ASSESSMENT OF FERMENTED PRODUCTS ON THE FLAVOR PROFILE OF WHITE BREAD AND SALT SUBSTITUTES ON VISCOELASTIC PROPERTIES OF WHEAT GLUTEN AND ON FERMENTATION PROPERTIES OF WHEAT DOUGH

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Bachelor of Science in Food Science and Technology

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Faisalabad, Pakistan

2010.

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2014

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Title of Study: ASSESSMENT OF FERMENTED PRODUCTS ON THE FLAVOR PROFILE OF WHITE BREAD AND SALT SUBSTITUTES ON VISCOELASTIC PROPERTIES OF WHEAT GLUTEN AND ON FERMENTATION PROPERTIES OF WHEAT DOUGH

Major Field: Food Science

Abstract:

Reduction of sodium chloride in daily intake has been received a lot of attention as increased consumption of NaCl is associated to cardiovascular diseases. NaCl plays an important role not only in improving the flavor of bread but also in rheological properties of wheat flour. Fermented products, sourdough and tempe flour (a fermented wheat/soy flour mixture) were used in formulation of bread. Both fermented products have the potential to increase the nutritional profile of bread by providing biological active compounds, vitamins and minerals and hydrolyzed protein, carbohydrate and lipids which help to improve the flavor and digestibility of bread. This study aimed to analyze the effect of fermented products on the flavor profile of white bread and rheological properties on dough. A commercial wheat flour (11% protein) was treated with sourdough (0, 11, 17 and 33%) tempe (0, 2, 3.5 and 5%) and NaCl (0, 0.5, 0.75, 1.0 and 1.5%) using a randomized complete block with three replications. In Study I, 5% tempe lowered the scores of flavor profile and 11% sourdough did not affect the sensory parameters. Tempe at 3.5% with 17% sourdough gave similar saltiness perception at 0.75 and 1.5% NaCl. Sourdough at 33% gave more pronounced effect on flavor profile than 17% sourdough. At 33% sourdough and 3.5% tempe, 2% NaCl increased the viscosity of gluten and decreased the elastic recovery. Sourdough at 33% and 3.5% tempe increased Hm, h, total volume, volume lost and volume retained and decreased T1 in dough fermentation properties. This was in part explained by the hydrolyzed wheat and soy proteins which interfered with gluten network formation and resulted in more viscous and less elastic dough.

Study II aimed to analyze the effect of sodium chloride substitutes on dough rheological properties. Three commercial flours (9.8, 10.9 and 13.3% protein) were treated with 1 and 2% levels of salt substitutes using a randomized complete block with three replications. Results indicated that flour with 9.8% protein increased the viscosity of gluten with an increase in salt levels, whereas, flour with 13.3% protein did not show any significant effect on gluten viscoelastic properties with increase in salt level. Flour with 10.9% protein showed decrease in viscosity and increase in elastic recovery of gluten with increase in salt level. Salt substitutes at 1 and 2% increased Hm, total volume, volume lost and lower h and T1 values while increased viscosity of gluten and decreased elastic recovery with salt substitutes compared to controls. Reduced sodium salt substitutes affected gluten network formation and yeast activity which resulted in a negative effect on rheological properties of wheat flour compared to control (NaCl).

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CHAPTER I

INTRODUCTION

Statement of problem

There has been a lot of emphasis on salt reduction in daily intake recently. Increased consumption of sodium chloride is associated to detrimental effects to human health as it correlated to hypertension, renal disorder, cardiovascular diseases and obesity (Doyle and Glass, 2010; He and MacGregor, 2008a). Wheat is staple food in major parts of the world. Main source of sodium intake is processed food because higher levels of sodium are added for processing or preservation purposes (Maples et al, 1982). In large population areas wheat bread is the main source of sodium consumption (James et al, 1987). Sodium chloride is important in improving handling of wheat dough as it facilitates protein aggregation (Guerrieri, 2004; Ukai et al, 2008). Sodium chloride also controls yeast activity in yeast leavened cereal products (Miller, 2008). There has been a lot of research focusing on the arena of salt reduction in foods. Sodium content of cereal products can be reduced gradually without affecting flavor significantly (Girgis et al, 2003). Sodium chloride is important for improving flavor of wheat bread (Beck et al, 2012a). Sodium and potassium gluconates had no significant effect on rheology of wheat dough up to 50% substitution of sodium chloride (Takano and Kondou, 2002). Fermented products have been used to improve bread flavor and to reduce salt content (Yezbick et al, 2013). In previous studies salt reduction affected rheological properties of wheat dough significantly (Larsson, 2002;

Lynch et al, 2009). Reduction in sodium chloride level not only affects flavor of bread but also changes the viscoelastic properties of gluten as well as fermentation properties of wheat dough.

Purpose of Study

The objectives of this study were:

1) To analyze the effect of sourdough, wheat-tempe flour and sodium chloride at different levels on flavor profile of white bread.

2) To investigate the effect of sourdough, wheat-tempe flour and sodium chloride on rheological properties of gluten as well as on fermentation properties of wheat dough.

3) To determine the effect of commercial sodium chloride substitutes at 1 and 2% levels on three flours of different protein content (9.8, 10.9 and 13.3%) on rheological properties of gluten and on fermentation properties of wheat dough.

Hypothesis

Null hypothesis of this study are as follows:

1) There is no significant effect on flavor profile of white bread with the addition of sourdough and wheat-tempe flour compared to control treatments

2) There is no significant effect on rheological properties of gluten and on fermentation properties of wheat dough with the addition of sourdough and wheat-tempe flour.

3) There is no significant difference in rheological properties of gluten and on fermentation properties of wheat dough with the addition of commercial sodium chloride substitutes at 1 and 2% levels compared to controls on any of the three flours.

Alternate Hypothesis

If null hypothesis is rejected, then the effect of sourdough and wheat-tempe flour will be explained in terms of compounds responsible for flavor profile of white bread and on protein changes to explain rheological properties of gluten as well as on fermentation properties of wheat dough. Also, the effect of commercial sodium chloride substitutes at 1 and 2% level on three flours will be explained in terms of changes in gluten protein network and on fermentation properties of what dough.

Assumptions

The alternate hypothesis will use these assumptions to explain the effects observed. It is assumed that sourdough and wheat-tempe flour have a pronounced effect on flavor profile of white bread and also on rheological properties of wheat flour. Sourdough has hydrolyzed gluten which releases amino acids responsible of distinct aroma and flavor. Soy bean and wheat kernel's character changes during tempe fermentation and results in strong roasted beany flavor. Addition of fermented products dilute the gluten content of flour which effects gluten network formation and also gas holding capacity of wheat dough. Commercial sodium chloride substitutes contain reduced sodium content which interferes with gluten network formation and reduce the elasticity of gluten, also has a different rate of control of yeast activity during fermentation test.

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CHAPTER II

REVIEW OF LITERATURE

Effect of NaCl on gluten network

Sodium chloride (NaCl) is added in all the cereal based food products and it plays two important roles; one is to increase the sensory properties and improve the texture of the final product(Miller, 2008). The gluten of wheat flour determines the strength of dough. Gluten proteins get hydrated and form a network between its constituents, glutenins and gliadins (Belton, 1999).

Glutenins have a positive effect in strengthening the dough because they form cross links with their own molecules (MacRitche, 1992). Gliadin provides the extensibility in dough and imparts viscous behavior (Song and Zheng, 2008). Sodium chloride is added (2%) in flour by weight to improve flavor and rheological properties (Larsson, 2002). It was reported that reduction of sodium chloride from 2% to 1% interferes with gluten network formation which affects the dough strength as poor aggregation of gluten with 1% NaCl weakens the gluten network (Beck et al, 2012b) . The difference in gluten network structure depends on its hydration at the beginning of mixing. NaCl delays the hydration of gluten and gluten network formation (McCann and Day, 2013).

Effect of sodium chloride at the levels of 0, 1 and 2% on gluten network formation with two commercial flours with different protein contents; high protein flour (13.5%), low protein flour (Protein= 9%) was investigated. Dough development time for the two samples was different and it was attributed to the protein content. Fully developed dough was examined by confocal laser scanning micrograph (CLSM) to study the microstructure. In the presence of the salt, gluten formed stronger fibrous structure in which starch granules were embedded, whereas, in the absence of the salt, gluten formed a scattered, thinner network like a honeycomb (McCann and Day, 2013)

The dough was further studied to understand the hydration of gluten. For this purpose, the microstructure of dough with high protein content flour was treated with 0 and 2% salt concentrations. Without the NaCl, gluten network started forming after 2 minutes mixing and was fully developed at 6 minutes. On the other hand the dough containing 2% NaCl formed larger and stronger fibrils of gluten at the end of the mixing time (McCann and Day, 2013). During mixing, gluten proteins form a very flexible network via inter-chain and intra-chain hydrophobic interactions, disulfide bonds, van der walls forces and dipole-dipole interactions (MacRitche, 1992).

Another study provided logical explanation behind the delayed hydration of gluten in the presence of NaCl. NaCl gives an electrostatic shield to the charged amino acids i.e. hydrophilic ends. It serves another purpose of shielding the repulsion forces between gluten molecules and allowing them to interact easily via hydrophobic interactions, which results in β sheet conformation of the gluten molecules (Wellner et al, 2003).

Wheat gluten contains 75% proteins, 8% of moisture, 6-10% of lipids and small amounts of starch and fiber (Qian et al, 2008). Gluten proteins are hydrophobic in nature and they interact with lipids, as they repel water (Pareyt et al, 2011).

Day and collaborators (2009) stated that sodium chloride helps to detach the lipid from gluten protein. Lipids interfere with the non-covalent forces between the gluten aggregates, this result in less cohesive gluten network. In the presence of the salt repulsion between gluten molecules decreases and they tend to form a firm network (Wellner et al, 2003).

The interfacial properties of gluten with various electrolytes were studies by using Langmuir film balance system. Gluten samples treated with different electrolytes were sprayed dried at 927cm^2 area in an amount of 0.2 mg. The system was left for 30 min to equilibrate before applying compression of 0.515 cm^2/s. Gluten film's stability and elasticity was measured by calculating its collapsing behavior and its resistance to change respectively. Chloride salts draw the water molecules towards it and cause more aggregation of gluten proteins. At high salt concentrations the stability of gluten film was increased, whereas, the elasticity was decreased. But the elasticity did not decrease in the presence of calcium chloride. It was assumed that under the treatment of calcium chloride, gluten forms more disulfide bonds which help to strengthen the gluten film (Balla et al, 1998).

A study was conducted to analyze gluten separation at different salt concentrations. It was found that higher salt concentration helped to separate more protein content from the dough. The dough was treated with 0, 0.5, 1, 2, 4 and 7% (based on flour weight) of sodium chloride. Addition of salt decreased the water requirement for Soissons wheat flour. The highest gluten fraction was separated when dough was treated with 4% of salt. At 7% sodium chloride hardly any separation of gluten was observed. At 0% salt there was only limited separation of gluten was noticed. Separation of gluten is dependent on the salt concentration, up to 4% NaCl maximum gluten was separated but at 7% NaCl separation was negatively affected. At low salt concentrations (0, 1%) gluten interactions were comparatively weak, gluten aggregates were formed rapidly but then broke down easily. At higher salt concentrations (2, 4%) gluten interactions were strong and larger aggregates are formed. At 7% of salt concentration the interactions were very strong but then breakage of gluten aggregates happened easily as well (Zalm et al, 2010).

The phenomenon of gluten aggregation and disaggregation and how salt affects the gluten network was analyzed in a study (Ukai et al, 2008). Gliadin subunits of gluten were aggregated by the addition of the NaCl in a short time. With the increase in the salt concentration there was an increasing in aggregation noticed. Salt causes changes in the secondary structure of the gliadin-rich proteins which causes the aggregation. Fourier transform infrared spectroscopy (FT-IR) analysis indicated that the only difference in the secondary structure of gliadin-rich protein, with or without the salt was the decrease in β-turn. In the presence of NaCl more protein was found cross linked. An increase in the β-sheet was observed on the addition of sodium chloride. This indicates that β-sheet structure facilitated the aggregation. Salt only facilitated the formation of the gluten network in flour with low protein content. Salt did not show strong impact in gluten network formation with high protein flours. The quality of bread is determined by the protein content hypothetically (Ukai et al, 2008).

Secondary structure of gluten

Effect of different salts (NaCl, NaBr, NaI) on the secondary structure of wheat gluten were studied (Ukai et al, 2008). FT-IR analysis was conducted to study the secondary structure of the wheat prolamins. In the presence of NaCl (I M) more β sheet conformation was noticed, whereas, with NaBr lower intermolecular β-sheets formed (Ukai et al, 2008).

NaI treatment showed increasing trend of β-turn secondary structure of gluten. NaI made gluten molecules soluble, gluten tend to form β-turn conformation when soluble. The comparative analysis of different salts on the secondary structure of the gluten indicated that increasing NaCl concentrations resulted in more intermolecular β-sheet conformation in gluten structure and less β-turn conformation. NaBr increasing concentrations cause an increase in the β-turns, initially in lower concentration of NaBr there was an increase in β-sheet conformation was noticed. The salt affected the conformation of gluten secondary structure by altering the equilibrium in native state between β-sheets and β-turns (Wellner et al, 2003).

