.5	±	7.89	a				
F2	S1	2	179.6	±	3.35	a				
F2	S2	1	229.3	±	6.89	a				
F2	S2	2	208.7	±	9.39	a				
F2	S3	1	191.9	±	2.51	a				
F2	S3	2	208.9	±	1.45	a				
F2	S4	1	377.9	±	177.36	a				
F2	S4	2	192.4	±	7.44	a				
F2	S5	1	219.1	±	4.54	a				
F2	S5	2	188.4	±	4.79	a				

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F2 protein content 10.9%, 14% moisture basis.

Table 22. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on area to Rmax of hard red winter wheat (F3) [abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Area to Rmax (mN-cm)**				**I**	**II**	**III**	**P-value**
F3	C	0	295.8	±	9.49	f				<.0001
F3	C	1	1310.7	±	60.14	ab	343.2			
F3	C	2	1402.1	±	47.35	a				
F3	S1	1	470.4	±	6.15	e		-64.1		
F3	S1	2	1393.5	±	63.49	a	196.2			
F3	S2	1	344.5	±	16.35	f		-73.7		
F3	S2	2	1163.1	±	74.78	cd	237.6		-17.0	
F3	S3	1	388.2	±	8.49	ef		-70.4		
F3	S3	2	1246.2	±	50.54	bc	221.1		-11.1	
F3	S4	1	372.9	±	12.50	ef		-71.6		
F3	S4	2	1132.3	±	13.69	cd	203.6		-19.2	
F3	S5	1	1219.1	±	47.16	bc				
F3	S5	2	1077.2	±	32.52	d	-11.6		-23.2	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F3 protein content 13.4%, 14% moisture basis.

Table 23. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on total area of soft red winter wheat (F1) [abcde]

							Percentage change (%)			
Flour	Salt	Amount	Total area (mN-cm)				I	II	III	P-value
F1	C	0	646.6	±	20.70	h				<.0001
F1	C	1	1081.2	±	7.34	abcd	67.2			
F1	C	2	1170.6	±	33.93	a				
F1	S1	1	974.7	±	50.33	efg		-9.8		
F1	S1	2	1141.3	±	28.43	ab	17.1			
F1	S2	1	928.6	±	22.22	fg		-14.1		
F1	S2	2	980.3	±	34.52	efg				
F1	S3	1	899.5	±	46.24	g		-16.8		
F1	S3	2	1168.4	±	28.44	a	29.9			
F1	S4	1	997.2	±	20.84	def				
F1	S4	2	1053.7	±	42.51	bcde			-10.0	
F1	S5	1	1015.6	±	12.13	cdef				
F1	S5	2	1099.3	±	51.04	abc				

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F1 protein content 9.8%, 14% moisture basis.

Table 24. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on total area of hard red winter wheat (F2) [abcde]

							Percentage change (%)			
Flour	Salt	Amount	Total area (mN-cm)				I	II	III	P-value
F2	C	0	296.6	±	17.64	a				0.378
F2	C	1	306.3	±	20.61	a				
F2	C	2	295.2	±	18.64	a				
F2	S1	1	323.9	±	6.08	a				
F2	S1	2	284.1	±	14.93	a				
F2	S2	1	358.9	±	2.03	a				
F2	S2	2	326.2	±	14.91	a				
F2	S3	1	307.9	±	1.49	a				
F2	S3	2	350.7	±	2.19	a				
F2	S4	1	501.4	±	188.34	a				
F2	S4	2	291.1	±	9.20	a				
F2	S5	1	294.0	±	17.75	a				
F2	S5	2	311.1	±	8.90	a				

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F2 protein content 10.9%, 14% moisture basis.

Table 25. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on area of hard red winter wheat (F3) [abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**Total area (mN-cm)**				**I**	**II**	**III**	**P-value**
F3	C	0	430.2	±	16.04	e				<.0001
F3	C	1	1745.0	±	73.95	bcd	305.6			
F3	C	2	2079.6	±	81.93	a	19.2			
F3	S1	1	552.7	±	15.41	e		-68.3		
F3	S1	2	1900.5	±	97.11	abc	243.9			
F3	S2	1	455.5	±	18.78	e		-73.9		
F3	S2	2	1822.2	±	146.37	bc	300.1		-12.4	
F3	S3	1	482.2	±	10.02	e		-72.4		
F3	S3	2	1944.8	±	61.87	ab	303.3			
F3	S4	1	448.5	±	15.35	e		-74.3		
F3	S4	2	1543.3	±	78.93	d	244.1		-25.8	
F3	S5	1	1790.2	±	89.30	bc				
F3	S5	2	1721.2	±	28.65	cd			-17.2	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F3 protein content 13.4%, 14% moisture basis.

Table 26. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on R_{max}/E_{max} of soft red winter wheat (F1) [abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**R_{max}/E_{max} (mN/cm)**				**I**	**II**	**III**	**P-value**
F1	C	0	72.02	±	4.93	bcd				<.0001
F1	C	1	76.78	±	5.53	bc				
F1	C	2	78.98	±	6.98	bc				
F1	S1	1	48.21	±	5.48	f		-37.2		
F1	S1	2	79.23	±	3.05	bc	64.3			
F1	S2	1	59.94	±	2.28	def		-21.9		
F1	S2	2	64.97	±	8.76	cde				
F1	S3	1	52.17	±	6.61	ef		-32.0		
F1	S3	2	100.86	±	4.68	a	93.3		27.7	
F1	S4	1	81.74	±	2.80	b				
F1	S4	2	101.40	±	1.95	a	24.1		28.4	
F1	S5	1	67.77	±	1.62	bcd				
F1	S5	2	80.49	±	5.77	b				

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F1 protein content 9.8%, 14% moisture basis.

Table 27. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on R_{max}/E_{max} of hard red winter wheat (F2) [abcde]

							Percentage change (%)			
Flour	**Salt**	**Amount**	**R_{max}/E_{max}(mN/cm)**				**I**	**II**	**III**	**P-value**
F2	C	0	51.2	±	0.44	e				<.0001
F2	C	1	71.4	±	2.53	bc	39.5			
F2	C	2	88.9	±	7.31	a	24.5			
F2	S1	1	68.7	±	0.94	bc				
F2	S1	2	70.4	±	2.08	bc			-20.9	
F2	S2	1	49.1	±	1.21	e		-31.2		
F2	S2	2	72.4	±	2.94	bc	47.3		-18.6	
F2	S3	1	57.5	±	2.23	de		-19.5		
F2	S3	2	84.9	±	3.04	a	47.7			
F2	S4	1	53.0	±	3.70	e		-25.8		
F2	S4	2	63.9	±	1.60	cd	20.6		-28.1	
F2	S5	1	48.0	±	5.78	e		-32.8		
F2	S5	2	74.6	±	4.16	b	55.4		-16.1	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F2 protein content 10.9%, 14% moisture basis.

Table 28. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on R_{max}/E_{max} of hard red winter wheat (F3) [abcde]

							Percentage change (%)			
Flour	Salt	Amount	Rmax/Emax (mN/cm)				I	II	III	P-value
F3	C	0	56.4	±	0.46	b				<.0001
F3	C	1	61.5	±	4.21	ab				
F3	C	2	66.2	±	5.85	a				
F3	S1	1	44.0	±	1.67	cd		-28.4		
F3	S1	2	43.5	±	1.40	cd			-34.3	
F3	S2	1	44.8	±	1.48	c		-27.2		
F3	S2	2	41.3	±	0.94	cd			-37.7	
F3	S3	1	39.5	±	0.69	cd		-35.8		
F3	S3	2	59.0	±	6.77	ab	49.5			
F3	S4	1	36.4	±	0.23	d		-40.7		
F3	S4	2	37.1	±	0.59	cd			-44.1	
F3	S5	1	38.7	±	1.01	cd		-37.1		
F3	S5	2	62.4	±	2.64	ab	61.4			

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

[b]Percentage change I: Comparison between 1 and 2% level of the same salt.

[c]Percentage change II: Comparison between 1% commercial sodium chloride substitute and 1% NaCl (Control, C).

[d]Percentage change III: Comparison between 2% commercial sodium chloride substitute and 2% NaCl (Control, C).

[e]F3 protein content 13.4%, 14% moisture basis.