The increase in the β-sheets was related to protein aggregation in the presence of salt. This aggregation also provides an explanation of dough treated with salt; showed less gluten volume in ultracentrifugation (separation of gluten from dough technique) and more gluten aggregation in dough fractions, making dough elastic which is interpreted as strong dough and was measured by strain sweep test (Larsson, 2002). Wheat gluten has 33% amino acids with charge on them, salt helps to shield the repulsion between these charged groups and make it easier for these amino acids to interact with each other and form aggregates (Galal et al, 1978b)

β-sheets conformations were found in solid parts of glutenin aggregates; linked by hydrogen bonding, whereas, the mobile part of wheat prolamins had β-turn conformations. The secondary structure changes in wheat gluten were dependent on salt concentration (Wellner et al, 2003).

Effect of salt on gluten hydration

Wheat gluten is rather insoluble in water because of the large molecules and intermolecular interactions. Only the glutenins of gluten have the tendency to form disulfide bonds among its molecules and provide elasticity to the gluten polymer. Glutenins and gliadins interact with each other non-covalently to form a viscoelastic gluten network (Veraverbeke and Delcour, 2002).

The effect of different salts on hydrated gluten structure was studied with infra-red spectroscopy. Gluten was treated with NaCl, KBr, $MgBr_2$, $MgCl_2$, $MgSO_4$ and Na_2SO_4. All these salts affected on gluten more at higher concentrations. The water uptake by gluten depends on the salt type and salt concentration. This water uptake can be associated with the ability of a particular salt to increase protein-water interactions and decrease protein-protein interactions. Increased water uptake destabilized the gluten structure, whereas, decrease water uptake indicated a stabilized gluten network (Bruun et al, 2007).

Sulfate salts showed decreased water uptake/hydration of gluten which confirms its stabilizing effect. This finding supported observations reported in previous literature, dough improvement in terms of strength and elasticity, on the addition of sulfate salt in weak dough (Hoseney et al, 1992).

NaCl improves dough (Beck et al, 2012a) cause aggregation of wheat prolamins (Ukai et al, 2008) and has very little effect on the water absorption by wheat gluten. Potassium ion is categorized as slightly chaotropic. Chaotropic anions interact with hydrophobic parts of proteins and cause hydration, solubility and unfolding of protein structure which is called salting in (Kalra et al, 2001). Hydration of gluten affects the secondary structure of the protein. In solubilized form there was more β-turn conformation (Mejri et al, 2005). Hydration results in reduced numbers of β-helical structure and an increase in β-turns (Mejri et al, 2005).

NaCl showed a very small increasing trend in solubility of gluten at pH of 4 and 6. At alkaline pH solubility decreased because protein-protein interactions were favored as salt deprotonated the polar surface of gluten protein. Potassium chloride affected the solubility of gluten in positive manner. Potassium chloride has more ionic strength than NaCl in aqueous solution. It facilitated the hydration of gluten by improving the water-protein interaction (Mejri et al, 2005).

Hydrated gluten (partially hydrolyzed) contains 49% of β-turns, 34% of β-sheets and 16% of α-helix. Gluten in native (not hydrated) form contains more β-sheet structure. Hydration caused the conversion of β-sheets to β-turns (Mejri et al, 2005).

Effect of salt on gluten rheology

Gluten plays a very important role in determining baking quality of wheat flour as it contributes in elasticity, strength and water absorption capacity of the dough (Wieser, 2007). A study was conducted to understand the rheological properties of the gluten and water soluble pentosans. For this purpose gluten and pentosans were extracted from defatted wheat flour which was sieved and slurry was made from this sieved portion of flour. Centrifugation helped in further separation, kneading was carried out followed by freeze drying of gluten. To evaluate the effect of ionic strength on gluten and gluten-pentosans mixture, both were treated with 0.09, 0.27, 0.34 and 0.54 M of solutions prepared by 50% of NaCl. To study the rheology, creep recovery test and oscillation test were performed (Ma et al, 2012).

Viscoelastic properties of gluten were also studied under different concentrations of salt. Elasticity parameter values reached the maximum at the concentration of 4% of NaCl and these values decreased as the salt concentration was increased. At high salt concentration, strength of hydrated gluten gel was decreased (Ma et al, 2012)

The results of oscillation frequency sweep test suggested that at 4% of NaCl concentration, dynamic moduli was higher and resulted in increased resistance to small deformation. When the salt concentration increased from 4% it made water molecules more accessible to gluten protein which resulted in reduced dynamic moduli (Ma et al, 2012)

When the gluten was hydrated it showed typical rheological properties. Salt concentrations affect the gluten gel strength by changing the secondary structure conformation of gluten and glutenin-gliadin interactions which are explained by the phenomenon of aggregation and disaggregation (Ukai et al, 2008).

Need for salt substitutes

Sodium chloride is used on daily basis to enhance the flavor of the food products as well as to improve the textural properties. In baking industry it is used to strengthen the dough and to improve the rheological properties of dough and gluten (Beck et al, 2012a). Sodium chloride is considered as one of the major factor in elevating blood pressure. Its excessive consumption can lead to obesity, renal disorders and cardiovascular diseases (He and MacGregor, 2008b). There is a need to find salt substitute which can be incorporated in food products with minimum alteration of taste and textural properties.

Low sodium salt substitutes

A seasoning with low sodium content has been formulated. This seasoning contains 40 to 50% by weight of NaCl, 25-35% by weight of potassium chloride and 15 to 25% of either magnesium chloride or magnesium sulfate. This combination of salts provides saltiness perception equivalent to common salt, serves as a dietary supplement of magnesium as well. This mixture of salts cut down the sodium content by 50 percent when compared to the table salt. Potassium chloride caused a bitter after taste, magnesium helps to mask the bitter taste. Sodium chloride is damaging for health mainly due to its sodium content. This salt substitute reduced the sodium content by half (Rood and Tilkian, 1984).

The combination of lysine, chlorides and succinic acid resulted in salty taste. Lysine was used in higher molar concentration as it attributed saltiness perception. Low sodium or low potassium salts were also formulated by adding sodium or potassium in addition to chloride, succinic acid and lysine (Turk, 1993).

Another salt substitute was patented. Sodium free and potassium free salt had a desirable salty taste. L-lysine has a sweet taste and succinic acid has sour in taste, this resulted in salty flavor which resembles the sodium chloride without having sodium in it. L-lysine is used in almost double the amount of chlorides and succinic acid (Turk, 1993). Low sodium and low potassium salts were formulated by adding monosodium, disodium or monopotassium. Low sodium salt contained only 1.22% of sodium by weight (Turk, 1993).

Sodium free salt comprised of amino acid, a sugar like glucose and a source of potassium either dipotassium phosphate or potassium chloride was patented (Mohlenkamp Jr and Hiler, 1981). This salt substitute has salty flavor even though potassium is only present less than 50 percent by weight (Mohlenkamp Jr and Hiler, 1981).

Sodium free salt substitute comprised of nucleotide component, amino acid mixture, glucose, potassium chloride and potassium phosphate was patented. This substitute of salt has salty flavor without any bitter taste, which is usually caused by potassium chloride. Saltiness perception of potassium chloride increased by the combination of other added ingredients which helped to reduce the potassium chloride content (Mohlenkamp Jr and Hiler, 1981).

Low sodium salt substitute containing binder agent 0-40 parts, bulking agent 5-70 parts which is non-gritty and 30-90 parts of sodium chloride has been patented (DuBois and Tsau, 1992). The bulking agent was coated with sodium chloride and use of binding agent was optional. This substitute of salt was handled like common table salt and gave similar saltiness perception with lower sodium content. More saltiness with less sodium was possible by making rapid dissolution of salt particles. Common table salt has dense larger granules which do not get solubilized in saliva instantaneously. When NaCl is sprinkled on snacks it does not give salty perception right at that moment for that reason NaCl is usually used in excess to get the desired saltiness taste. According to DuBois and Tsau sodium chloride is less efficient in providing salty flavor. They claimed that their salt substitute has less density when compared to the common table salt. Fine particles of sodium chloride and bleached flour were mixed, optional binder could be used. This mixture was then granulated with water to form particles with density lower than

0.6gram/cc. The author claimed that their salt substitute is more suitable for sprinkling on prepared food (DuBois and Tsau, 1992).

A patent salt substitute contained calcium ascorbate as a major component also had sodium chloride, potassium chloride and ascorbic acid. It had pH of 4-5, salty flavor just like sodium chloride (Gregory, 1996).

A low sodium salt substitute was formulated with three plants aqueous extract with umami and salty taste. These were characterized as plant salt substitutes (PSS), saltiness was 0.65 relative to NaCl meaning that 1% NaCl was equivalent to saltiness of 1.55% PSS. PSS had 43% less sodium than the regular salt (Lee, 2011). Three selected plant extracts were saltwater, kukoshi and sea tangle are forms of brown sea weeds which were spray dried for storage (Lee, 2011).

Effect of reduced salt or salt substitutes on bread quality

Cereal products and bread contribute with about 30% of sodium daily intake. The saltiness perception can be increased by spatial distribution of the salt. A dough ball was cut from stacked dough sheets containing different sodium chloride concentration with homogenous and heterogeneous distribution of salt containing 1 and 1.5% of NaCl and then baked. Consumer acceptance test did not show any significant difference in saltiness perception of bread samples with homogenous distribution of NaCl, whereas, in samples with heterogeneous distribution of NaCl; 1% NaCl showed 117% more saltiness perception compared to control (2% NaCl). Samples containing 1.5% NaCl in heterogeneous manner showed 52% increase in saltiness perception compared to control   This strategy helps to reduce the sodium content of bread (Noort et al, 2010).

Sodium and potassium gluconates were used as salt substitute in bread to determine the potential of reduced sodium or sodium free bread (Takano and Kondou, 2002). When the sodium chloride was replaced by 75% with sodium gluconate or 50% by potassium gluconate, it had no effect on rheological properties of dough. Full replacement of sodium chloride by either of the gluconates resulted in reduced resistance to extension; dough extended easily and there were no effects in handling of dough. The authors concluded that sodium chloride can be replaced by potassium of sodium gluconate. The gluconates decreased the fermentation time. Sodium or potassium gluconate assisted rapid starch granules swelling during baking which resulted in shorter baking time. Replacement of sodium chloride by half reduced the baking time by two minutes, no difference in loaf volume was observed (Takano and Kondou, 2002).

Sourdough

Sourdough fermentation is a traditional process practiced in rye and wheat baking for a long time. Spontaneous dough fermentation of cereals is the oldest food method known to mankind. Its main purpose was to produce more gaseous piece of dough which would result in more volume of bread (Clarke and Arendt, 2005; Spicher and Nierle, 1984). Dough is prepared by mixing equal amount of water and wheat flour after that it is kept for 24 hours at 26_35ºC which facilitates the fermentation. With each feeding of flour and water, dough becomes more acidic as lactic acid bacteria becomes dominant (Coda et al, 2014; Gobbetti, 1998). Sourdough can be classified into three groups. Dough which is being propagated continuously to keep the micro flora activated is type 1 dough, in this type of dough Lactobacillus sanfranciscensis is the dominant microorganism isolated from it and Lactobacillus pontis can also be found (Böcker et al, 1995). Type 2 sourdough needs feeding continuously and for longer fermentation periods. This type of dough can be produced in larger amounts and stored up to 1 week. Due to longer fermentation periods gas produced by lactic acid bacteria is reduced and commercial baker’s yeast is added for leavening purposes (Vogel et al, 1994). Type 3 sourdough is generally known as artificially composed dried sourdough, in this sourdough lactic acid bacteria are selected with regard to their activity on drying (Böcker et al, 1995). Sourdough fermentation is known to improve the nutritional profile of the wheat bread. It gives unique flavor, palatability and improves the textural properties of whole wheat flour bread. It increases the bioactive compounds, minerals and helps to lower the glycemic index by degrading carbohydrates (Katina, Arendt, Liukkonen, et al, 2005). Sourdough also helps to delay the staling process and prevents the spoilage caused by bacteria and fungus (Kulp, 2003). Sourdough fermentation degrades the gluten of wheat and affects the rheology of dough. According to a study sourdough fermentation activates the indigenous cereal enzymes by providing acidic environment. This degradation of gluten alters the texture of the bread as well (Thiele, 2003; Thiele et al, 2004).

Sourdough micro flora has mixture of yeast and lactic acid bacteria (LAB). LAB produces acid and organic compounds through the degradation of carbohydrates, lipids and proteins of flour. It also produces ethanol, acetic acid, flavoring compounds and other important enzymes. It facilitates the pleasant sensory and nutritional profile of the wheat bread (Thiele et al, 2002). Lactic acid bacteria help in breaking down of gluten by degrading it into smaller peptides and amino acids. These amino acids enhances the flavor profile of the wheat bread (Gänzle et al, 2008; Gobbetti et al, 2014; Rizzello et al, 2010).