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CHAPTER VI

CONCLUSION

The objective of Study I was to analyze the effect of sourdough (0, 11, 17 and 33%), tempe (0, 2, 3.5 and 5%) and NaCl (0, 0.5, 0.75, 1 and 1.5%) at different levels on flavor profile of white bread. In first sensory session bread samples with 0% tempe scored significantly higher (approx. 6) on flavor profile compared to 5% tempe (approx. 4-5) on the 9-point hedonic scale. The effect of sourdough and NaCl on the scores was not significant. In second sensory session it was concluded that 0.75 and 1.5% NaCl received similar scores for saltiness perception which means that the panelists perceived similar and sourdough levels.17 and 33% did not have any significant impact on the saltiness perception. Tempe at 2% decreased the scores of overall palatability significantly. During the final baking session it was concluded that 3.5% tempe resulted in significantly lower scores in all flavor parameters except saltiness with some treatment combinations. Samples with 3.5% scored higher than 0% tempe. In a few combinations, 17% sourdough scored higher than 0 and 33% sourdough. The highest score (6.4) for saltiness parameter was observed in the combination where 17% sourdough, 3.5% and 0.75% NaCl was present. Here, panelists did not detect the 50% reduction in salt from 1.5% to 0.75%.

Study II was aimed at assessing the effect of NaCl, wheat-soybean tempe flour and sourdough on the mixing and extension properties of wheat dough. A trend of an in increase in development time, stability time and breakdown time as observed in most of the treatment combinations. An exceptional result was observed in treatment combinations containing 33% sourdough and 2%

tempe where 2% NaCl resulted in 38% lower stability time than 1.5% NaCl. . It was also observed that the development time of the reference control dough with no fermented products (only 2% NaCl) was 16.8 min which was very high compared to all the treatments with fermented products ranging from 6.1 -12.9 min. NaCl results in delay of hydration and consequently a longer time is required for the dough to develop. Whereas, addition of fermented products like sourdough results in dilution of the gluten structure and therefore, a faster hydration resulting in a lower development time. The effect of tempe on development time was non-significant in all the treatments except the treatments with 33% sourdough and 2% NaCl. Here, 3.5% tempe showed 33% lower development time than 2% tempe. A general trend of a decrease in stability time and breakdown time was observed with an increase in tempe level from 2 to 3.5%. The effect of sourdough revealed that values of development time, stability time and breakdown were inversely proportional to the level of sourdough added. NaCl and tempe did not quite show any pattern of changes in resistance and extensibility with the variation in their levels. However, the effect of sourdough displayed that inclusion of 33% resulted in a significantly higher resistance and R_{max} value than 17% sourdough in all the treatment combinations that contained the fermented products. Whereas, in case of maximum extensibility (E_{max}) increase in sourdough level decreased the E_{max} value. But when compared to the control, it was seen that E_{max}, Area to R_{max} and Total area under the curve of dough with fermented products was very low compared to the dough with just 2% NaCl (no fermented products). This can be concluded that inclusion of sourdough and tempe poses a negative impact on the gluten network as proposed by (Islam et al., 2007).

Study III was done to analyze the effect of salt substitutes on rheological properties of wheat flour. When mixing and micro-extension properties of flours treated with NaCl and commercial sodium chloride (NaCl) substitutes were studied, varieties of conclusions were drawn. Although myriad of results were produced, development time and stability time increased with the increase in the salt content in dough. Finally, time to breakdown did not give any results from which conclusions can be drawn. In case of mixing properties, water absorption did not have any significant variation in in three flours which was unexpected. In Flour F1, a general trend of 2% commercial sodium chloride (NaCl) substitutes was higher development time than 1% salts. In flour F2, 1% commercial NaCl substitute treatments had lower values than 1% C (NaCl). In flour 1, 2% S3 resulted in a remarkably high (488%) higher development time than 2% C. This can be possibly due to the fact that salt S3 is coarser than NaCl. In Flour F1, 1 and 2% NaCl had a significantly higher maximum resistance to extension R_{max} than their respective level of salt substitutes due to the protein crosslinking and therefore having comparatively stronger dough than the ones treated with commercial sodium chloride (NaCl) substitutes. In flour F3, it was observed that 1 and 2% C had a higher total area under the curve than 1 and 2% reduced salts respectively. Analysis of micro-extension of dough tells us that the maximum resistance to extension increased with the increase in salt content. Extensibility resulted in a variety of results in F1, F2 and F3 and therefore a general trend can't be concluded. Finally, when area was analyzed, results portrayed that there was a directly proportional relationship between level of salt and area covered. Also, NaCl resulted in a higher area than commercial sodium chloride (NaCl) substitutes when each level of salt was analyzed

CHAPTER VII

FUTURE STUDIES

1. In Study I, the reduction of 50% salt (1.5% to 0.75% NaCl) was not detected by panelists with the treatment combination of 17% sourdough and 3.5% tempe. But, this treatment led to the reduction other score parameters as well. Future studies can be done with the addition of L-lysine and L-arginine that can be used as a bitterness blocker.
2. In Study II, the effect of fermented products (wheat-soybean tempe flour and sourdough) was studied. Usage of fermented products led to increase in viscosity of dough and decrease in elasticity. Future studies can be performed with the addition of L-ascorbic acid which facilitates the formation of disulfide bonds. Also, transglutaminase can be added to improve the viscoelastic property of flour.
3. A comparative study on mixing and extension properties in Study II can be performed between the effect of chemically acidified dough and sourdough.
4. In Study III, future studies can be done on replacing NaCl with such NaCl substitutes which would provide improved mixing and extension properties

APPENDIX I

Table 1. Parameter abbreviations

Tests	Abbr.	Units	Parameters
Farinograph	WA	%	Water Absorption
	DT	min	Development time
	ST	min	Stability time
	TBD	min	Breakdown time
Extension	Rmax	N	Maximum resistance to extension
	Emax	mm	Extensibility at maximum resistance
	Area to Rmax	N/mm	Work required to extend the dough to Rmax
	Total Area	N/mm	Total work

Table 2. Definiton of farinograph parameters

Parameters	Definition
Water absorption (corrected to 14% moisture)	Absorption is the amount of water required to center the farinograph curve on the 500-Brabender unit (BU) line. This relates to the amount of water needed for a flour to be optimally processed into end products. Absorption is expressed as a percentage.
Development time (min)	Indicates the interval between zero minutes and the peak (maximum height) of the curve ie., shows first signs of weakening.
Stability time (min)	The difference in time, to the nearest half-minute, between the point where the top of the curve first intercepts the 500 B.U. line (arrival time), and the point where the top of the curve leaves the 500 B.U. line (departure time).
Breakwon time (min)	The time to the nearest half-minute form the start of the mixing until there has been a decrease of 30 Brabender Units from the peak point.

APPENDIX II

Sensory ballot sheet used for bread flavor profile evaluation
Date________

Sample number_______ **Age_____** **Gender________-**

Instructions:

1. FOOD ALLERGEN WARNING : contains **SOY**
2. Saltiness perception should be the primary concentration
3. Careful judgement of other parameters
4. Parameters
   - Saltiness perception
   - Sweet
   - Sour
   - Pasteboardy (dry mouth feel)
   - Aroma
   - Bitter
   - Overall palatability

Please make a mark beside the answer best describing your response to the attribute at the top of the column.

Panelist code_______

Responses	**Saltiness**	**Sweetness**	**Sour**	**Pasteboardy (dry mouth feel)**	**Aroma**	**Bitterness**	**Overall palatability**
9 Like extremely							
8 Like very much							
7 Like moderately							
6 Like slightly							
5 Neither like, nor dislike							
4 Dislike slightly							
3 Dislike moderately							
2 Dislike very much							
1 Dislike extremely							

IRB approval

Oklahoma State University Institutional Review Board

Date:	Wednesday, July 03, 2013
IRB Application No	AG1335
Proposal Title:	Natural Replacer of Sodium Chloride in Bread
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 7/2/2016

Principal Investigator(s):

Subhasree Goswami	Rabia Javid	Patricia Rayas Duarte
#23, 716 N Husband	606 E Redbud Dr. T267	107 FAPC
Stillwater, OK 74075	Stillwater, OK 74075	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

X The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI, advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Cordell North (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Shelia M. Kennison

Shelia Kennison, Chair
Institutional Review Board

PARTICIPANT INFORMATION
OKLAHOMA STATE UNIVERSITY

Title: (Natural replacer of Salt in bread)

Investigator(s): Rabia Javid, Subhasree Goswami affiliated with OSU)

Purpose: The main purpose of this study is to reduce the sodium content in bread and therefore to find natural replacer of salt with the help of sourdough and Soy protein, which are considered GRAS (Generally Recognized As Safe). Since sodium is considered being responsible for the high blood pressure which leads to heart diseases, we are striving hard to fight out this serious problem. We are trying to come up with the suitable combination of sourdough and Soy proteins incorporated in wheat flour which would result in desired palatability in bread. The human subjects would help us to detect the optimum saltiness perception with different levels of salt (which involves no hazard). Subjects would help us to simulate a consumer point of view regarding the aroma, saltiness perception and overall palatability.

What to Expect: Participation in this research will involve completion of one questionnaire for each bread sample they will be provided with. There will be around maximum of 12 samples in each session along with the questionnaire. All the questions will be expected to complete at once and each session would take around 15 minutes. Each sensory panel consists of two sub sessions; each session will take 15 minutes, total of 30 minutes per sensory session.