A study was conducted using two different strains of lactobacilli and controlled fermentation in artificially acidic environment to compare the proteolysis of glutenin in presence and absence of microbial metabolic activities. The degree of proteolysis was determined by measuring the amino nitrogen content in sourdough. The amount of nitrogen increased during fermentation and almost doubled after 24 h of fermentation. This study also suggested that levels of amino nitrogen were higher in L. pontis as compared to L. sanfranciscensis. Sourdoughs and acidified dough showed increased amino nitrogen compared to the control dough. (Thiele et al, 2004).There are different factors affecting the flavor production in sourdough e.g. type of cereal flour, exogenous and endogenous components in sour dough, different processing steps in baking specially heat treatment can affect the generation of flavoring compounds in sourdough bread (Hansen and Hansen, 1994). Sucrose addition in wheat dough stimulates the LAB and yeast growth which enhances the production of lactic acid and acetic acid (Gobbetti and Corsetti, 1997; Gobbetti et al, 1996). Salt (NaCl) affects directly yeast metabolism which decreases its competition with LAB for available sugars and other soluble carbohydrates under typical fermentation temperature (De Vuyst and Vancanneyt, 2007). LAB produce lactic acid and acetic acid as primary metabolites, citric and malic acids are produced in comparatively lesser amounts. The ratio of lactic acid to acetic acid is very important for final product flavor (Linko et al, 1997). LAB produces lactic acid and acetic acid at a slower rate when combined with yeast culture, whereas, rapid production of lactic and acetic acid has been observed in monocultures of LAB (Merseburger et al, 1995). Few aldehydes in sourdough are a result of autoxidation or enzymatic oxidation of lipids present in wheat (Frankel, 1983). There are two categories of flavoring compounds produced during sourdough fermentation, volatiles and non-volatiles. Acetic and lactic acids are non-volatile compounds and cause a decrease in pH which results in the acidification of dough. These compounds mainly contribute to the aroma of sourdough bread (Galal et al, 1978a). Volatile compounds include ketones, esters, aldehydes, alcohols and these are produced during biochemical actions of sourdough fermentation and are responsible of imparting unique flavor (Schieberle, 1996; Spicher and Nierle, 1984). Yeasts and LAB may facilitate the conversion through metabolizing the amino acids or by transforming them into secondary compounds which can further act as precursors of flavors (Gänzle, 2014; Hansen and Hansen, 1994; Schieberle, 1996). The amino acid leucine and phenylalanine metabolize into 3-methylbutanol, 3-methylbutanal and 2-phenylethanol via Ehrlich pathway of Saccharomyces cerevisiae (Dickinson et al, 1998; Ehrlich, 1907; Hazelwood et al, 2008) S. cerevisiae uses the Ehrlich pathway to degrade the aromatic and branched amino acids (phenylalanine, tyrosine, tryptophan, isoleucine, leucine and valine). S. cerevisiae is only able to use amino acids with ammonium ions, which in turn causes the release of flavor-active aldehydes and isoalcohols (Sentheshanmuganathan, 1960). Conversion of arginine into ornithine is carried out by Lactobacillus pontis (Gänzle et al, 2007; Vogel et al, 1994). Ornithine is a precursor of roasty-flavored 2-acetyl-1-pyrroline. Leucine produces its corresponding aldehydes and acids 3-methylbutanal and 3-methyl butanoic acid, similarly phenylalanine produces phenyl acetaldehyde and phenyl acetic acid (Hofmann et al, 2000). Increased content of flavor compounds derived from metabolizing amino acids are related to improved taste and palatability in wheat sourdough, 3-methybutanol, 2-methylpropanoic acid, 3-methybutanoic acid and 2-phenylethanol are the examples of metabolized amino acids in sourdough (Hansen and Hansen, 1994)

CHAPTER III

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

ABSTRACT

The sodium content in bread comes from NaCl in the formula for 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 analyze the effect of fermented products (sourdough and wheat-soy tempe flour) and sodium chloride on flavor profile of white bread. 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 using AACC International Optimized Straight Dough Bread Baking Method. Sensory analysis was conducted to determine the saltiness and other sensory parameters by 80 untrained panelists. Tempe at 5% significantly decreased the scores of all flavor parameters, whereas, sourdough (11, 17 and33%) and NaCl (0.5, 1.0 and 1.5%) did not affect any of the flavor parameters. Tempe 2% and sourdough (0, 17 and 33%) did not affect the flavor profile but NaCl (0, 0.75 and 1.5%) significantly increased scores of flavor parameter except aroma. Tempe (0, 3.5%) sourdough (0, 17 and 33%) and NaCl (0, 0.75 and 1.5%) had significant effect on flavor parameters. In terms of saltiness, bread samples with tempe 3.5% and 17% sourdough had similar saltiness perception for 0.75 and 1.5% NaCl. The results suggested that addition of fermented products can enhance saltiness perception of white bread with lower amounts of NaCl when used at appropriate concentration. Fermented products can affect flavor profile of white bread significantly.

Keywords: flavor profile, sensory session, bread, tempe, sourdough, NaCl

1 Introduction

Sourdough fermentation is a traditional process practiced with rye and wheat bread baking for a long time. Its main purpose is to produce a more gaseous dough which would result in more volume in bread (Chavan and Chavan, 2011; Spicher and Nierle, 1984). Sourdough fermentation is known to improve the nutritional profile of wheat bread. It gives unique flavor, palatability and improves the textural properties of whole wheat flour bread. Bioactive compounds and minerals are increased in bread processed from sourdough fermentation while starch availability is decreased, thus lowering the glycemic index of bread (Katina, 2005). Sourdough also helps to delay the staling process and prevents the spoilage caused by fungi and bacteria (Kulp, 2003).The micro flora of sourdough is a mixture of yeast and lactic acid bacteria (LAB) (Clarke and Arendt, 2005). LAB produce aldehydes, ketones, alcohols, isoalcohols and organic acids by degradation of carbohydrates, proteins and lipids present in flour, and they help in the breaking down of gluten by hydrolysis into smaller peptides and amino acids. These amino acids enhanced the flavor profile of the wheat bread (Kulp and Lorenz, 2003; Spicher and Nierle, 1984). L. sanfrancisensis and L. pontis, under controlled fermentation in an artificial acidic environment were used to compare the difference in proteolysis of glutenins in the presence and absence of microbial metabolic activities (Thiele et al, 2004). The degree of proteolysis was determined by measuring the amino nitrogen content in sourdough. The amount of nitrogen increased during fermentation and almost doubled after 24h, which indicates increased hydrolysis of proteins present in flour. The levels of amino nitrogen were higher in the dough with L. pontis compared to L. sanfranciscensis, indicating a higher degree of proteolysis in dough containing L. ponis. Sourdoughs and acidified dough showed increased amino nitrogen when compared to the control dough. (Thiele et al, 2004). Different factors affected the flavor production in sourdough, e.g., type of cereal flour; exogenous and endogenous components in sour dough; and different processing steps in baking, especially heat treatment, which can affect the generation of flavor compounds (Hansen and Hansen, 1994). Sucrose addition in wheat dough stimulates the LAB and yeast growth which increases the production of lactic acid and acetic acid (Gänzle et al, 2008; Gobbetti, 1998; Gobbetti and Corsetti, 1997). Salt (NaCl) reduces the growth of yeast and decreases its competition with LAB for available sugars and other soluble carbohydrates under the typical fermentation temperature range of 28±4ºC (De Vuyst and Vancanneyt, 2007). LAB produces lactic acid and acetic acid as primary metabolites; citric and malic acids were produced in comparatively lesser amounts. The ratio of lactic acid to acetic acid was very important for the flavor of the final sourdough wheat bread (Linko et al, 1997). LAB produce lactic acid and acetic acid at a slower rate in the presence of yeast culture compared to LAB monocultures, where rapid production of lactic acid and acetic acid were observed (Merseburger et al, 1995). Few aldehydes in sourdough resulted from autoxidation or enzymatic oxidation of lipids present in wheat (Frankel, 1983). There are two categories of flavoring compounds produced during sourdough fermentation, volatiles and non-volatiles. Acetic and lactic acids are non-volatile compounds and cause a decrease in pH which results in the acidification of dough. These compounds mainly contribute to the aroma of sourdough bread (Galal et al, 1978a). Volatile compounds include ketones, esters, aldehydes, and alcohols were produced during biochemical actions of sourdough fermentation and responsible for imparting the unique flavor (Schieberle, 1996; Spicher and Nierle, 1984). Yeasts and LAB may facilitate the conversion through metabolizing the amino acids or by transforming them into secondary compounds which can further act as precursors of flavors (Gänzle, 2014; Hansen and Hansen, 1994; Schieberle, 1996). The amino acid leucine and phenylalanine were metabolized into 3-methylbutanol, 3-methylbutanal and 2-phenylethanol via the Ehrlich pathway of Saccharomyces cerevisiae (Dickinson et al, 1998; Ehrlich, 1907; Hazelwood et al, 2008) S. cerevisiae used the Ehrlich pathway to degrade the aromatic and branched amino acids (phenylalanine, tyrosine, tryptophan, isoleucine, leucine and valine). S. cerevisiae was only able to use amino acids with ammonium ions, which in turn caused the release of flavor-active aldehydes and isoalcohols (Sentheshanmuganathan, 1960). Conversion of arginine into ornithine was carried out by Lactobacillus pontis (Gänzle et al, 2007; Vogel et al, 1994). Ornithine is a precursor of roasty-flavored 2-acetyl-1-pyrroline. Leucine produces its corresponding aldehydes and acids, 3-methylbutanal and 3-methyl butanoic acid; similarly, phenylalanine produces phenyl acetaldehyde and phenyl acetic acid (Hofmann et al, 2000). The increased content of flavor compounds derived from metabolizing amino acids are related to improved taste and palatability in wheat sourdough. 3-methybutanol, 2-methylpropanoic acid, 3-methybutanoic acid and 2-phenylethanol are the examples of metabolized amino acids in sourdough (Hansen and Hansen, 1994). There has been a lot of research done on salt reduction in cereal products. Increased consumption of sodium chloride leads to health problems (He and MacGregor, 2008a). It has been reported that the sodium chloride level in wheat bread can be reduced by 25% gradually without effecting overall acceptability (Girgis et al, 2003). Bread samples containing 1.36% sodium chloride level were preferred compared to bread samples containing higher levels of salt by panelists in a consumer acceptance test (Salovaara et al, 1982). Similarly, in another study, panelists preferred bread samples containing 1.25% sodium chloride compared to a higher salt level (Collyer, 1966). A study on the reduction of sodium content in white bread by a fermented soy product (natural flavor enhancer, prepared with soy bean, water, wheat and sodium chloride) reported that a 40% reduction did not affect overall liking of the bread in a consumer acceptance test with 94 untrained panelists (Jimenez-Maroto et al, 2013). Another study was conducted on the reduction of sodium chloride of white bread by yeast leavened soy bread and sourdough soy bread. It was reported that in a consumer acceptance test with 55 panelists, 83% participants preferred yeast leavened soy bread over sourdough soy bread (Yezbick et al, 2013).

The objective of this study was to analyze the effect of sourdough and wheat-tempe flour on the flavor profile of white bread with an underlying motive of reducing sodium content with the addition of fermented products.

2 Materials and Methods

2.1 Materials

Commercial all-purpose flour. Whole wheat flour and soybeans were purchased from a local supermarket. Billing hard red winter wheat grains 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 Levain preparation (sourdough)

Sourdough culture was prepared as descried by Suas (Suas, 2008). The preparation method was five days long. On day 1, 500 g of whole wheat flour and 500 g of bread flour (all purpose) were mixed with 1000 g of tap water and incubated for 24 h. On day 2,500 g of bread flour and 500 g of tap water were mixed with 500 g of the previous day's starter and left for 6-8 h to ferment followed by another feeding of bread flour and tap water after 16-18 h. A similar formula and schedule was applied after every 6-8 h and then 16-18 h for days 3, 4 and 5. The fermentation temperature was about 27±2ºC. The final mature culture of sourdough was used in bread formulation.

2.2.2 Tempe preparation

Wheat soy bean tempe was prepared as described by Murtni (2014). Wheat and soy beans were used at 1:1 (w/w) ratio and soaked overnight. Wheat and soy beans were boiled separately for 15-20 min and cooled to room temperature by rinsing separately. The seed coat of soy beans was peeled manually. The wheat and soy beans were mixed and the inoculum (0.1% mix culture tempe inoculum) was added. The mixture was packed in zip-lock bags. The bags were perforated to allow proper air circulation. Incubation was carried out in a damp, slightly warm environment, 30±2ºC for 36-48 h. The fermented mixture was dried in an oven at 60ºC (Fisher Scientific Company LLC. Grand Prairie, TX), milled in a 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^{o}C until it was needed (Murtini, 2014).

2.2.3 Baking and Sensory

Three baking and sensory evaluation sessions were conducted using a combination of sourdough (0, 11, 17 and 33%), tempe (0, 2, 3.5 and 5%) and sodium chloride (0, 0.5, 0.75 and 1.5%). A 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 100g mixer (Swanson-Working pin-type, National Mfg. Co. TMCO Inc, Lincoln, NE). Optimum mixing time was obtained from various baking trials. After baking, breads were cooled down and stored in polythene zip-lock bags for 24 h. Bread loaves were sliced in 2*2 cm size pieces for sensory analysis. Each treatment had a random three digit code assigned. A consumer acceptance test was conducted with 80 untrained panelists at the Oklahoma State University campus in Stillwater, OK. A sample of sensory tools is in Appendix II. A nine point hedonic scale was used to evaluate the flavor profile of bread (saltiness, sweetness, bitterness, sourness, pasteboardy, aroma and overall palatability). The panelists participated voluntarily and were comprised of students, staff and faculty members, with age range from 18 to 60 years. The sensory evaluation was approved by Institutional Review Board (IRB) at Oklahoma State University.

2.3 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 3x3x2. The experimental design was randomized complete block.

3. Results

3.1 Sensory analysis of bread

3.1.1 First sensory analysis

In the first sensory analysis of bread session, sourdough was added in different combinations, e.g., 11, 17 and 33%, whereas tempe was added at two levels, 0 and 5% respectively. Sodium chloride was added at 0.5, 1 and 1.5%.

3.1.1.1 Saltiness

3.1.1.1.1 Effect of Salt

One important parameter in the sensory analysis of the bread was saltiness. Sodium chloride levels were compared at different levels of sourdough and tempe. No significantly different saltiness was perceived with treatments containing 11% sourdough and 0% tempe among three levels of sodium chloride (0.5, 1 and 1.5%), and an overall mean of 6.1 (Like slightly) was recorded (Table 1). Saltiness perception was not significant in the presence of 5% tempe, and an overall mean of 4.7 was recorded placing saltiness perception within the range of “Slightly disliked” and “Neither like nor dislike”. Saltiness was not perceived as significantly different with the treatment containing sourdough at 17% with 0% tempe among three levels of sodium chloride (0.5, 1 and 1.5%) with overall mean of 6.3 (Like slightly). In the presence of 5% tempe no significant saltiness was perceived and an overall mean of 4.7 was recorded, placing saltiness perception within the range of “Slightly dislike” and “Neither like nor dislike”. Sodium chloride among three levels (0.5, 1 and 1.5%) gave no significantly different saltiness perception with the treatment containing 33% sourdough level with 0% of tempe and an overall mean of 6.5 was recorded placing saltiness perception within the range of “Slight like” and “Moderately like”. In the presence of 5% tempe and 33% sourdough level, an insignificant saltiness perception was given among three levels of sodium chloride (0.5, 1 and 1.5%). In the presence of 5% tempe, the same sourdough level gave no significant difference in saltiness perception among three levels of sodium chloride and an overall mean of 5.2 (Neither like nor dislike) was recorded (Table 1).

3.1.1.1.2 Effect of Tempe

Another comparison was done to study the effect of tempe levels on saltiness. Sodium chloride among three levels (0.5, 1 and 1.5%) for treatment containing 11% sourdough in the presence of 0 or 5% tempe resulted in significantly different saltiness perception (Table 2). In this analysis, average saltiness scores of 6.2, 6.1 and 6.1 representing “Slightly like” were recorded for 0.5, 1 and 1.5% sodium chloride level in the presence of 0% tempe. In the presence of 5% tempe, average saltiness scores of 4.7, 4.7 and 5.2 representing “Neither like nor dislike” were recorded. Treatment containing 17% sourdough gave a significantly different saltiness perception among three levels of sodium chloride in the presence of 0 and 5% tempe levels, average scores of 6.1, 6.3 and 6.6 representing “Slightly like” were recorded for 0.5, 1 and 1.5% sodium chloride levels in the presence of 0% tempe. In the presence of 5% tempe, average saltiness scores of 4.8, 5.1 and 4.4 representing “Neither like nor dislike” were recorded. Treatments containing 33% of sourdough gave a significantly different saltiness perception in the presence of 0 and 5% tempe among three levels of sodium chloride. Average saltiness scores of 6.2, 6.7 and 6.8 representing “Moderately like” were recorded in the presence of 0% tempe. Saltines scores of 4.7, 5.4 and 5.5 representing “Neither like nor dislike” were recorded for 0.5, 1 and 1.5% sodium chloride levels respectively in the presence of 5% tempe (Table 2).

3.1.1.1.3 *Effect of Sourdough*

Sourdough levels were compared at given levels of tempe and sodium chloride (Table 3). Three levels of sourdough (11, 17 and 33%) in the presence of 0% tempe gave no significant difference in saltiness perception and overall means of 6.1, 6.3 and 6.5 were recorded for 0.5, 1 and 1.5% sodium chloride level respectively. In the presence of 5% tempe, sourdough levels (11, 17 and 33%) did not result in a significantly different saltiness perception for 0.5 and 1% sodium chloride level, with overall means of 4.7 and 5.0 respectively, whereas at 1.5% sodium chloride level, sourdough at 33% and 11% levels gave the same saltiness perception with an overall mean of 5.3 (Neither like nor dislike). With 16% sourdough level, an average saltiness score of 4.4 (Slightly dislike) was recorded.

3.1.1.2 Sweetness

3.1.1.2.1 *Effect of Salt*

Sodium chloride among three levels (0.5, 1 and 1.5%) at a given level of sourdough and tempe were considered. Treatment containing sourdough at 11% among three levels of sodium chloride (0.5, 1 and 1.5%) with 0% and 5% tempe resulted in sweetness perception which was not significantly different with the overall means of 5.8 and 4.4, representing “Like slightly” and “ Dislike slightly” respectively. Similarly, treatment containing sourdough at 17% with 0 and 5% tempe levels were compared among three levels of sodium chloride (0.5, 1 and 1.5%), resulting in an insignificant difference in sweetness perception with average scores of 6.1 and 4.5 respectively. In treatments containing 33% sourdough level and 0% tempe, sodium chloride among three levels (0.5, 1 and 1.5%) resulted in similar sweetness perception which was not significantly different with the overall mean of 6.2 representing “Like slightly”. In the presence of

5% tempe, the same sourdough level gave an insignificant difference in sweetness perception for three levels of sodium chloride (0.5, 1, and 1.5%) with the average score of 5 representing "Neither like nor dislike" (Appendix III Table 1)

3.1.1.2.2 Effect of Tempe

Tempe levels were compared at given levels of sourdough and sodium chloride (Appendix III Table 2). Treatment containing sourdough at 11% level in the presence of 5% and 0% tempe resulted in a significantly different sweetness perception for three levels of sodium chloride (0.5, 1 and 1.5%). At 0.5% sodium chloride level in the presence of 11% sourdough, average scores of 4.5 (within the range of "Slightly dislike" and "Neither like nor dislike") were recorded. For sweetness in the presence of 5% tempe, an average sweetness score of 6.0 for 0% tempe level was recorded. For 1% sodium chloride level, an average score of 4.2 was recorded in the presence of 5% tempe, whereas an average score of 6.0 was recorded for 0% tempe. In the presence of 1.5% sodium chloride level, an average score of 4.7 (Neither like nor dislike) was recorded when 5% tempe was present and an average score of 5.6 (Slightly like) was recorded for sweetness with 0% tempe. Treatment containing sourdough at 17% level in the presence of 0.5% sodium chloride, gave a significant difference in sweetness perception with 5% and 0% tempe levels resulting in average scores of 4.4 and 6.1 respectively. At 1% sodium chloride, the same sourdough level resulted in a significant difference of sweetness perception when tempe levels of 5% and 0% were compared with average scores of 4.7 and 6.0. In the presence of 1.5% sodium chloride, sourdough at 17% level resulted in a significantly different sweetness perception for 5% and 0% tempe levels. Panelists gave average scores of 4.3 and 6.3 respectively. Treatment containing 33% sourdough level with 0.5% sodium chloride did not result in significant sweetness perception in the presence of 5% tempe, and also with 0% tempe level. The same sourdough level in the presence of 1% sodium chloride resulted in significant difference of sweetness perception with 5% tempe and 0% tempe levels with average scores of 4.8 and 6.6 respectively. Similarly, in the presence of 1.5% sodium chloride, sourdough at 33% level gave a significant difference in sweetness perception when tempe levels of 5% and 0% were compared; panelists gave average scores of 5.3 with 5% tempe and 6.4 with 0% tempe.

3.1.1.2.3 *Effect of Sourdough*

Sourdough among three levels (11, 17 and 33%) in the presence of 0.5% sodium chloride for 0% tempe did not result in significant difference for sweetness perception with an overall mean of 6.1 representing "Like slightly" (Appendix III Table 3). At 1% and 1.5% sodium chloride level, sourdough among three levels (11, 17 and 33%) did not result in a significantly different sweetness perception when 0% tempe level was studied. At 1% NaCl, sweetness perception had an overall mean of 6.3 for three levels of sourdough, whereas at 1.5% NaCl an overall mean of 6.5 was recorded. Three levels of sourdough (11, 17 and 33%) were compared at 0.5% sodium chloride level in the presence of 5% tempe which did not result in a significantly different sweetness perception; an overall mean of 4.7 representing "Dislike slightly" was recorded. At 1% sodium chloride level, sweetness perception in the presence of 5% tempe among three levels of sourdough was not statistically significant with overall mean of 5.0. When 1.5% sodium chloride level was studied in the presence of 5% tempe, a statistically significant sweetness perception was recorded among three levels of sourdough (11, 17 and 33%). At 33% sourdough, an average score of 5.5 was recorded, whereas for 17% sourdough level the average score of 4.4 was recorded. 11% sourdough resulted in an average score of 5.2 for sweetness perception.

3.1.1.3 Sourness

3.1.1.3.1 ***Effect of Salt***

Sodium chloride levels were compared at given levels of sourdough and tempe levels (Appendix III Table 4). Treatment containing sourdough at 11% with 0% tempe resulted in the same sourness perception when three levels of sodium chloride were compared and there was no significant sourness perception recorded with an overall mean of 5.6. The same sourness was perceived in the presence of 5% tempe for the same level of sourdough with three levels of sodium chloride which means that it was not statistically significant either, with an overall mean of 4.1. Treatment containing sourdough at 17 % in the presence of 0% tempe resulted in a statistically insignificant sourness perception for three levels of sodium chloride with an overall mean of 6.0. In the presence of 5% tempe no statistically significant sourness perception was recorded either, with an overall mean of 4.2. Sodium chloride among three levels (0.5, 1 and 1.5%) in the presence of 33% sourdough at 0% tempe level did not result in a significantly different sourness perception with an overall mean of 6.1 representing “Like slightly”. Sourdough at the same level in the presence of 5% tempe did not result in significantly different sourness perception when sodium chloride was compared among three levels (0.5, 1 and 1.5%) with an overall mean of 4.6 representing “Dislike slightly”.

3.1.1.3.2 *Effect of Tempe*

Tempe levels were varied at given levels of sodium chloride and sourdough (Appendix III Table 5). Significantly different sourness perception was recorded for 11% sourdough among three levels of sodium chloride when 0% and 5% tempe levels were compared. At 5% tempe level in the presence of 11% sourdough sourness, perception scores for 0.5, 1 and 1.5% sodium chloride were 3.8, 4.3 and 4.2, and for 0% tempe average scores for three levels of sodium chloride (0.5, 1 and 1.5%) were 5.6, 5.6 and 5.6 respectively. Sourdough at 17% in the presence of three levels of sodium chloride (0.5, 1 and 1.5%) gave significantly different sourness perception when tempe was compared at 0% and 5% levels. In the presence of 5% tempe, the average scores of sourness perception for 0.5, 1 and 1.5% sodium chloride were 4.2, 4.3 and 4.1 respectively. Similarly at 0% tempe, average scores of sourness perception for 0.5, 1 and 1.5% sodium chloride were 5.8, 5.9 and 6.3. Sourdough at 33% level in the presence of 0.5% sodium chloride resulted in a significantly different sourness perception when 0% and 5% tempe levels were compared: in the presence of 5% tempe the average score recorded was 4.4 and at 0% tempe level the average score of 5.9 was recorded. At 1% and 1.5% sodium chloride, sourdough with the same level resulted in significantly different sourness perception for 5% and 0% tempe levels. At 1% sodium chloride in the presence of 5% tempe, the average score of sourness perception was 4.9, whereas at 0% tempe levels the average sourness perception score was 6.2. Similarly, for 1.5% sodium chloride in the presence of 5% tempe the average score recorded was 4.9 and in the presence of 0% tempe the average score of sourness perception was 6.9.

3.1.1.3.3 *Effect of Sourdough*

Sourdough levels were compared at given levels of tempe and sodium chloride. At 0.5% sodium chloride for 0% tempe level among three levels of sourdough

(11, 17 and 33%), no significantly different sourness perception resulted, with an overall mean of 5.7 (Appendix III Table 6). Sodium chloride at 1% in the presence of 0% tempe did not result in a significantly different sourness perception when three levels of sourdough (11, 17 and 33%) were compared among themselves with an overall mean of 5.9. The same insignificant sourness perception was recorded with an overall mean of 6.1 in the presence of 1.5% sodium chloride, 0% tempe and for three levels of sourdough. In the presence of 5% tempe, sodium chloride at 0.5% resulted in the same sourness perception, not significantly different when sourdough was compared among 11, 17 and 33% levels with an overall mean of 4.1 representing "Dislike slightly". Similarly, three levels of sourdough were compared for 1% and 1.5% sodium chloride level in the presence of 5% tempe, which gave the same sourness perception which was not significantly different with an overall mean of 4.4.