Risks: Please be advised that Soy and gluten will be a part of the product so anybody allergic to these should refrain from participating.

Benefits: Reduction of Sodium chloride (salt) in bread will reduce the daily consumption of sodium, which is one of the main reasons of hypertension and heart diseases.

Compensation: A gift bag with some useful stuff (pens, flash drives, aprons, key rings and some candies) for all the subjects will be provided at the end of 7 sessions (each has 2 sub-session) of sensory panel. It will take approximately 3 hours for 7 sessions to be completed.

Your Rights: Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time, without penalty.

Confidentiality: All information about you will be kept confidential and will not be released. Only age and gender will be revealed (no names will be recorded or asked). In the beginning of each session of sensory panel, all subjects will be asked to read the sensory instrument given. Instructions will be provided. Each sensory panel (two sessions) will be reported as a group, there will be subgroups according to the treatment.

Contacts: You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:

Rabia Javid (M.S)
Ph: 712-574-2411
Address: 606 E Redbud Drive T267, Stillwater, OK.74075
Department: FAPC

Subhasree Goswami (M.S)
Ph: 405-612-6696
Address: #23 716 North Husband, Stillwater, OK.74075
Department: FAPC

Dr. Patricia Rayas_-Duarte, Ph.D .
Ph: 405-744-6468
Address: Room 123 FAPC, OSU.74078
Department: FAPC

"If you have questions about your rights as a research volunteer, you may contact"

Shelia Kennison , Ph.D.,IRB Chair,
219 Cordell North,
Stillwater, OK 74078
405-744-3377
irb@okstate.edu

Okla. State Univ.
IRB
Approved 7-3-13
Expires 7-2-16
IRB# AG-13-35

APPENDIX III

Table 1. Effect of NaCl (0.5, 1.0 and 1.5%) on saltiness score of white bread at different levels of sourdough (11, 17 and 33%) and tempe (0 and 5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Salty	P-value
11	0	0.5	6.2 ± 0.27	0.9745
11	0	1.0	6.1 ± 0.27	
11	0	1.5	6.1 ± 0.21	
11	5	0.5	4.8 ± 0.23	0.3549
11	5	1.0	4.7 ± 0.30	
11	5	1.5	5.3 ± 0.32	
17	0	0.5	6.1 ± 0.31	0.5856
17	0	1.0	6.4 ± 0.34	
17	0	1.5	6.6 ± 0.38	
17	5	0.5	4.9 ± 0.28	0.2949
17	5	1.0	5.1 ± 0.25	
17	5	1.5	4.5 ± 0.38	
33	0	0.5	6.3 ± 0.32	0.3435
33	0	1.0	6.8 ± 0.33	
33	0	1.5	6.9 ± 0.29	
33	5	0.5	4.8 ± 0.50	0.2871
33	5	1.0	5.4 ± 0.43	
33	5	1.5	5.5 ± 0.40	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 2. Effect of sourdough (11, 17 and 33%) on saltiness score of white bread at different levels of tempe (0 and 5%) and NaCl (0.5, 1.0 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Salty				P-value
0	0.5	11	6.2	±	0.3		0.9732
0	0.5	17	6.1	±	0.3		
0	0.5	33	6.3	±	0.3		
0	1.0	11	6.1	±	0.3		0.3472
0	1.0	17	6.4	±	0.3		
0	1.0	33	6.8	±	0.3		
0	1.5	11	6.1	±	0.2		0.2308
0	1.5	17	6.6	±	0.4		
0	1.5	33	6.9	±	0.3		
5	0.5	11	4.8	±	0.2		0.9574
5	0.5	17	4.9	±	0.3		
5	0.5	33	4.8	±	0.5		
5	1.0	11	4.7	±	0.3		0.3028
5	1.0	17	5.1	±	0.3		
5	1.0	33	5.4	±	0.4		
5	1.5	11	5.3	±	0.3	ab	0.0461
5	1.5	17	4.5	±	0.4	b	
5	1.5	33	5.5	±	0.4	a	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 3. Effect of NaCl (0.5, 1.0 and 1.5%) on bitterness score of white bread at different levels of sourdough (11, 17 and 33%) and tempe (0 and 5%).

Sourdough (%)	**Tempe (%)**	**NaCl (%)**	**Bitter**			**P-value**
11	0	0.5	5.7	±	0.26	0.8900
11	0	1.0	5.9	±	0.26	
11	0	1.5	5.8	±	0.26	
11	5	0.5	3.8	±	0.28	0.1638
11	5	1.0	3.9	±	0.29	
11	5	1.5	4.5	±	0.31	
17	0	0.5	6.0	±	0.29	0.9748
17	0	1.0	6.1	±	0.34	
17	0	1.5	6.1	±	0.37	
17	5	0.5	4.1	±	0.25	0.8342
17	5	1.0	3.9	±	0.27	
17	5	1.5	3.8	±	0.32	
33	0	0.5	6.1	±	0.32	0.8628
33	0	1.0	6.1	±	0.31	
33	0	1.5	5.9	±	0.29	
33	5	0.5	3.8	±	0.43	0.4968
33	5	1.0	4.3	±	0.45	
33	5	1.5	3.9	±	0.42	

[a]Mean (n=3) ± standard error.

Table 4. Effect of sourdough (11, 17 and 33%) on bitterness score of white bread at different levels of tempe (0 and 5%) and NaCl (0.5, 1.0 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Bitter			P-value
0	0.5	11	5.7	±	0.26	0.6022
0	0.5	17	6.0	±	0.29	
0	0.5	33	6.1	±	0.32	
0	1.0	11	5.9	±	0.26	0.8841
0	1.0	17	6.1	±	0.34	
0	1.0	33	6.1	±	0.31	
0	1.5	11	5.8	±	0.26	0.7108
0	1.5	17	6.1	±	0.37	
0	1.5	33	5.9	±	0.29	
5	0.5	11	3.8	±	0.28	0.7526
5	0.5	17	4.1	±	0.25	
5	0.5	33	3.8	±	0.43	
5	1.0	11	3.9	±	0.29	0.5182
5	1.0	17	3.9	±	0.27	
5	1.0	33	4.3	±	0.45	
5	1.5	11	4.5	±	0.31	0.1994
5	1.5	17	3.8	±	0.32	
5	1.5	33	3.9	±	0.42	

[a]Mean (n=3) ± standard error.

Table 5. Effect of NaCl (0.5, 1.0 and 1.5%) on sourness score of white bread at different levels of sourdough (11, 17 and 33%) and tempe (0 and 5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Sour			P-value
11	0	0.5	5.7	±	0.23	0.9920
11	0	1.0	5.6	±	0.27	
11	0	1.5	5.7	±	0.21	
11	5	0.5	3.8	±	0.24	0.3951
11	5	1.0	4.4	±	0.32	
11	5	1.5	4.2	±	0.34	
17	0	0.5	5.9	±	0.31	0.4828
17	0	1.0	6.0	±	0.34	
17	0	1.5	6.4	±	0.40	
17	5	0.5	4.2	±	0.33	0.9449
17	5	1.0	4.3	±	0.28	
17	5	1.5	4.2	±	0.30	
33	0	0.5	6.0	±	0.34	0.5875
33	0	1.0	6.2	±	0.33	
33	0	1.5	6.4	±	0.25	
33	5	0.5	4.4	±	0.36	0.6232
33	5	1.0	4.7	±	0.45	
33	5	1.5	4.9	±	0.42	

[a]Mean (n=3) ± standard error.

Table 6. Effect of tempe (0 and 5%) on sourness score of white bread at different levels of sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Sour**			**P-value**
11	0.5	0	5.7	±	0.23	<0.0001
11	0.5	5	3.8	±	0.24	
11	1.0	0	5.6	±	0.27	0.0037
11	1.0	5	4.4	±	0.32	
11	1.5	0	5.7	±	0.21	0.0010
11	1.5	5	4.2	±	0.34	
17	0.5	0	5.9	±	0.31	0.0003
17	0.5	5	4.2	±	0.33	
17	1.0	0	6.0	±	0.34	0.0005
17	1.0	5	4.3	±	0.28	
17	1.5	0	6.4	±	0.4	<0.0001
17	1.5	5	4.2	±	0.3	
33	0.5	0	6.0	±	0.34	0.0017
33	0.5	5	4.4	±	0.36	
33	1.0	0	6.2	±	0.33	0.0013
33	1.0	5	4.7	±	0.45	
33	1.5	0	6.4	±	0.25	0.0016
33	1.5	5	4.9	±	0.42	

[a]Mean (n=3) ± standard error.

Table 7. Effect of sourdough (11, 17 and 33%) on sourness score of white bread at different levels of tempe (0 and 5%) and NaCl (0.5, 1.0 and 1.5%).