3.1.1.4 Pasteboardiness

3.1.1.4.1 ***Effect of Salt***

This parameter determines that whether the bread samples left a dry mouth after taste or not. Treatment containing sourdough at 11% gave the same pasteboardy perception, not statistically significant in the presence of 0 and 5% tempe when sodium chloride was compared among three levels (0.5, 1 and 1.5%) with an overall mean of 6 and 4.1 respectively (Appendix III Table 7). Sourdough level at 17% with 0% and 5% tempe resulted in the same pasteboardy perception which was not significantly different for three levels of sodium chloride (0.5, 1, and 1.5%) and had the overall mean of 5.7 and 4.2 representing "Like slightly" and "Dislike slightly" respectively. Sourdough at 33% with 0% tempe resulted in similar, not significant pasteboardy perception when three levels of sodium chloride (0.5, 1 and 1.5%) were compared with an overall mean of 5.7. In the presence of 5% tempe, the same sourdough level gave an insignificant pasteboardy perception with three levels of sodium chloride and an overall mean of 4.2 representing "Dislike slightly".

3.1.1.4.2 ***Effect of Tempe***

Another comparison was done to study the effect of tempe on pasteboardy perception at given levels of sourdough and sodium chloride (Apendix III Table 8). Treatment containing 11% sourdough in the presence of 0% tempe for three levels of sodium chloride (0.5,1 and 1.5%) was analyzed and gave a significantly different pasteboardy perception; panelists gave scores of 6, 6.5 and 5.5 respectively whereas in the presence of 5% tempe, the samples received the scores of 4.1, 4.1 and 4. Sourdough levels of 17% were compared with three levels of sodium chloride (0.5, 1 and 1.5%) in the presence of 0% and 5% tempe. 17% sourdough level resulted in a significantly different pasteboardy perception in the presence of 0% and 5% tempe for three levels of sodium chloride. Panelists gave scores of 5.7, 5.8 and 6 when sourdough level of 17 % was analyzed in the presence of 0% tempe for 0.5, 1 and 1.5% sodium chloride respectively. Panelists recorded the scores of 4, 4.4 and 4.3 for 0.5, 1 and 1.5% sodium chloride level in the presence of 5% tempe. Sourdough level at 33% in the presence of 0.5% sodium chloride resulted in a significantly different pasteboardy perception when tempe levels of 0% and 5% were compared; the average scores were 5.5 and 3.9 respectively. The same sourdough level in the presence of 1% sodium chloride gave significantly different scores for this particular parameter with 0% and 5% tempe; average scores were 6 and 4.1 respectively. Sourdough at 33% with 1.5% sodium chloride gave a significantly different pasteboardy perception for 0% and 5% tempe level with average scores of 5.8 and 4.6 respectively.

3.1.1.4.3 ***Effect of Sourdough***

Another comparison was done to study the effect of sourdough on this particular parameter. Sourdough among three levels (11. 17 and 33%) did not result in a significantly different pasteboardy perception in the presence of 0 and 5% tempe for three levels of sodium chloride (0.5, 1, and 1.5%). In the presence of 0% tempe, sourdough among three levels (11, 17 and 33%) with sodium chloride levels of 0.5, 1 and 1.5% resulted in overall means of 5.7, 6 and 5.7 respectively, whereas in the presence of 5% tempe the overall means of 4, 4.2 and 4.3 were recorded with 0.5, 1 and 1.5% sodium chloride (Appendix III Table 9).

3.1.1.5 Aroma

3.1.1.5.1 ***Effect of Salt***

All panelists were given bread samples in zip-lock bags and asked to smell the aroma of each bread samples for this particular parameter (Appendix III Table 10). Treatment containing sourdough level of 11% in the presence of 0% tempe gave the same aroma among three levels of sodium chloride, not significantly different with an overall mean of 6.5. Likewise, in the presence of 5% tempe, the similar aroma perception was recorded with an overall mean of 4.8. Sodium chloride among three levels (0.5, 1 and 1.5%) in the presence of 17% sourdough and 0% tempe resulted in the similar aroma perception, not significantly different with an overall mean of 6.3, whereas in the presence of 5% tempe, the similar aroma was perceived as not statistically significant with an overall mean of 4.8 representing “Dislike slightly”. At 33% sourdough level in the presence of 0% tempe, sodium chloride among three levels (0.5, 1 and 1.5%) resulted in the same aroma which was not significantly different with an overall mean of 6.4 representing “Like slightly”. The same sourdough level in the presence of 5% tempe, resulted in the similar aroma perception scores which was not significantly different for three levels of sodium chloride with an overall mean of 5.1

3.1.1.5.2 *Effect of Tempe*

Sourdough level at 11% in the presence 0.5,1 and 1.5% sodium chloride gave a significantly different aroma perception when tempe was compared among 0% and 5% tempe levels (Appendix III Table 11). For 0.5% sodium chloride, 11% sourdough gave an average score of 6.9 in the presence of 0% tempe, whereas an average score of 4.5 was recorded in the presence of 5% tempe. For 1% sodium chloride, the same sourdough gave a significantly different aroma perception with an average score of 6.4 in the presence of 0% tempe and 5.1 for 5% tempe. Sodium chloride at 1.5% with 11% sourdough resulted in an average score of 6.2 in the presence of 0% tempe and a score of 5 was recorded for 5% tempe. At 0.5% sodium chloride in the presence of 17% sourdough, a significantly different aroma perception was recorded for 0% and 5% tempe levels and average scores of 6.3 and 5 were recorded. At 1% sodium chloride level, the same sourdough level as discussed earlier resulted in a significantly different aroma perception between two levels of tempe (0, 5%) with average scores of 6.3 and 4.7 respectively. Sodium chloride at 1.5% level resulted in a significantly different aroma perception in the presence of 17% sourdough for 0% and 5% tempe levels and average scores as given by untrained panelists of 6.5 and 4.8 were recorded. Sourdough level at 33% in the presence of 0.5% sodium chloride resulted in a significantly different aroma perception for 0% and 5% tempe levels with average scores of 6.2 and 5.2 respectively. The same sourdough level in the presence of 1% sodium chloride gave a significantly different aroma perception for 0% and 5% tempe levels; average scores of 6.5 and 5.2 were recorded. At 1.5% sodium chloride level, tempe between two levels (0 and 5%) in the presence of 33% sourdough resulted in a significantly different aroma perception and average scores of 6.5 and 5.1 were recorded.

3.2.1.5.3 *Effect of Sourdough*

Sourdough was compared among three levels (11, 17 and 33%) in the presence of 0.5% sodium chloride and 0% tempe level (Appendix III Table 12). There was no significantly different aroma perception recorded among three levels of sourdough, and an overall mean of 6.4 was recorded representing “Like slightly”. Sodium chloride at 1% in the presence of 0% tempe and sourdough among three levels (11, 17 and 33%) resulted in the same aroma perception, not significantly different and a similar overall mean of 6.4 was reported. Similarly, sodium chloride at 1.5% resulted in a statistically insignificant aroma perception in the presence of 0% tempe among three levels of sourdough with an overall mean of 6.4. In the presence of 5% tempe, sourdough among three levels did not result in a significantly different scores of aroma perception when sodium chloride levels of 0.5, 1 and 1.5% were analyzed with overall means of 4.9, 5 and 4.9 respectively.

3.1.1.6 Bitterness

3.1.1.6.1 *Effect of Salt*

Sourdough level at 11% in the presence of 0% and 5% tempe resulted in the same bitterness perception when sodium chloride was compared among three levels; the overall mean of 5.7 was recorded in the presence of 0% tempe, whereas in the presence of 5% tempe, an overall mean of 3.9 was recorded for bitterness perception which represents “Dislike slightly” (Table 4). For treatments containing sourdough level of 17% in the presence of 0% tempe, sodium chloride among three levels (0.5, 1 and 1.5%) resulted in the same bitterness perception which was not significantly different and had an overall mean of 6.0 representing “Like slightly”. In the presence of 5% tempe, the same sourdough level gave an insignificant bitterness perception when sodium chloride was compared among three levels (0.5, 1 and 1.5%) and an overall mean of 3.8 was recorded that represents “Dislike slightly”. Sourdough at 33% level in the presence of 0% tempe gave the same bitterness perception for sodium chloride among three levels (0.5, 1 and 1.5%), which means that bitterness perception was not significantly different among three levels of sodium chloride and had an overall mean of 5.9 representing “Like slightly”. The same sourdough level in the presence of 5% tempe resulted in the similar bitterness perception scores with three levels of sodium chloride, which was not significantly different at all and an overall mean of 3.9 was recorded that represented” Dislike slightly”.

3.1.1.6.2 ***Effect of Tempe***

Sourdough level at 11% between two levels of tempe (0, 5%) in the presence of 0.5% sodium chloride resulted in a significantly different bitterness perception and average scores of 5.6 for 0% tempe and 3.7 for 5% tempe were recorded (Table 5). Sodium chloride at 1% level for the same sourdough level gave a significantly different bitterness perception and an average score of 5.9 was recorded for 0% tempe level and 3.9 was recorded for 5% tempe level. At 1.5% sodium chloride level, a significant bitterness perception was recorded with 0% and 5% tempe level and average scores of 5.7 and 4.5 were recorded. Tempe between two levels (0, 5%) in the presence of 17% sourdough and 0.5% sodium chloride resulted in a significant bitterness perception; panelists recorded an average score of 6.0 in the presence of 0% tempe and 4.0 in the presence of 5% tempe level. The same sourdough level in the presence of 1% sodium chloride gave a significant bitterness perception for 0% and 5% tempe levels with average scores of 6.0 and 3.8 respectively. At 1.5% sodium chloride in the presence of 0% and 5% tempe for the same sourdough, significantly different bitterness perceptions were recorded with average scores of 6.1 and 3.8. Sourdough at 33% level in the presence of 0.5% sodium chloride gave significantly different bitterness perceptions in the presence of 0% and 5% tempe and average scores of 6.1 and 3.8 respectively were recorded. The same sourdough level in the presence of 1% sodium chloride gave statistically significant bitterness perception for 0% and 5% tempe levels and average scores of 6.1 and 4.3 were recorded. In the presence of 1.5% sodium chloride level, 33% sourdough also resulted in a significant bitterness perception for 0% and 5% tempe levels; average scores of 5.8 and 3.8 respectively were recorded.

3.1.1.6.3 ***Effect of Sourdough***

Sourdough among three levels (11, 17 and 33%) in the presence of 0.5% sodium chloride and 0% tempe resulted in similar bitterness perception, which was not significant with an overall mean of 5.9 recorded (Table 6). In the presence of 1% sodium chloride sourdough among three levels resulted in same bitterness perception for 0% tempe, which was not significantly different with an overall mean of 6.0 recorded. At 1.5% sodium chloride, similar bitterness was perceived among three levels of sourdough in the presence of 0% tempe and an overall mean of 5.8 was recorded. In the presence of 5% tempe, sourdough among three levels with 0.5% sodium chloride gave similar insignificant bitterness perception with an overall mean of 3.8. Similarly in the presence of 5% tempe, sourdough among three levels gave similar bitterness perception, which was not significant, and an overall mean of 4 was recorded for both 1% and 1.5% sodium chloride.

3.1.1.7 Overall palatability

3.1.1.7.1 ***Effect of Salt***

Sodium chloride among three levels (0.5, 1 and 1.5%) with 11% sourdough gave the same palatability perception for 0% and 5% tempe, with overall means of 6.1 and 4.2

respectively. Sourdough at 17% level in the presence 0% tempe resulted in the same palatability which was not statistically significant among three levels of sodium chloride (0.5, 1 and 1.5%) with an overall mean of 6.4. In the presence of 5% tempe with the same sourdough level, sodium chloride among three levels gave similar palatability, not significantly different with an overall mean of 4.2 (Table 7). Sourdough level at 33% in the presence of 0% tempe gave the same insignificant palatability perception among three levels of sodium chloride (0.5, 1 and 1.5%) and an overall mean of 6.5 representing "Like slightly". The same sourdough level in the presence of 5% tempe gave the same palatability which was not significantly different among three levels of sodium chloride with an overall mean of 4.3 representing "Dislike slightly".

3.1.1.7.2 ***Effect of Tempe***

Sourdough levels at 11% also resulted in a significantly different palatability for 0.5, 1 and 1.5% sodium chloride in the presence of 0% and 5% tempe levels (Table 8). At 0.5% sodium chloride and 11% sourdough, significantly different scores were recorded between two levels of tempe. For 0% tempe, an average score of 6.1 was recorded, and for 5% tempe, an average score of 4 was recorded. At 1% sodium chloride, an average score of 6.3 was recorded in the presence of 0% tempe and 4.4 in the presence of 5% tempe. For 1.5% sodium chloride, an average score of 6 was recorded in the presence of 0% tempe and an average score of 4.3 was recorded when 5% tempe was present. Sourdough level at 17% in the presence of 0.5% sodium chloride level resulted in significantly different palatability scores among 0% and 5% tempe levels with average scores of 6.3 and 4.4 respectively. In the presence of 1% sodium chloride, the same sourdough level gave a significantly different palatability with an average score of 6.4 with 0% tempe and 4.1 with 5% tempe. Similarly, with 1.5% sodium chloride a significantly different palatability was recorded with an average score of 6.7 in the presence of 0% tempe and 4.2 in the presence of 5% tempe. Sourdough level at 33% in the presence of 0.5% sodium chloride resulted in a significantly different palatability among 0% and 5% tempe levels with average scores of 6.3 and

4.2 respectively. The same sourdough level in the presence of 1% sodium chloride gave a significantly different palatability for 0% and 5% tempe, and average scores of 6.6 and 4.6 were recorded. Sodium chloride at 1.5% in the presence of 33% sourdough gave a significantly different palatability scores between two levels of tempe with an average score of 6.7 recorded for 0% tempe and 4.2 for 5% tempe level.