Tempe (%)	**NaCl (%)**	**Sourdough (%)**	**Sour**			**P-value**
0	0.5	11	5.7	±	0.23	0.8302
0	0.5	17	5.9	±	0.31	
0	0.5	33	6.0	±	0.34	
0	1.0	11	5.6	±	0.27	0.4474
0	1.0	17	6.0	±	0.34	
0	1.0	33	6.2	±	0.33	
0	1.5	11	5.7	±	0.21	0.1426
0	1.5	17	6.4	±	0.4	
0	1.5	33	6.4	±	0.25	
5	0.5	11	3.8	±	0.24	0.3905
5	0.5	17	4.2	±	0.33	
5	0.5	33	4.4	±	0.36	
5	1.0	11	4.4	±	0.32	0.6903
5	1.0	17	4.3	±	0.28	
5	1.0	33	4.6	±	0.44	
5	1.5	11	4.2	±	0.34	0.2165
5	1.5	17	4.1	±	0.29	
5	1.5	33	4.9	±	0.42	

[a]Mean (n=3) ± standard error.

Table 8. Effect of NaCl (0.5, 1.0 and 1.5%) on sweetness score of white bread at different levels of sourdough (11, 17 and 33%) and tempe (0 and 5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Sweet			P-value
11	0	0.5	6.1	±	0.19	0.5135
11	0	1.0	6.0	±	0.27	
11	0	1.5	5.7	±	0.24	
11	5	0.5	4.6	±	0.22	0.4263
11	5	1.0	4.3	±	0.27	
11	5	1.5	4.8	±	0.31	
17	0	0.5	6.1	±	0.30	0.7056
17	0	1.0	6.0	±	0.30	
17	0	1.5	6.3	±	0.33	
17	5	0.5	4.5	±	0.26	0.6653
17	5	1.0	4.7	±	0.21	
17	5	1.5	4.4	±	0.28	
33	0	0.5	5.8	±	0.32	0.0951
33	0	1.0	6.6	±	0.32	
33	0	1.5	6.4	±	0.22	
33	5	0.5	5.0	±	0.38	0.6050
33	5	1.0	4.9	±	0.41	
33	5	1.5	5.3	±	0.37	

[a]Mean (n=3) ± standard error.

Table 9. Effect of tempe (0 and 5%) on sweetness score of white bread at different levels of sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Sweet			P-value
11	0.5	0	6.1	±	0.19	0.0001
11	0.5	5	4.6	±	0.22	
11	1.0	0	6.0	±	0.27	<0.0001
11	1.0	5	4.3	±	0.27	
11	1.5	0	5.7	±	0.24	0.0257
11	1.5	5	4.8	±	0.31	
17	0.5	0	6.1	±	0.3	<0.0001
17	0.5	5	4.5	±	0.26	
17	1.0	0	6.0	±	0.3	0.0023
17	1.0	5	4.7	±	0.21	
17	1.5	0	6.3	±	0.33	<0.0001
17	1.5	5	4.4	±	0.28	
33	0.5	0	5.8	±	0.32	0.1092
33	0.5	5	5.0	±	0.38	
33	1.0	0	6.6	±	0.32	<0.0001
33	1.0	5	4.9	±	0.41	
33	1.5	0	6.4	±	0.22	0.0099
33	1.5	5	5.3	±	0.37	

[a]Mean (n=3) ± standard error.

Table 10. Effect of sourdough (11, 17 and 33%) on sweetness score of white bread at different levels of tempe (0 and 5%) and NaCl (0.5, 1.0 and 1.5%).

Tempe (%)	**NaCl (%)**	**Sourdough (%)**	**Sweet**			**P-value**
0	0.5	11	5.8	±	0.32	0.6452
0	0.5	17	6.1	±	0.3	
0	0.5	33	6.1	±	0.19	
0	1.0	11	6.0	±	0.27	0.2663
0	1.0	17	6.0	±	0.3	
0	1.0	33	6.6	±	0.32	
0	1.5	11	5.7	±	0.24	0.1029
0	1.5	17	6.3	±	0.33	
0	1.5	33	6.4	±	0.22	
5	0.5	11	4.6	±	0.22	0.3718
5	0.5	17	4.5	±	0.26	
5	0.5	33	5	±	0.38	
5	1.0	11	4.3	±	0.27	0.3114
5	1.0	17	4.7	±	0.21	
5	1.0	33	4.9	±	0.41	
5	1.5	11	4.8	±	0.31	0.0711
5	1.5	17	4.4	±	0.28	
5	1.5	33	5.3	±	0.37	

[a]Mean (n=3) ± standard error.

Table 11. Effect of NaCl (0.5, 1.0 and 1.5%) on pasteboardiness score of white bread at different levels of sourdough (11, 17 and 33%) and tempe (0 and 5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Pasteboardy			P-value
11	0	0.5	6.1	±	0.24	0.1223
11	0	1.0	6.5	±	0.33	
11	0	1.5	5.6	±	0.25	
11	5	0.5	4.1	±	0.28	0.9759
11	5	1.0	4.2	±	0.29	
11	5	1.5	4.1	±	0.37	
17	0	0.5	5.8	±	0.35	0.9664
17	0	1.0	5.8	±	0.38	
17	0	1.5	5.9	±	0.44	
17	5	0.5	4.0	±	0.31	0.6432
17	5	1.0	4.4	±	0.23	
17	5	1.5	4.4	±	0.27	
33	0	0.5	5.6	±	0.35	0.6472
33	0	1.0	6.0	±	0.34	
33	0	1.5	5.9	±	0.34	
33	5	0.5	3.9	±	0.38	0.3181
33	5	1.0	4.2	±	0.38	
33	5	1.5	4.7	±	0.40	

[a]Mean (n=3) ± standard error.

Table 12. Effect of tempe (0 and 5%) on pasteboardiness score of white bread at different levels of sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Pasteboardy			P-value
11	0.5	0	6.1	±	0.24	<0.0001
11	0.5	5	4.1	±	0.28	
11	1.0	0	6.5	±	0.33	<0.0001
11	1.0	5	4.2	±	0.29	
11	1.5	0	5.6	±	0.25	0.0006
11	1.5	5	4.1	±	0.37	
17	0.5	0	5.8	±	0.35	0.0002
17	0.5	5	4.0	±	0.31	
17	1.0	0	5.8	±	0.38	0.0053
17	1.0	5	4.4	±	0.23	
17	1.5	0	5.9	±	0.44	0.0010
17	1.5	5	4.4	±	0.27	
33	0.5	0	5.6	±	0.35	0.0010
33	0.5	5	3.9	±	0.38	
33	1.0	0	6.0	±	0.34	0.0002
33	1.0	5	4.2	±	0.38	
33	1.5	0	5.9	±	0.34	0.0148
33	1.5	5	4.7	±	0.40	

[a]Mean (n=3) ± standard error.

Table 13. Effect of sourdough (11, 17 and 33%) on pasteboardiness score of white bread at different levels of tempe (0 and 5%) and NaCl (0.5, 1.0 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Pasteboardy			P-value
0	0.5	11	6.1	±	0.24	0.5529
0	0.5	17	5.8	±	0.35	
0	0.5	33	5.6	±	0.35	
0	1.0	11	6.5	±	0.33	0.2628
0	1.0	17	5.8	±	0.38	
0	1.0	33	6.0	±	0.34	
0	1.5	11	5.6	±	0.25	0.7748
0	1.5	17	5.9	±	0.44	
0	1.5	33	5.9	±	0.34	
5	0.5	11	4.1	±	0.28	0.9096
5	0.5	17	4.0	±	0.31	
5	0.5	33	3.9	±	0.38	
5	1.0	11	4.2	±	0.29	0.8213
5	1.0	17	4.4	±	0.23	
5	1.0	33	4.2	±	0.38	
5	1.5	11	4.1	±	0.37	0.4222
5	1.5	17	4.4	±	0.27	

[a]Mean (n=3) ± standard error

Table 14. Effect of NaCl (0.5, 1.0 and 1.5%) on aroma score of white bread at different levels of sourdough (11, 17 and 33%) and tempe (0 and 5%).

Sourdough (%)	**Tempe (%)**	**NaCl (%)**	**Aroma**			**P-value**
11	0	0.5	7.0	±	0.22	0.1981
11	0	1.0	6.5	±	0.24	
11	0	1.5	6.2	±	0.22	
11	5	0.5	4.5	±	0.30	0.2511
11	5	1.0	5.2	±	0.33	
11	5	1.5	5.1	±	0.31	
17	0	0.5	6.3	±	0.29	0.7969
17	0	1.0	6.3	±	0.35	
17	0	1.5	6.6	±	0.37	
17	5	0.5	5.0	±	0.28	0.8658
17	5	1.0	4.8	±	0.31	
17	5	1.5	4.8	±	0.33	
33	0	0.5	6.3	±	0.32	0.8011
33	0	1.0	6.6	±	0.30	
33	0	1.5	6.5	±	0.25	
33	5	0.5	5.2	±	0.38	0.9512
33	5	1.0	5.3	±	0.46	
33	5	1.5	5.1	±	0.43	

[a]Mean (n=3) ± standard error.