3.1.1.7.3 ***Effect of Sourdough***

Sodium chloride at 0.5% in the presence of 0% tempe resulted in the same palatability among three levels of sourdough (11, 17 and 33%) with an overall mean of 6.2 representing "Like slightly" (Table 9). Sourdough among three levels (11, 17 and 33%) in the presence of 1% sodium chloride and 0% tempe gave the same palatability which was not significant with an overall mean of 6.4. At 1.5% sodium chloride level with 0% tempe, the same palatability was recorded, not significant with an overall mean of 6.4. In the presence of 5% tempe, sourdough among three levels (11, 17 and 33%) with 0.5, 1 and 1.5% sodium chloride resulted in the same palatability, which was not significant with an overall mean of 4.2, 4.3 and 4.2 representing "Dislike slightly"

3.1.2 Second sensory analysis

The objective of the second sensory session was to compare breads with reduced sodium content and a combination of fermented products to study their effect on the flavor profile of the bread. In this sensory session, sourdough was added in 0%, 17% and 33% levels and tempe percentage was reduced from 5% to 2% and there were two combinations of tempe used, 0% and 2%. Sodium chloride was used in 0%, 0.75% and 1.5%. These combinations were chosen based on the statistical analysis of the first sensory session. This sensory session had 18 treatments was analyzed by 80 untrained panelists.

3.1.2.1 Saltiness

3.1.2.1.1 ***Effect of Salt***

Sodium chloride among three levels (0. 0.75 and 1.5%) in the presence of 0% sourdough and tempe resulted in significantly different saltiness perceptions (Table 10). Sodium chloride at 0.75 and 1.5% gave the same saltiness perception with an overall mean of 5.6 representing "Neither like nor dislike", whereas with 0% sodium chloride an average score of 4.6 was recorded which represents "Dislike slightly". In the presence of 2% tempe, sodium chloride among three levels gave significantly different saltiness perceptions. With 0.75 and 1.5% sodium chloride, the same saltiness was perceived with 2% tempe and an overall mean of 5.4 (Neither like nor dislike) was recorded, but with 0% sodium chloride and 2% tempe,an average score of 4.1 (Dislike slightly) was recorded. Sodium chloride among three levels resulted in a significantly different saltiness perception in the presence of 0% tempe and 17% sourdough. Sodium chloride at 0.75 and 1.5% levels gave the same saltiness perception in the presence of 0% tempe with an overall mean of 5.5, and with 0% sodium chloride an average score of 3.9 was recorded. In the presence of 17% sourdough and 2% tempe, significantly different saltiness perceptions were recorded among three levels of sodium chloride. 0.75 and 1.5% sodium chloride resulted in the same saltiness perception with an overall mean of 5.3, but with 0% sodium chloride a significantly different saltiness was perceived with an average score of 3.8. Sourdough at 33% with 0% tempe resulted in significantly different saltiness perceptions among three levels of sodium chloride (0, 0.75 and 1.5%). Sodium chloride at 0.75 and 1.5% level with 33% sourdough gave the same saltiness perception with an overall mean of 5.3 (Neither like nor dislike), whereas with 0% sodium chloride and 33% sourdough, an average score of 4.3 (Dislike slightly) was recorded (Table 22). A similar trend was noticed in the presence of 2% tempe and 33% sourdough. Sodium chloride at 0.75 and 1.5% level resulted in the same saltiness perception with an overall mean of 5, and with 0% sodium chloride a significantly different saltiness was perceived with an average score of 3.9 (Dislike slightly).

3.1.2.1.2 *Effect of Tempe*

In the presence of 0 and 2% level of tempe, saltiness perception was not detected as significantly different by consumers. At all three levels of sodium chloride (0, 0.75 and 1.5%), saltiness perception was not significantly different in the presence of 0 and 2% tempe (Table 11). Sodium chloride at 0% along with 0 and 2% tempe resulted in the same saltiness perception with an overall mean of 4.3 (Dislike slightly). Similarly, in the presence of 0.75 and 1.5% sodium chloride along with 2% tempe, the same saltiness was recorded. With 0.75% sodium chloride an overall mean of 5.4 was reported, and with 1.5% sodium chloride an overall mean of 5.6 was recorded. Sourdough at 17% along with 0 and 2% tempe also resulted in the same saltiness perception when each sodium chloride level was compared. At 0% sodium chloride, sourdough at 17% with 0 and 2% tempe gave the same saltiness perception, which was not significant; an overall mean of 3.8 (Dislike slightly) was recorded. The same sourdough level with 0 and 2% tempe in the presence of 0.75% sodium chloride resulted in the same saltiness perception with an overall mean of 5.5 (Neither like nor dislike). Sodium chloride at 1.5% level gave an overall mean of 5.3 in the presence of 17% sourdough along with 0 and 2% tempe. Similarly, with 33% sourdough along with 0 or 2% tempe, three levels of sodium chloride resulted in the same saltiness perception, which was not significant. With 0% sodium chloride along with 33% sourdough in the presence of 0 and 2% tempe, an overall mean of 4.1 (Dislike slightly) was recorded, whereas with 0.75% sodium chloride along with 33% sourdough in the presence of 0 and 2% tempe, an overall mean of 5 (Neither like nor dislike) was recorded. Sodium chloride at 1.5% level in the presence of 33% sourdough along with 0 and 2% tempe resulted in the same saltiness perception which was not significant, with an overall mean of 5.3 (Neither like nor dislike).

3.1.2.1.3 *Effect of Sourdough*

Sourdough among three levels (0. 17 and 33%) with 0% sodium chloride did not affect the saltiness perception significantly, with an overall mean of 4.2 (Dislike slightly) recorded (Table 12). In the presence of 0% tempe and 0.75% sodium chloride, the same saltiness perception was recorded when sourdough was compared among three levels (0. 17 and 33%), with an overall mean of 5.4 (Neither like nor dislike) recorded. Similarly, in the presence of 1.5% sodium chloride and 0% tempe, the same saltiness was perceived by untrained panelists among three levels of sourdough and an overall mean of 5.5 (Neither like nor dislike) was reported. Sodium chloride at 0, 0.75 and 1.5% level in the presence of 2% tempe resulted in the same saltiness perception among three levels of sourdough (0, 17 and 33%); overall mean of 3.9 was recorded with 0% sodium chloride, and with 0.75% sodium chloride an overall mean of 5.1 was recorded. Similarly, with 1.5% sodium chloride an overall mean of 5.3 was recorded.

3.1.2.2 Sweetness

3.1.2.2.1 Effect of Salt

Sodium chloride among three levels (0, 0.75 and 1.5%) in the presence of 0% sourdough and tempe resulted in significantly different sweetness perceptions. Sodium chloride at 0.75 and 1.5% gave the same sweetness perception with an overall mean of 5.7 representing "Slightly like" (Appendix III Table 13), whereas with 0% sodium chloride an average score of 4.7 was recorded which represents "Dislike slightly". In the presence of 2% tempe, sodium chloride among three levels gave a significantly different sweetness perception. With 0.75 and 1.5% sodium chloride, the same sweetness was perceived with 2% tempe and an overall mean of 5.1 (Neither like nor dislike) was recorded, but with 0% sodium chloride and 2% tempe, an average score of 4.7

(Neither like nor dislike) was recorded. Sodium chloride among three levels resulted in significantly different sweetness perceptions in the presence of 0% tempe and 17% sourdough. Sodium chloride at 0.75 and 1.5% levels gave the same sweetness perception in the presence of 0% tempe with an overall mean of 5.4 (Neither like nor dislike), and with 0% sodium chloride an average score of 4.4 (Slightly dislike) was recorded. The same sourdough with 2% tempe gave a significantly different sweetness perception among three levels of sodium chloride (0, 0.75 and 1.5%). An average score of 4.7 (Neither like nor dislike) was recorded with 0.75% sodium chloride, and with 1.5% sodium chloride an average score of 4.5 (Slightly dislike) was recorded. Sodium chloride at 0% gave an average score of 3.7 (Slightly dislike). Sourdough at 33% in the presence of 0% tempe resulted in the same, not significant sweetness perception among three levels of sodium chloride (0, 0.75 and 1.5%), and an overall mean of 4.8 (Neither like nor dislike) was recorded. In the presence of 2% tempe and 33% sourdough, sodium chloride at 0.75 and 1.5% levels resulted in the same sweetness perception with an overall mean of 4.7 (Neither like nor dislike), and with 0% sodium chloride a significantly different sweetness was perceived with average score of 3.7 (Dislike slightly).

3.1.2.2.2 Effect of Tempe

At three levels of sodium chloride (0, 0.75 and 1.5%), sweetness perception was not different in the presence of 0 and 2% of tempe (Appendix III Table 14). Sodium chloride at 0% along with 0 and 2% tempe resulted in the same sweetness perception with an overall mean of 4.3 (Dislike slightly). Similarly, in the presence of 0.75 and 1.5% sodium chloride along with 0 and 2% tempe, the same sweetness was recorded. With 0.75% sodium chloride an overall mean of 5.3 (Neither like nor dislike) was reported, and with 1.5% sodium chloride an overall mean of 5.5 (Neither like nor dislike) was recorded. Sourdough at 17% along with 0 and 2% tempe also resulted in the same sweetness perception when each sodium chloride level was compared. At 0% sodium chloride, sourdough 17% with 0 and 2% tempe gave the same sweetness perception, which was not significant; an overall mean of 4 (Dislike slightly) was recorded. The same sourdough level with 0 and 2% tempe in the presence of 0.75% sodium chloride resulted in the same, not significant sweetness perception, with an overall mean of 5.1 (Neither like nor dislike). Sodium chloride at 1.5% level with 17% of sourdough among the two levels of tempe resulted in a significantly different sweetness perception. Average scores of 5.3 in the presence of 0% tempe and 4.5 in the presence of 2% tempe were recorded. Sourdough with 33% along with 0 and 2% tempe in the presence of 0% sodium chloride resulted in a significantly different sweetness perception and an average scores of 4.5 (Dislike slightly) was recorded in the presence of 0% tempe. An average score of 3.7 was recorded in the presence of 2% tempe. Sodium chloride at 0.75% along with 33% sourdough in the presence of 0 and 2% tempe reported the same sweetness perception, which was not significant, with an overall mean of 4.7(Neither like nor dislike) recorded. Sodium chloride at 1.5% level in the presence of 33% sourdough along with 0 and 2% tempe resulted in the same, not significant sweetness perception and an overall mean of 5 (Neither like nor dislike) was recorded.

3.1.2.2.3 ***Effect of Sourdough***

Sourdough among three levels (0. 17 and 33%) with 0% sodium chloride did not affect the sweetness perception significantly, and an overall mean of 4.5 (Dislike slightly) was recorded (Appendix III Table 15). In the presence of 0% tempe and 0.75% sodium chloride, the same sweetness perception was recorded when sourdough was compared among three levels (0. 17 and 33%) and an overall mean of 5.3 (Neither like nor dislike) was recorded. Similarly in the presence of 1.5% sodium chloride and 0% tempe, the same sweetness was perceived by untrained panelists among three levels of sourdough and an overall mean of 5.4 (Neither like nor dislike) was reported. Sodium chloride at 0, 0.75 and 1.5% levels in the presence of 2% tempe resulted in the same, not significant sweetness perception among three levels of sourdough (0, 17 and 33%); an overall mean of 3.8 (Slightly dislike) was recorded with 0% sodium chloride, and with 0.75%

sodium chloride an overall mean of 4.7 (Neither like nor dislike) was recorded. Similarly with 1.5% sodium chloride, the overall mean of 4.8 was recorded.

3.1.2.3 Sourness

3.1.2.3.1 ***Effect of Salt***

Sodium chloride among three levels (0. 0.75 and 1.5%) in the presence of 0% sourdough and tempe resulted in significantly different sourness perceptions. Sodium chloride at 0.75 and 1.5% gave significantly different sourness perceptions with average scores of 5.1 and 5.6 respectively, representing “Neither like nor dislike” (Appendix III Table 16), whereas with 0% sodium chloride an average score of 4.5 was recorded which represents “Dislike slightly”. In the presence of 2% tempe, sodium chloride among three levels gave significantly different sourness perceptions, with 0.75 and 1.5% sodium chloride the same sourness was perceived with 2% tempe and an overall mean of 5.2 (Neither like nor dislike) was recorded, but with 0% sodium chloride and 2% tempe, an average score of 4.1 (Slightly dislike) was recorded. Sodium chloride among three levels resulted in significantly different sourness perceptions in the presence of 0% tempe and 17% sourdough. Sodium chloride at 0.75 and 1.5% levels gave the same sourness perception in the presence of 0% tempe with an overall mean of 5.4 (Neither like nor dislike), and with 0% sodium chloride an average score of 4.2 (Slightly dislike) was recorded. The same sourdough level with 2% tempe gave significantly different sourness perceptions among three levels of sodium chloride (0, 0.75 and 1.5%). An average score of 4.6 (Neither like nor dislike) was recorded with 0.75% sodium chloride, and with 1.5% sodium chloride an average score of 4.5 (Slightly dislike) was recorded. Sodium chloride at 0% gave an average score of 3.6 (Slightly dislike). Sourdough at 33% in the presence of 0% tempe resulted in the same, not significant sourness perception among three levels of sodium chloride (0, 0.75 and 1.5%), and overall mean of 4.8 (Neither like nor dislike) was recorded. In the presence of 2% tempe and 33% sourdough, sodium chloride at 0.75 and 1.5% levels resulted in the same sourness perception with overall mean of 4.8 (Neither like nor dislike), and with 0% sodium chloride a significantly different sourness was perceived with an average score of 3.2 (Dislike moderately).