Table 15. Effect of tempe (0 and 5%) on aroma score of white bread at different levels of sourdough (11, 17 and 33%) and NaCl (0.5, 1.0 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Aroma**			**P-value**
11	0.5	0	7.0	±	0.22	<0.0001
11	0.5	5	4.5	±	0.30	
11	1.0	0	6.5	±	0.24	0.0027
11	1.0	5	5.2	±	0.33	
11	1.5	0	6.2	±	0.22	0.0079
11	1.5	5	5.1	±	0.31	
17	0.5	0	6.3	±	0.29	0.0029
17	0.5	5	5.0	±	0.28	
17	1.0	0	6.3	±	0.35	0.0008
17	1.0	5	4.8	±	0.31	
17	1.5	0	6.6	±	0.37	<0.0001
17	1.5	5	4.8	±	0.33	
33	0.5	0	6.3	±	0.32	0.0264
33	0.5	5	5.2	±	0.38	
33	1.0	0	6.6	±	0.30	0.0052
33	1.0	5	5.3	±	0.46	
33	1.5	0	6.5	±	0.25	0.0033
33	1.5	5	5.1	±	0.43	

[a]Mean (n=3) ± standard error.

Table 16. Effect of sourdough (11, 17 and 33%) on aroma score of white bread at different levels of tempe (0 and 5%) and NaCl (0.5, 1.0 and 1.5%).

Tempe (%)	**NaCl (%)**	**Sourdough (%)**	**Aroma**	**P-value**
0	0.5	11	7.0 ± 0.22	0.2055
0	0.5	17	6.3 ± 0.29	
0	0.5	33	6.3 ± 0.32	
0	1.0	11	6.5 ± 0.24	0.8635
0	1.0	17	6.3 ± 0.35	
0	1.0	33	6.6 ± 0.30	
0	1.5	11	6.2 ± 0.22	0.6682
0	1.5	17	6.6 ± 0.37	
0	1.5	33	6.5 ± 0.25	
5	0.5	11	4.5 ± 0.30	0.3026
5	0.5	17	5.0 ± 0.28	
5	0.5	33	5.2 ± 0.38	
5	1.0	11	5.2 ± 0.33	0.4874
5	1.0	17	4.8 ± 0.31	
5	1.0	33	5.3 ± 0.46	
5	1.5	11	5.1 ± 0.31	0.7889
5	1.5	17	4.8 ± 0.33	
5	1.5	33	5.1 ± 0.43	

[a]Mean (n=3) ± standard error.

Table 17. Effect of NaCl (0.5, 1.0 and 1.5%) on palatability score of white bread at different levels of sourdough (11, 17 and 33%) and tempe (0 and 5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Palatability			P-value
8	0	0.5	6.2	±	0.23	0.6806
8	0	1.0	6.4	±	0.29	
8	0	1.5	6.0	±	0.21	
8	5	0.5	4.0	±	0.27	0.4677
8	5	1.0	4.5	±	0.32	
8	5	1.5	4.4	±	0.36	
5	0	0.5	6.4	±	0.28	0.5841
5	0	1.0	6.5	±	0.36	
5	0	1.5	6.8	±	0.30	
5	5	0.5	4.4	±	0.29	0.8325
5	5	1.0	4.2	±	0.26	
5	5	1.5	4.3	±	0.30	
2	0	0.5	6.4	±	0.28	0.7699
2	0	1.0	6.6	±	0.27	
2	0	1.5	6.7	±	0.24	
2	5	0.5	4.2	±	0.34	0.4779
2	5	1.0	4.7	±	0.43	
2	5	1.5	4.2	±	0.37	

[a]Mean (n=3) ± standard error.

Table 18. Effect of sourdough (11, 17 and 33%) on palatability score of white bread at different levels of tempe (0 and 5%) and NaCl (0.5, 1.0 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Palatability			P-value
0	0.5	11	6.2	±	0.23	0.8210
0	0.5	17	6.4	±	0.28	
0	0.5	33	6.4	±	0.28	
0	1.0	11	6.4	±	0.29	0.8749
0	1.0	17	6.5	±	0.36	
0	1.0	33	6.6	±	0.27	
0	1.5	11	6.0	±	0.21	0.1380
0	1.5	17	6.8	±	0.30	
0	1.5	33	6.7	±	0.24	
5	0.5	11	4.0	±	0.27	0.5643
5	0.5	17	4.4	±	0.29	
5	0.5	33	4.2	±	0.34	
5	1.0	11	4.5	±	0.32	0.5139
5	1.0	17	4.2	±	0.26	
5	1.0	33	4.7	±	0.43	
5	1.5	11	4.4	±	0.36	0.8998
5	1.5	17	4.3	±	0.30	
5	1.5	33	4.2	±	0.37	

[a]Mean (n=3) ± standard error.

Table 19. Effect of NaCl (0.0, 0.75 and 1.5%) on sourness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 2%).

Sourdough (%)	Tempe (%)	NaCl (%)	Sour				P-value
0	0	0.0	4.6	±	0.25	b	0.0371
0	0	0.75	5.1	±	0.24	ab	
0	0	1.5	5.6	±	0.27	a	
0	2	0.0	4.1	±	0.3	b	0.0011
0	2	0.75	4.9	±	0.35	a	
0	2	1.5	5.6	±	0.27	a	
17	0	0.0	4.2	±	0.28	b	0.0025
17	0	0.75	5.4	±	0.21	a	
17	0	1.5	5.4	±	0.26	a	
17	2	0.0	3.6	±	0.29	b	0.0073
17	2	0.75	4.7	±	0.26	a	
17	2	1.5	4.7	±	0.31	a	
33	0	0.0	4.4	±	0.26		0.0685
33	0	0.75	4.8	±	0.27		
33	0	1.5	5.3	±	0.31		
33	2	0.0	3.2	±	0.30	b	<0.0001
33	2	0.75	4.7	±	0.31	a	
33	2	1.5	5.0	±	0.31	a	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 20. Effect of tempe (0 and 2%) on sourness score of white bread at different levels of sourdough (0, 17 and 33%) and NaCl (0.0, 0.75 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Sour	P-value
0	0.0	0	4.6 ± 0.25	0.2340
0	0.0	2	4.1 ± 0.30	
0	0.75	0	5.1 ± 0.24	0.6127
0	0.75	2	4.9 ± 0.35	
0	1.5	0	5.6 ± 0.27	0.9500
0	1.5	2	5.6 ± 0.27	
17	0.0	0	4.2 ± 0.28	0.1175
17	0.0	2	3.6 ± 0.29	
17	0.75	0	5.4 ± 0.21	0.0604
17	0.75	2	4.7 ± 0.26	
17	1.5	0	5.4 ± 0.26	0.0695
17	1.5	2	4.7 ± 0.31	
33	0.0	0	4.4 ± 0.26	0.0040
33	0.0	2	3.2 ± 0.30	
33	0.75	0	4.8 ± 0.27	0.7540
33	0.75	2	4.7 ± 0.31	
33	1.5	0	5.3 ± 0.31	0.4153
33	1.5	2	5.0 ± 0.31	

[a]Mean (n=3) ± standard error.

Table 21. Effect of sourdough (0, 17 and 33%) on sourness score of white bread at different levels of tempe (0 and 2%) and NaCl (0.0, 0.75 and 1.5%).

Tempe (%)	**NaCl (%)**	**Sourdough (%)**	**Sour**			**P-value**
0	0.0	0	4.6	±	0.25	0.6787
0	0.0	17	4.2	±	0.28	
0	0.0	33	4.4	±	0.26	
0	0.75	0	5.1	±	0.24	0.3229
0	0.75	17	5.4	±	0.21	
0	0.75	33	4.8	±	0.27	
0	1.5	0	5.6	±	0.27	0.7516
0	1.5	17	5.4	±	0.26	
0	1.5	33	5.3	±	0.31	
2	0.0	0	4.1	±	0.30	0.0893
2	0.0	17	3.6	±	0.29	
2	0.0	33	3.2	±	0.30	
2	0.75	0	4.9	±	0.35	0.7879
2	0.75	33	4.7	±	0.31	
2	0.75	17	4.7	±	0.26	
2	1.5	0	5.6	±	0.27	0.0813
0	1.5	17	4.7	±	0.31	
2	1.5	33	5.0	±	0.31	

[a]Mean (n=3) ± standard error.

Table 22. Effect of NaCl (0.0, 0.75 and 1.5%) on sweetness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 2%).

Sourdough (%)	**Tempe (%)**	**NaCl (%)**	**Sweet**				**P-value**
0	0	0.0	4.8	±	0.24	b	0.0132
0	0	0.75	5.7	±	0.27	a	
0	0	1.5	5.9	±	0.32	a	
0	2	0.0	4.0	±	0.25	b	0.0054
0	2	0.75	5.0	±	0.30	a	
0	2	1.5	5.3	±	0.25	a	
17	0	0.0	4.4	±	0.26	b	0.0112
17	0	0.75	5.5	±	0.26	a	
17	0	1.5	5.4	±	0.32	a	
17	2	0.0	3.8	±	0.30	b	0.0284
17	2	0.75	4.8	±	0.26	a	
17	2	1.5	4.5	±	0.29	ab	
33	0	0.0	4.6	±	0.30		0.2557
33	0	0.75	5.0	±	0.26		
33	0	1.5	5.2	±	0.28		
33	2	0.0	3.7	±	0.27	b	0.0066
33	2	0.75	4.6	±	0.30	a	
33	2	1.5	4.9	±	0.30	a	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 23. Effect of tempe (0 and 2%) on sweetness score of white bread at different levels of sourdough (0, 17 and 33%) and NaCl (0.0, 0.75 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Sweet			P-value
0	0.0	0	4.8	±	0.24	0.0591
0	0.0	2	4.0	±	0.25	
0	0.75	0	5.7	±	0.27	0.0631
0	0.75	2	5.0	±	0.30	
0	1.5	0	5.9	±	0.32	0.1308
0	1.5	2	5.3	±	0.25	
17	0.0	0	4.4	±	0.26	0.1017
17	0.0	2	3.8	±	0.30	
17	0.75	0	5.5	±	0.26	0.068
17	0.75	2	4.8	±	0.26	
17	1.5	0	5.4	±	0.32	0.0325
17	1.5	2	4.5	±	0.29	
33	0.0	0	4.6	±	0.30	0.0325
33	0.0	2	3.7	±	0.27	
33	0.75	0	5.0	±	0.26	0.3448
33	0.75	2	4.6	±	0.30	
33	1.5	0	5.2	±	0.28	0.4883
33	1.5	2	4.9	±	0.30	

[a]Mean (n=3) ± standard error.

Table 24. Effect of sourdough (0, 17 and 33%) on sweetness score of white bread at different levels of tempe (0 and 2%) and NaCl (0.0, 0.75 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Sweet			P-value
0	0.0	0	4.8	±	0.24	0.6360
0	0.0	17	4.4	±	0.26	
0	0.0	33	4.6	±	0.30	
0	0.75	0	5.7	±	0.27	0.1397
0	0.75	17	5.5	±	0.26	
0	0.75	33	5.0	±	0.26	
0	1.5	0	5.9	±	0.32	0.2301
0	1.5	17	5.4	±	0.32	
0	1.5	33	5.2	±	0.28	
2	0.0	0	4.0	±	0.25	0.6777
2	0.0	17	3.8	±	0.30	
2	0.0	33	3.7	±	0.27	
2	0.75	0	5.0	±	0.30	0.6016
2	0.75	17	4.8	±	0.26	
2	0.75	33	4.6	±	0.30	
2	1.5	0	5.3	±	0.25	0.1664
2	1.5	17	4.5	±	0.29	
2	1.5	33	4.9	±	0.30	

[a]Mean (n=3) ± standard error.

Table 25. Effect of NaCl (0.0, 0.75 and 1.5%) on pasteboardiness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 2%).

Sourdough (%)	**Tempe (%)**	**NaCl (%)**	**Pasteboardy**				**P-value**
0	0	0.0	4.4	±	0.29	b	0.0373
0	0	0.75	4.9	±	0.32	ab	
0	0	1.5	5.6	±	0.34	a	
0	2	0.0	3.5	±	0.34	b	0.0029
0	2	0.75	4.8	±	0.35	a	
0	2	1.5	4.9	±	0.35	a	
17	0	0.0	3.6	±	0.29		0.0526
17	0	0.75	4.5	±	0.34		
17	0	1.5	4.7	±	0.32		
17	2	0.0	3.4	±	0.36		0.0637
17	2	0.75	4.3	±	0.29		
17	2	1.5	4.4	±	0.33		
33	0	0.0	3.7	±	0.30	b	0.0055
33	0	0.75	4.0	±	0.31	b	
33	0	1.5	5.1	±	0.34	a	
33	2	0.0	3.8	±	0.38		0.1360
33	2	0.75	4.4	±	0.35		
33	2	1.5	4.8	±	0.33		

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 26. Effect of tempe (0 and 2%) on pasteboardiness score of white bread at different levels of sourdough (0, 17 and 33%) and NaCl (0.0, 0.75 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Pasteboardy**			**P-value**
0	0.0	0	4.3	±	0.28	0.0614
0	0.0	2	3.4	±	0.33	
0	0.75	0	4.9	±	0.31	0.8347
0	0.75	2	4.8	±	0.34	
0	1.5	0	5.5	±	0.33	0.1644
0	1.5	2	4.9	±	0.35	
17	0.0	0	3.6	±	0.29	0.5926
17	0.0	2	3.3	±	0.35	
17	0.75	0	4.5	±	0.33	0.6301
17	0.75	2	4.3	±	0.28	
17	1.5	0	4.6	±	0.32	0.4867
17	1.5	2	4.3	±	0.32	
33	0.0	0	3.6	±	0.30	0.7481
33	0.0	2	3.8	±	0.38	
33	0.75	0	3.9	±	0.31	0.3356
33	0.75	2	4.4	±	0.34	
33	1.5	0	5.1	±	0.34	0.4538
33	1.5	2	4.7	±	0.33	

[a]Mean (n=3) ± standard error.

Table 27. Effect of sourdough (0, 17 and 33%) on pasteboardiness score of white bread at different levels of tempe (0 and 2%) and NaCl (0.0, 0.75 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Pasteboardy			P-value
0	0.0	0	4.3	±	0.28	0.2230
0	0.0	17	3.6	±	0.29	
0	0.0	33	3.6	±	0.30	
0	0.75	0	4.9	±	0.31	0.1148
0	0.75	17	4.5	±	0.33	
0	0.75	33	3.9	±	0.31	
0	1.5	0	5.5	±	0.33	0.1735
0	1.5	17	4.6	±	0.32	
0	1.5	33	5.1	±	0.34	
2	0.0	0	3.4	±	0.33	0.5995
2	0.0	17	3.3	±	0.35	
2	0.0	33	3.8	±	0.38	
2	0.75	0	4.8	±	0.34	0.4907
2	0.75	17	4.3	±	0.28	
2	0.75	33	4.4	±	0.34	
2	1.5	0	4.9	±	0.35	0.4768
2	1.5	17	4.3	±	0.32	
2	1.5	33	4.7	±	0.33	

[a]Mean (n=3) ± standard error.

Table 28. Effect of NaCl (0.0, 0.75 and 1.5%) on aroma score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 2%).

Sourdough (%)	Tempe (%)	NaCl (%)	Aroma	P-value
0	0	0.0	5.7 ± 0.32	0.5454
0	0	0.75	6.1 ± 0.30	
0	0	1.5	6.2 ± 0.21	
0	2	0.0	5.0 ± 0.36	0.3371
0	2	0.75	5.0 ± 0.25	
0	2	1.5	5.5 ± 0.27	
17	0	0.0	5.8 ± 0.24	0.832
17	0	0.75	6.0 ± 0.30	
17	0	1.5	5.7 ± 0.24	
17	2	0.0	5.1 ± 0.31	0.3514
17	2	0.75	5.6 ± 0.27	
17	2	1.5	5.0 ± 0.32	
33	0	0.0	5.2 ± 0.32	0.2765
33	0	0.75	5.8 ± 0.30	
33	0	1.5	5.7 ± 0.28	
33	2	0.0	4.5 ± 0.35	0.2738
33	2	0.75	5.0 ± 0.29	
33	2	1.5	5.0 ± 0.28	

[a]Mean (n=3) ± standard error.

Table 29. Effect of tempe (0 and 2%) on aroma score of white bread at different levels of sourdough (0, 17 and 33%) and NaCl (0.0, 0.75 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Aroma**	**P-value**
0	0.0	0	5.7 ± 0.32	0.0692
0	0.0	2	5.0 ± 0.36	
0	0.75	0	6.1 ± 0.30	0.0114
0	0.75	2	5.0 ± 0.25	
0	1.5	0	6.2 ± 0.21	0.1298
0	1.5	2	5.5 ± 0.27	
17	0.0	0	5.8 ± 0.24	0.0692
17	0.0	2	5.1 ± 0.31	
17	0.75	0	6.0 ± 0.30	0.3321
17	0.75	2	5.6 ± 0.27	
17	1.5	0	5.7 ± 0.24	0.0899
17	1.5	2	5.0 ± 0.32	
33	0.0	0	5.2 ± 0.32	0.0790
33	0.0	2	4.5 ± 0.35	
33	0.75	0	5.8 ± 0.30	0.0605
33	0.75	2	5.0 ± 0.29	
33	1.5	0	5.7 ± 0.28	0.1152
33	1.5	2	5.0 ± 0.28	

[a]Mean (n=3) ± standard error.