3.1.2.3.2 ***Effect of Tempe***

At three levels of sodium chloride (0, 0.75 and 1.5%), sourness perception was not different among 0 and 2% of tempe. Sodium chloride at 0% along with 0 and 2% tempe resulted in the same sourness perception with an overall mean of 4.3 (Dislike slightly) (Appendix III Table 17). Similarly, in the presence of 0.75 and 1.5% sodium chloride along with 0 and 2% tempe, the same sourness was recorded. With 0.75% sodium chloride an overall mean of 5 (Neither like nor dislike) was reported, and with 1.5% sodium chloride an overall mean of 5.5 (Neither like nor dislike) was recorded. Sourdough at 17% along with 0 and 2% tempe also resulted in the same sourness perception when each sodium chloride level was compared. At 0% sodium chloride, sourdough 17% with 0 and 2% tempe gave the same sourness perception, which was not significant; an overall mean of 3.9 (Dislike slightly) was recorded. The same sourdough level with 0 and 2% tempe in the presence of 0.75% sodium chloride resulted in the same, not significant sourness perception with an overall mean of 5 (Neither like nor dislike). Sodium chloride at 1.5% level resulted in a significantly different sourness perception and an overall mean of 5 was recorded in the presence of 17% sourdough along with 0 and 2% tempe. Sourdough with 33% along with 0 and 2% tempe in the presence of 0% sodium chloride resulted in a significantly different sourness perception and an average score of 4.3 (Slightly dislike) was recorded with 0% tempe and an average score of 3.2 (Moderately dislike) was recorded in the presence of 2% tempe. Sodium chloride at 0.75% along with 33% sourdough in the presence of 0 and 2% tempe gave the same sourness perception, which was not significant; an overall mean of 4.7 (Neither like nor dislike) was recorded. Sodium chloride at 1.5% level in the presence of 33%

sourdough along with 0 and 2% tempe resulted in the same, not significant sourness perception and an overall mean of 5.1 (Neither like nor dislike) was recorded.

3.1.2.3.3 *Effect of Sourdough*

Sourdough among three levels (0. 17 and 33%) with 0% sodium chloride did not affect the sourness perception significantly, and an overall mean of 4.3 (Dislike slightly) was recorded (Appendix III Table 18). In the presence of 0% tempe and 0.75% sodium chloride, the same sourness perception was recorded when sourdough was compared among three levels (0. 17 and 33%), and an overall mean of 5.1 (Neither like nor dislike) was recorded. Similarly, in the presence of 1.5% sodium chloride and 0% tempe, the same sourness was perceived by untrained panelists among three levels of sourdough and an overall mean of 5.4 (Neither like nor dislike) was reported. Sodium chloride at 0, 0.75 and 1.5% level in the presence of 2% tempe resulted in the same, not significant sourness perception among three levels of sourdough (0, 17 and 33%); an overall mean of 3.6 (Slightly dislike) was recorded with 0% sodium chloride, and with 0.75% sodium chloride an overall mean of 4.7 (Neither like nor dislike) was recorded. Similarly, with 1.5% sodium chloride the average score of 5 was recorded.

3.1.2.4 Pasteboardy

3.1.2.4.1 *Effect of Salt*

Pasteboardy is defined as a dry mouth feel. This parameter measures dry mouth aftertaste of the bread products under study. This parameter was compared in three sets. In first comparison, variation in sodium chloride levels was studied (Appendix III Table 19). Sodium chloride among three levels (0. 0.75 and 1.5%) in the presence of 0% sourdough and tempe resulted in significantly different pasteboardy perceptions. Sodium chloride at 0.75 and 1.5%

gave significantly different pasteboardy perceptions with average scores of 4.9 and 5.5 respectively, representing “Neither like nor dislike”, whereas with 0% sodium chloride an average score of 4.3 was recorded which represents “Dislike slightly”. In the presence of 2% tempe, sodium chloride among three levels gave significantly different pasteboardy perceptions. With 0.75 and 1.5% sodium chloride the same pasteboardiness was perceived with 2% tempe and average score of 4.9 (Neither like nor dislike) was recorded, but with 0% sodium chloride and 2% tempe, an average score of 3.4 (Moderately dislike) was recorded. Sourdough at 17% in the presence of 0 and 2% tempe resulted in the same pasteboardy perception among three levels of sodium chloride, with an overall mean of 4.2 in the presence of 0% tempe and 3.9 in the presence of 2% tempe were recorded. Sourdough at 33% in the presence of 0% tempe resulted in significantly different pasteboardy perceptions among three levels of sodium chloride. Sodium chloride at 0 and 0.75% resulted in the same pasteboardy perception with an overall mean of 3.7 (Slightly dislike), whereas with 1.5% sodium chloride an average score of 5.1 was recorded. The same sourdough level in the presence of 2% tempe resulted in the same pasteboardy perception among three levels of sodium chloride with an overall mean of 4.3 (Slightly dislike).

3.1.2.4.2 *Effect of Tempe*

Sodium chloride at 0% along with 0 and 2% tempe resulted in the same pasteboardy perception with an overall mean of 3.8 (Dislike slightly) (Appendix III Table 20). Similarly, in the presence of 0.75 and 1.5% sodium chloride along with 0 and 2% tempe the same, not significant pasteboardy perception was recorded. With 0.75% sodium chloride an overall mean of 4.8 was reported and with 1.5% sodium chloride an overall mean of 5.2 was recorded. Sourdough at 17% along with 0 and 2% tempe also resulted in the same pasteboardy perception when each sodium chloride level was compared. At 0% sodium chloride, sourdough 17% with 0 and 2% tempe gave the same pasteboardy perception, which was not significant. An overall mean of 3.4 (Dislike slightly) was recorded. The same sourdough level with 0 and 2% tempe in the presence of 0.75% sodium chloride resulted in same pasteboardy perception with an overall mean of 4.4 (Slightly dislike). Sodium chloride at 1.5% level gave an overall mean of 4.4 in the presence of 17% sourdough along with 0 and 2% tempe. Similarly with 33% sourdough along with 0 or 2% tempe, three levels of sodium chloride resulted in same pasteboardy perception, which was not significant. With 0% sodium chloride along with 33% sourdough in the presence of 0 and 2% tempe, an overall mean of 3.7 (Dislike slightly) was recorded, whereas with 0.75% sodium chloride along with 33% sourdough in the presence of 0 and 2% tempe, an overall mean of 4.1 (slightly dislike) was recorded. Sodium chloride at 1.5% level in the presence of 33% sourdough along with 0 and 2% tempe resulted in the same pasteboardy perception, which was not significant, and an overall mean of 4.9 (Neither like nor dislike) was recorded.

3.1.2.4.3 *Effect of Sourdough*

Sourdough among three levels (0. 17 and 33%) with 0% sodium chloride did not affect the pasteboardy perception significantly, and an overall mean of 3.8 (Dislike slightly) was recorded (Appendix III Table 21). In the presence of 0% tempe and 0.75% sodium chloride the same, not significant pasteboardy perception was recorded when sourdough was compared among three levels (0. 17 and 33%) and an overall mean of 4.3 (Slightly dislike) was recorded. Similarly, in the presence of 1.5% sodium chloride and 0% tempe, the same pasteboardy perception was perceived by untrained panelists among three levels of sourdough and overall mean of 5 (Neither like nor dislike) was reported. Sodium chloride at 0, 0.75 and 1.5% level in the presence of 2% tempe resulted in the same, not significant pasteboardy perception among three levels of sourdough (0, 17 and 33%), and an overall mean of 3.5 (Slightly dislike) was recorded with 0% sodium chloride, and with 0.75% sodium chloride an overall mean of 4.5 (Neither like nor dislike) was recorded. Similarly, with 1.5% sodium chloride the overall mean of 4.6 was recorded.

3.1.2.5 Aroma

3.1.2.5.1 ***Effect of Salt***

Aroma of any product is very important as it plays an important role in its edibility. Levels of sodium chloride did not result in a significant difference in aroma of these particular bread products (Appendix III Table 22). Sodium chloride among three levels (0. 0.75 and 1.5%) resulted in the same, not significant aroma perception in the presence of 0% sourdough and tempe with an overall mean of 5.9 (Like slightly). Tempe at 2% also resulted in the same, not significantly different aroma perception among three levels of sodium chloride with an overall mean of 5.1 (Neither like nor dislike). Sourdough at 17% in the presence of 0 and 2% tempe also gave an insignificant aroma perception among three levels of sodium chloride (0, 0.75 and 1.5%) with an overall mean of 5.8 (Like slightly) with 0% tempe, and with 2% tempe an overall mean of 5.1 was recorded. Sourdough at 33% in the presence of 0 and 2% tempe resulted in the same aroma perception; an overall mean of 5.5 was recorded with 0% tempe and an overall mean of 4.8 with 2% tempe was reported.

3.1.2.5.2 ***Effect of Tempe***

Sodium chloride at 0% along with 0 and 2% tempe resulted in the same aroma perception with an overall mean of 5.3 (Neither like nor dislike) (Appendix III Table 23). In the presence of 0.75% sodium chloride along with 0 and 2% tempe, a significantly different aroma perception was recorded. With 0.75% sodium chloride an average score of 6 (Like slightly) was reported with 0% tempe, whereas with 2% tempe an average score of 5 (Neither like nor dislike) was recorded. Sodium chloride at 1.5% gave the same, not significantly different aroma perception with 0 and 2% tempe; an overall mean of 5.8 (Like slightly) was recorded. Sourdough at 17%

along with 0 and 2% tempe also resulted in the same aroma perception when each sodium chloride level was compared. At 0% sodium chloride, sourdough 17%, with 0 and 2% tempe gave the same, not significantly different aroma perception and an overall mean of 5.4 (Neither like nor dislike) was recorded. The same sourdough level with 0 and 2% tempe in the presence of 0.75% sodium chloride resulted in a not significantly different aroma perception with an overall mean of 5.7 (Like slightly).Sodium chloride at 1.5% level gave an overall mean of 5.3 in the presence of 17% sourdough along with 0 and 2% tempe. Similarly, with 33% sourdough along with 0 or 2% tempe, the three levels of sodium chloride resulted in the same aroma perception, which was not significant. With 0% sodium chloride along with 33% sourdough in the presence of 0 and 2% tempe, an overall mean of 4.7 (Neither like nor dislike) was recorded, whereas with 0.75% sodium chloride along with 33% sourdough in the presence of 0 and 2% tempe, an overall mean of 5.4 (Neither like nor dislike) was recorded. Sodium chloride at 1.5% level in the presence of 33% sourdough along with 0 and 2% tempe resulted in the same, not significantly different aroma perception and an overall mean of 5.3 (Neither like nor dislike).

3.1.2.5.3 ***Effect of Sourdough***

Sourdough among three levels (0. 17 and 33%) with 0% sodium chloride did not affect the aroma perception significantly, and an overall mean of 5.5 (Neither like nor dislike) was recorded (Appendix III Table 24). In the presence of 0% tempe and 0.75% sodium chloride the same, not significantly different aroma perception was recorded when sourdough was compared among three levels (0. 17 and 33%) and an overall mean of 5.9 (Like slightly) was recorded. Similarly, in the presence of 1.5% sodium chloride and 0% tempe, the same aroma perception was perceived by untrained panelists among the three levels of sourdough and an overall mean of 5.8 (Like slightly) was reported. Sodium chloride at 0, 0.75 and 1.5% level in the presence of 2% tempe resulted in the same, not significant aroma perception among three levels of sourdough (0, 17 and 33%), and an overall mean of 4.7 (Neither like nor dislike) was recorded with 0% sodium chloride, and with 0.75% sodium chloride an overall mean of 5.1 (Neither like nor dislike) was recorded. Similarly, with 1.5% sodium chloride an overall mean of 5.1 was recorded.