Table 30. Effect of sourdough (0, 17 and 33%) on aroma score of white bread at different levels of tempe (0 and 2%) and NaCl (0.0, 0.75 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Aroma			P-value
0	0.0	0	5.7	±	0.32	0.2371
0	0.0	17	5.8	±	0.24	
0	0.0	33	5.2	±	0.32	
0	0.75	0	6.1	±	0.30	0.7997
0	0.75	17	6.0	±	0.30	
0	0.75	33	5.8	±	0.30	
0	1.5	0	6.2	±	0.21	0.4315
0	1.5	17	5.7	±	0.24	
0	1.5	33	5.7	±	0.28	
2	0.0	0	5.0	±	0.36	0.2659
2	0.0	17	5.1	±	0.31	
2	0.0	33	4.5	±	0.35	
2	0.75	0	5.0	±	0.25	0.3395
2	0.75	17	5.6	±	0.27	
2	0.75	33	5.0	±	0.29	
2	1.5	0	5.5	±	0.27	0.3566
0	1.5	17	5.0	±	0.32	
2	1.5	33	5.0	±	0.28	

[a]Mean (n=3) ± standard error.

Table 31. Effect of NaCl (0, 0.75 and 1.5%) on sourness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 3.5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Sour				P-value
0	0.0	0.0	3.9	±	0.33	b	<0.0001
0	0.0	0.75	5.5	±	0.27	a	
0	0.0	1.5	5.6	±	0.27	a	
0	3.5	0.0	4.4	±	0.27	a	0.4582
0	3.5	0.75	4.9	±	0.24	a	
0	3.5	1.5	4.7	±	0.28	a	
33	0.0	0.0	3.6	±	0.28	b	0.0125
33	0.0	0.75	4.1	±	0.31	ab	
33	0.0	1.5	4.8	±	0.29	a	
33	3.5	0.0	3.5	±	0.27	a	0.0888
33	3.5	0.75	4.1	±	0.28	a	
33	3.5	1.5	4.4	±	0.36	a	
17	0.0	0.0	4	±	0.32	b	0.0013
17	0.0	0.75	5.2	±	0.26	a	
17	0.0	1.5	5.4	±	0.29	a	
17	3.5	0.0	3.2	±	0.25	b	<0.0001
17	3.5	0.75	5.8	±	0.26	a	
17	3.5	1.5	3.4	±	0.23	b	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 32. Effect of tempe (0 and 3.5%) on sourness scores of white bread at different levels of sourdough (0, 17 and 33) and sodium chloride (0, 0.75 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Sour	P-value
0	0.0	0.0	3.9 ± 0.33	0.2424
0	0.0	3.5	4.4 ± 0.27	
0	0.75	0.0	5.5 ± 0.27	0.1241
0	0.75	3.5	4.9 ± 0.24	
0	1.5	0.0	5.6 ± 0.27	0.023
0	1.5	3.5	4.7 ± 0.28	
33	0.0	0.0	3.6 ± 0.28	0.8535
33	0.0	3.5	3.5 ± 0.27	
33	0.75	0.0	4.1 ± 0.31	0.9509
33	0.75	3.5	4.1 ± 0.28	
33	1.5	0.0	4.8 ± 0.29	0.3248
33	1.5	3.5	4.4 ± 0.36	
17	0.0	0.0	4 ± 0.32	0.0425
17	0.0	3.5	3.2 ± 0.25	
17	0.75	0.0	5.2 ± 0.26	0.1241
17	0.75	3.5	5.8 ± 0.26	
17	1.5	0.0	5.4 ± 0.29	<0.0001
17	1.5	3.5	3.4 ± 0.23	

[a]Mean (n=3) ± standard error.

Table 33. Effect of sourdough (0, 17 and 33%) on sourness scores of white bread at different levels of tempe (0 and 3.5%) and sodium chloride (0, 0.75 and 1.5%)

Tempe (%)	NaCl (%)	Sourdough (%)	Sour	P-value
0.0	0.0	0	3.9 ± 0.33 a	
0.0	0.0	33	3.6 ± 0.28 a	0.5693
0.0	0.0	17	4.0 ± 0.32 a	
0.0	0.75	0	5.5 ± 0.27 a	
0.0	0.75	33	4.1 ± 0.31 b	0.0017
0.0	0.75	17	5.2 ± 0.26 a	
0.0	1.5	0	5.6 ± 0.27 a	
0.0	1.5	33	4.8 ± 0.29 a	0.1228
0.0	1.5	17	5.4 ± 0.29 a	
3.5	0.0	0	4.4 ± 0.27 a	
3.5	0.0	33	3.5 ± 0.27 b	0.0144
3.5	0.0	17	3.2 ± 0.25 b	
3.5	0.75	0	4.9 ± 0.24 b	
3.5	0.75	33	4.1 ± 0.28 b	0.0002
3.5	0.75	17	5.8 ± 0.26 a	
3.5	1.5	0	4.7 ± 0.28 a	
3.5	1.5	33	4.4 ± 0.36 a	0.0044
3.5	1.5	17	3.4 ± 0.23 b	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 34. Effect of NaCl (0, 0.75 and 1.5%) on sweetness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 3.5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Sweet				P-value
0	0.0	0.0	4.1	±	0.35	b	0.0011
0	0.0	0.75	5.3	±	0.25	a	
0	0.0	1.5	5.3	±	0.23	a	
0	3.5	0.0	4.2	±	0.25	b	0.0409
0	3.5	0.75	4.9	±	0.24	a	
0	3.5	1.5	4	±	0.26	b	
33	0.0	0.0	3.7	±	0.29	b	0.0044
33	0.0	0.75	4.9	±	0.25	a	
33	0.0	1.5	4.8	±	0.34	a	
33	3.5	0.0	3.8	±	0.29	b	0.0486
33	3.5	0.75	4.5	±	0.19	a	
33	3.5	1.5	3.7	±	0.26	b	
17	0.0	0.0	4.6	±	0.26	a	0.4374
17	0.0	0.75	4.9	±	0.24	a	
17	0.0	1.5	5.1	±	0.28	a	
17	3.5	0.0	3.5	±	0.25	b	<0.0001
17	3.5	0.75	5.5	±	0.29	a	
17	3.5	1.5	3.5	±	0.29	b	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 35. Effect of tempe (0 and 3.5%) on sweetness scores of white bread at different levels of sourdough (0, 17 and 33) and sodium chloride (0, 0.75 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Sweet	P-value
0	0.0	0.0	4.1 ± 0.35	0.6996
0	0.0	3.5	4.2 ± 0.25	
0	0.75	0.0	5.3 ± 0.25	0.3037
0	0.75	3.5	4.9 ± 0.24	
0	1.5	0.0	5.3 ± 0.23	0.0005
0	1.5	3.5	4 ± 0.26	
33	0.0	0.0	3.7 ± 0.29	0.9487
33	0.0	3.5	3.8 ± 0.29	
33	0.75	0.0	4.9 ± 0.25	0.4032
33	0.75	3.5	4.5 ± 0.19	
33	1.5	0.0	4.8 ± 0.34	0.0026
33	1.5	3.5	3.7 ± 0.26	
17	0.0	0.0	4.6 ± 0.26	0.0026
17	0.0	3.5	3.5 ± 0.25	
17	0.75	0.0	4.9 ± 0.24	0.1394
17	0.75	3.5	5.5 ± 0.29	
17	1.5	0.0	5.1 ± 0.28	<0.0001
17	1.5	3.5	3.5 ± 0.29	

[a]Mean (n=3) ± standard error.

Table 36. Effect of sourdough (0, 17 and 33%) on sweetness scores of white bread at different levels of tempe (0 and 3.5%) and sodium chloride (0, 0.75 and 1.5%)

Tempe (%)	**NaCl (%)**	**Sourdough (%)**	**Sweet**				**P-value**
0.0	0.0	0	4.1	±	0.35	a	0.0645
0.0	0.0	33	3.7	±	0.29	a	
0.0	0.0	17	4.6	±	0.26	a	
0.0	0.75	0	5.3	±	0.25	a	0.4291
0.0	0.75	33	4.9	±	0.25	a	
0.0	0.75	17	4.9	±	0.24	a	
0.0	1.5	0	5.3	±	0.23	a	0.466
0.0	1.5	33	4.8	±	0.34	a	
0.0	1.5	17	5.1	±	0.28	a	
3.5	0.0	0	4.2	±	0.25	a	0.1522
3.5	0.0	33	3.8	±	0.29	a	
3.5	0.0	17	3.5	±	0.25	a	
3.5	0.75	0	4.9	±	0.24	a	0.0575
3.5	0.75	33	4.5	±	0.19	a	
3.5	0.75	17	5.5	±	0.29	a	
3.5	1.5	0	4	±	0.26	a	0.4326
3.5	1.5	33	3.7	±	0.26	a	
3.5	1.5	17	3.5	±	0.29	a	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 37. Effect of NaCl (0, 0.75 and 1.5%) on pasteboardiness score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 3.5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Pasteboardy				Pvalue
0	0.0	0.0	4.0	±	0.38	a	0.1436
0	0.0	0.75	4.8	±	0.25	a	
0	0.0	1.5	4.5	±	0.24	a	
0	3.5	0.0	3.7	±	0.27	b	<0.0001
0	3.5	0.75	5.7	±	0.23	a	
0	3.5	1.5	4.9	±	0.30	a	
33	0.0	0.0	3.7	±	0.27	a	0.3036
33	0.0	0.75	4.3	±	0.27	a	
33	0.0	1.5	4.1	±	0.26	a	
33	3.5	0.0	3.5	±	0.25	b	<0.0001
33	3.5	0.75	4.8	±	0.21	a	
33	3.5	1.5	3.0	±	0.27	b	
17	0.0	0.0	4.0	±	0.31	b	<0.0001
17	0.0	0.75	4.0	±	0.28	b	
17	0.0	1.5	5.8	±	0.29	a	
17	3.5	0.0	4.5	±	0.30	b	0.0002
17	3.5	0.75	5.5	±	0.25	a	
17	3.5	1.5	3.8	±	0.24	b	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 38. Effect of tempe (0 and 3.5%) on pasteboardiness of white bread at different levels of sourdough (0, 17 and 33) and sodium chloride (0, 0.75 and 1.5%).

Sourdough (%)	NaCl (%)	Tempe (%)	Pasteboardy	P-value
0	0.0	0.0	4 ± 0.38	0.3401
0	0.0	3.5	3.7 ± 0.27	
0	0.75	0.0	4.8 ± 0.25	0.026
0	0.75	3.5	5.7 ± 0.23	
0	1.5	0.0	4.5 ± 0.24	0.279
0	1.5	3.5	4.9 ± 0.30	
33	0.0	0.0	3.7 ± 0.27	0.6557
33	0.0	3.5	3.5 ± 0.25	
33	0.75	0.0	4.3 ± 0.27	0.2264
33	0.75	3.5	4.8 ± 0.21	
33	1.5	0.0	4.1 ± 0.26	0.0076
33	1.5	3.5	3 ± 0.27	
17	0.0	0.0	4 ± 0.31	0.2029
17	0.0	3.5	4.5 ± 0.30	
17	0.75	0.0	4 ± 0.28	0.0002
17	0.75	3.5	5.5 ± 0.25	
17	1.5	0.0	5.8 ± 0.29	<0.0001
17	1.5	3.5	3.8 ± 0.24	

[a]Mean (n=3) ± standard error.

Table 39. Effect of sourdough (0, 17 and 33%) on pasteboardiness scores of white bread at different levels of tempe (0 and 3.5%) and sodium chloride (0, 0.75 and 1.5%).

Tempe (%)	NaCl (%)	Sourdough (%)	Pasteboardy				P-value
0.0	0.0	0	4	±	0.38	a	0.6325
0.0	0.0	33	3.7	±	0.27	a	
0.0	0.0	17	4	±	0.31	a	
0.0	0.75	0	4.8	±	0.25	a	0.1205
0.0	0.75	33	4.3	±	0.27	a	
0.0	0.75	17	4	±	0.28	a	
0.0	1.5	0	4.5	±	0.24	b	<0.0001
0.0	1.5	33	4.1	±	0.26	b	
0.0	1.5	17	5.8	±	0.29	a	
3.5	0.0	0	3.7	±	0.27	b	0.0216
3.5	0.0	33	3.5	±	0.25	b	
3.5	0.0	17	4.5	±	0.30	a	
3.5	0.75	0	5.7	±	0.23	a	0.0585
3.5	0.75	33	4.8	±	0.21	a	
3.5	0.75	17	5.5	±	0.25	a	
3.5	1.5	0	4.9	±	0.30	a	<00.0001
3.5	1.5	33	3	±	0.27	c	
3.5	1.5	17	3.8	±	0.24	b	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 40. Effect of NaCl (0, 0.75 and 1.5%) on aroma score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 3.5%).

Sourdough (%)	Tempe (%)	NaCl (%)	Aroma				P-value
0	0.0	0.0	4.6	±	0.30	b	<0.0001
0	0.0	0.75	5.4	±	0.25	b	
0	0.0	1.5	6.4	±	0.24	a	
0	3.5	0.0	4.8	±	0.26	a	0.6496
0	3.5	0.75	5.1	±	0.23	a	
0	3.5	1.5	5.1	±	0.28	a	
33	0.0	0.0	4.1	±	0.33	b	<0.0001
33	0.0	0.75	4.1	±	0.33	b	
33	0.0	1.5	5.6	±	0.25	a	
33	3.5	0.0	4.5	±	0.30	a	<0.0001
33	3.5	0.75	5.1	±	0.27	a	
33	3.5	1.5	3.0	±	0.23	b	
17	0.0	0.0	5.3	±	0.32	a	0.1923
17	0.0	0.75	5.3	±	0.23	a	
17	0.0	1.5	5.9	±	0.23	a	
17	3.5	0.0	5.0	±	0.26	b	<0.0001
17	3.5	0.75	6.2	±	0.27	a	
17	3.5	1.5	3.9	±	0.25	c	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

Table 41. Effect of tempe (0 and 3.5%) on aroma scores of white bread at different levels of sourdough (0, 17 and 33) and sodium chloride (0, 0.75 and 1.5%).

Sourdough (%)	**NaCl (%)**	**Tempe (%)**	**Aroma**	**P-value**
0	0.0	0.0	4.6 ± 0.30	0.6532
0	0.0	3.5	4.8 ± 0.26	
0	0.75	0.0	5.4 ± 0.25	0.5635
0	0.75	3.5	5.1 ± 0.23	
0	1.5	0.0	6.4 ± 0.24	0.0011
0	1.5	3.5	5.1 ± 0.28	
33	0.0	0.0	4.1 ± 0.33	0.3689
33	0.0	3.5	4.5 ± 0.30	
33	0.75	0.0	4.1 ± 0.33	0.0178
33	0.75	3.5	5.1 ± 0.27	
33	1.5	0.0	5.6 ± 0.25	<0.0001
33	1.5	3.5	3.0 ± 0.23	
17	0.0	0.0	5.3 ± 0.32	0.521
17	0.0	3.5	5.0 ± 0.26	
17	0.75	0.0	5.3 ± 0.23	0.0293
17	0.75	3.5	6.2 ± 0.27	
17	1.5	0.0	5.9 ± 0.23	<0.0001
17	1.5	3.5	3.9 ± 0.25	

[a]Mean (n=3) ± standard error.

Table 42. Effect of sourdough (0, 17 and 33%) on aroma scores of white bread at different levels of tempe (0 and 3.5%) and sodium chloride (0, 0.75 and 1.5%)

Tempe (%)	NaCl (%)	Sourdough (%)	Aroma				P-value
0.0	0.0	0	4.6	±	0.30	b	0.0128
0.0	0.0	33	4.1	±	0.33	b	
0.0	0.0	17	5.3	±	0.32	a	
0.0	0.75	0	5.4	±	0.25	a	0.0019
0.0	0.75	33	4.1	±	0.33	b	
0.0	0.75	17	5.3	±	0.23	a	
0.0	1.5	0	6.4	±	0.24	a	0.134
0.0	1.5	33	5.6	±	0.25	a	
0.0	1.5	17	5.9	±	0.23	a	
3.5	0.0	0	4.8	±	0.26	a	0.3651
3.5	0.0	33	4.5	±	0.30	a	
3.5	0.0	17	5.0	±	0.26	a	
3.5	0.75	0	5.1	±	0.23	b	0.0071
3.5	0.75	33	5.1	±	0.27	b	
3.5	0.75	17	6.2	±	0.27	a	
3.5	1.5	0	5.1	±	0.28	a	<0.0001
3.5	1.5	33	3.0	±	0.23	c	
3.5	1.5	17	3.9	±	0.25	b	

[a]Mean (n=3) ± standard error. Means followed by different letter and within each comparison group are statistically different (P= 0.05).

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