3.1.2.6 Bitter

3.1.2.6.1 ***Effect of Salt***

Sodium chloride among three levels (0, 0.75 and 1.5%) in the presence of 0% sourdough and tempe resulted in a not significantly different bitterness perception with an overall mean of 5.2 (Neither like nor dislike). Tempe at 2% with 0% sourdough also resulted in a not significantly different bitterness perception among the three levels of sodium chloride and an overall mean of 4.4 (Dislike slightly) was recorded (Table 13). Sourdough at 17% level with 0% tempe gave a significantly different bitterness perception among three levels of sodium chloride. The same bitterness was perceived with 0.75 and 1.5% sodium chloride level with an average score of 5.2, and with 0% sodium chloride an average score of 3.8 was recorded. A similar trend was noticed with 17% sourdough and 2% tempe. With 0.75 and 1.5% sodium chloride the same bitterness was perceived with an average score of 4.7, and with 0% sodium chloride an average score of 3.4 was recorded. Sourdough at 33% level along with 0% tempe resulted in the same bitterness perception among three levels of sodium chloride (0, 0.75 and 1.5%), which was not significant, and an overall mean of 4.5 (Dislike slightly) was recorded. The same sourdough level with 2% tempe resulted in a significantly different bitterness perception among three levels of sodium chloride. At 0.75 and 1.5% sodium chloride level, the same bitterness was perceived with an overall mean of 4.5 (Dislike slightly), and with 0% sodium chloride an overall mean of 3.1 (Dislike moderately) was recorded.

3.1.2.6.2 *Effect of Tempe*

Sodium chloride at 0% along with 0 and 2% tempe resulted in the same bitterness perception with an overall mean of 4.4 (Dislike slightly). In the presence of 0.75% sodium chloride along with 0 and 2% tempe the same, not significantly different bitterness perception was recorded with an overall mean of 4.9 (Table 14). Sodium chloride at 1.5% gave a significantly different bitterness perception with 0 and 2% tempe. An average score of 5.6 (Like slightly) was recorded with 0% tempe, and with 2% tempe an average score of 4.8 was recorded. Sourdough at 17% along with 0 and 2% tempe also resulted in the same bitterness perception when each sodium chloride level was compared. At 0% sodium chloride, sourdough 17% with 0 and 2% tempe gave the same, not significantly different bitterness perception and an overall mean of 3.6 (Dislike slightly) was recorded. The same sourdough level with 0 and 2% tempe in the presence of 0.75 and 1.5% sodium chloride resulted in a not significantly different bitterness perception with an overall mean of 5 (Neither like nor dislike), and with sodium chloride at 1.5% level an overall mean of 4.9 was recorded. Treatment containing 33% sourdough along with 0% tempe resulted in a significantly different bitterness perception. An average score of 4.4 was recorded with 0% tempe, whereas with 2% tempe an average score of 3.1 was recorded. With 0.75 and 1.5% Sodium chloride along with 33% sourdough in the presence of 0 and 2% tempe the same, not significantly different bitterness was perceived with an overall mean of 4.7 (Neither like nor dislike) in the presence of 0.75% sodium chloride, whereas with 1.5% sodium chloride an overall mean of 4.4 (Dislike slightly) was recorded.

3.1.2.6.3 *Effect of Sourdough*

Sourdough served as a variable at a given level of tempe and sodium chloride (Table 15). Sourdough among three levels (0. 17 and 33%) with 0 and 0.75% sodium chloride did not affect the bitterness perception significantly, and overall means of 4.3 (Dislike slightly) and 5 were recorded respectively. In the presence of 0% tempe and 1.5% sodium chloride a significantly different bitterness perception was recorded when sourdough was compared among three levels (0. 17 and 33%). With 0% sourdough, an average score of 5.6 was recorded. An average score of 4.6 was recorded with 33% sourdough, and with 17% sourdough an average score of 5.3 was recorded. Sodium chloride at 0, 0.75 and 1.5% level in the presence of 2% tempe resulted in the same, not significant bitterness perception among three levels of sourdough (0, 17 and 33%). An overall mean of 3.5 (Dislike slightly) was recorded with 0% sodium chloride, and with 0.75% sodium chloride an overall mean of 4.6 (Neither like nor dislike) was recorded. Similarly, with 1.5% sodium chloride an overall mean of 4.5 was recorded.

3.1.2.7 Overall palatability

3.1.2.7.1 *Effect of Salt*

This parameter helped to identify which treatments were more likeable than others. Sodium chloride among three levels (0. 0.75 and 1.5%) in the presence of 0% sourdough and tempe resulted in significantly different palatability perceptions (Table 16). Sodium chloride at 0.75 and 1.5% gave the same palatability with an average score of 4.9 representing “Neither like nor dislike”, whereas with 0% sodium chloride an average score of 4.6 was recorded which represents “Dislike slightly”. In the presence of 2% tempe, sodium chloride among three levels gave significantly different palatability perceptions, with 0.75 and 1.5% sodium chloride the same palatability was perceived with 2% tempe and an average score of 4.9 (Neither like nor dislike) was recorded, but with 0% sodium chloride and 2% tempe, an average score of 3.8 (Dislike slightly) was recorded. Sodium chloride among three levels resulted in significantly different palatability perceptions in the presence of 0% tempe and 17% sourdough. Sodium chloride at 0.75 and 1.5% levels gave the same palatability in the presence of 0% tempe with an average score of 5.8, and with 0% sodium chloride an average score of 3.6 was recorded. In the presence of 17% sourdough and 2% tempe a significantly different palatability was recorded among three levels of sodium chloride. 0.75 and 1.5% sodium chloride resulted in the same palatability with an average score of 4.6, but with 0% sodium chloride a significantly different palatability was perceived with anaverage score of 3.1.Sourdough at 33% with 0% tempe resulted in a significantly different palatability among the three levels of sodium chloride (0, 0.75 and 1.5%). Sodium chloride at 0.75 and 1.5% level with 33% sourdough gave the same palatability perception with an average score of 5 (Neither like nor dislike), whereas with 0% sodium chloride and 33% sourdough an average score of 3.5 (Dislike slightly) was recorded. A similar trend was noticed in the presence of 2% tempe and 33% sourdough. Sodium chloride at 0.75 and 1.5% level resulted in the same palatability with an average score of 4.6, and with 0% sodium chloride a significantly different palatability was perceived with an average score of 3.2 (Dislike moderately).

3.1.2.7.2 ***Effect of Tempe***

Sourdough and tempe at 0% level resulted in a significantly different palatability among 0 and 2% tempe levels: an average score of 4.6 was recorded with 0% tempe, and with 2% tempe an average score of 3.8 was recorded (Table 17). Similarly, a significantly different palatability was perceived with 0.75% sodium chloride between two levels of tempe. With 0% tempe an average score of 6.1 (Like slightly) was recorded, and with 2% tempe average score of 4.6 was recorded. Sodium chloride at 1.5% level resulted in the same, not significant palatability perception among 0 and 2% tempe levels, and an overall mean of 5.5 was recorded. Sourdough at 17% in the presence of 0% sodium chloride gave the same, not significant palatability between two levels of tempe and an overall mean of 3.4 was recorded. The same sourdough level gave a significantly different palatability for 0.75 and 1.5% sodium chloride among 0 and 2% tempe levels. Sodium chloride at 0.75% gave an average score of 6 in the presence of 0% tempe, whereas with 2% tempe an average score of 4.7 was recorded. Sodium chloride at 1.5% gave an average score of 5.5 in the presence of 0% tempe, and with 2% tempe an average score of 4.5 was recorded. Sourdough at 33% level for three levels of sodium chloride (0, 0.75 and 1.5%) gave the same, not significantly different palatability between two levels of tempe (0, 2%). Sodium chloride at 0% gave an overall mean of 3.3, and 0.75% sodium chloride gave an overall mean of 4.7. With 1.5% sodium chloride, an overall mean of 5 was recorded.

3.1.2.7.3 ***Effect of Sourdough***

In the presence of 0% sodium chloride and 0% tempe, sourdough among three levels resulted in significantly different palatability perceptions (Table 18). Sourdough at 17 and 33% in the presence of 0% tempe and sodium chloride gave the same palatability with an overall mean of 3.5, whereas with 0% sourdough an average score of 4.6 was recorded. Similarly, with 0.75% sodium chloride, sourdough among three levels gave significantly different palatability perceptions. An average score of 6 was recorded with 0 and 17% sourdough, and with 33% sourdough an average score of 4.9 was recorded. In the presence of 0% tempe and 1.5% sodium chloride a not significantly different palatability was recorded when sourdough was compared among three levels (0. 17 and 33%), with overall mean of 5.4 (Neither like nor dislike). Sodium chloride at 0, 0.75 and 1.5% level in the presence of 2% tempe resulted in the same, not significantly different palatability among three levels of sourdough (0, 17 and 33%); an overall mean of 3.3 (Dislike moderately) was recorded with 0% sodium chloride, and with 0.75% sodium chloride an overall mean of 4.6 (Neither like nor dislike) was recorded. Similarly, with 1.5% sodium chloride an overall mean of 4.8 was recorded.

3.1.3 Third sensory session

The third sensory session included sourdough at 0, 17 and 33% levels, whereas tempe level was elevated from 2% to 3.5% in this baking session. Sodium chloride was added at 0, 0.75 and 1.5% levels. The level of tempe was elevated based on statistical results from the second sensory session. Tempe level at 2% was not making a very prominent difference alone in terms of flavor profile.

3.1.3.1 Saltiness

3.1.3.1.1 *Effect of Salt*

The saltiness perception was significantly different with 0% tempe and sourdough among three levels of sodium chloride (0, 0.75 and 1.5%). All the panelists perceived the same saltiness for 0% and 0.75% sodium chloride levels with an overall mean of 4.3 (Dislike slightly), but saltiness was perceived as significantly different at 1.5% of sodium chloride level and an average score of 5.8 (Like slightly) was recorded ($P < 0.0001$) (Table 19). In the presence of 3.5% tempe, panelists perceived the same saltiness for 0.75% and 1.5% levels of sodium chloride with an overall mean of 5.6, whereas with 0% sodium chloride present the saltiness perception was significantly different with an average score of 4.6. Treatment containing sourdough at 17% in the presence of 0% tempe an sodium chloride among three levels gave the same saltiness perception, which was not significant, and an overall mean of 4.8 was recorded. When 3.5% tempe was added in 17% of sourdough, all three levels of sodium chloride gave a significantly different saltiness perception. A saltiness score of 6.4 at 0.75% of sodium chloride was recorded when compared with 1.5% and 0% of sodium chloride level. The least saltiness score of 3.6 (Dislike slightly) was recorded for 0% of sodium chloride, and with 1.5% sodium chloride an average score of 4.4 was reported ($P<.0001$). Sourdough levels at 33% in the presence of 0%

tempe among three levels of sodium chloride resulted in a significantly different saltiness perception. At 0 and 0.75% sodium chloride the same saltines was perceived with an overall mean of 4.1, whereas at 1.5% level of sodium chloride the saltiness perception was significantly different with an average score of 5.6 compared to lower levels of salt (P<.0001). An interesting finding was that at 3.5% level of tempe with 33% of sourdough, all three levels of sodium chloride (0. 0.75 and 1.5%) gave the same saltiness perception to all the panelists with an overall mean of 5.3 (Neither like nor dislike).

3.1.3.1.2 *Effect of Tempe*

Sodium chloride at 0% with tempe at 3.5% level did not make any significant difference in saltines perception with an overall mean of 4.3 (Dislike slightly). At 0.75% level of sodium chloride, tempe at 3.5% level did make a significant difference in saltiness perception. With 0% tempe an average score of 4.5 was recorded, whereas with 3.5% tempe an average score of 5.7 was recorded (Table 20). At 1.5% level of sodium chloride tempe at 0 and 3.5% did not make any significant difference in saltiness perception with an overall mean of 5.6 (Like slightly). Sourdough at 17% in the presence of 0 and 3.5% tempe with 0% sodium chloride level gave a significant saltiness perception. An average score of 4.6 was recorded with 0% tempe, and with 3.5% tempe an average score of 3.6 was recorded. But at 0.75% level of sodium chloride in the presence of 3.5% tempe with sourdough at 17% level an average score of 6.4 was recorded, and with 0% tempe an average score of 4.2 was recorded for saltiness perception. At 1.5% sodium chloride level the tempe levels of 0 and 3.5% along with 17% sourdough did not make any significant difference in saltiness perception and an overall mean of 4.6 was recorded. Sourdough at 33% level in the presence of 0 and 3.5% of tempe with 0% sodium chloride resulted in a significant difference in saltiness perception with an average score of 3.9 for 0% tempe and 5.1 with 3.5% tempe. When 0.75% level of sodium chloride was added in this equation, saltiness perception was higher in presence of 3.5% tempe with an average score of 5.2, whereas with 0%

tempe an average score of 4.3 was recorded. At 1.5% sodium chloride level, the saltiness perception was not significant for 33% of sourdough in the presence of 0 and 3.5% tempe, and an overall mean of 5.5 was recorded.

3.1.3.1.3 *Effect of Sourdough*

In the presence of 0% sodium chloride and tempe, sourdough among three levels (0, 17 and 33%) did not make any difference in saltiness perception with overall mean of 4.1 (Dislike slightly). The same insignificant saltiness perception was recorded for 0.75% level of sodium chloride in the presence of 0% tempe with an overall mean of 4.3 (Dislike slightly). But for 1.5% sodium chloride level, the saltiness score was 5.4 (Neither like nor dislike) when compared to 0% and 0.75% levels of sodium chloride, yet it still did not make any significant difference. In the presence of 3.5% tempe with 0% sodium chloride, the different sourdough levels (0, 17 and 33%) resulted in significant saltiness perception. Higher saltiness with the score of 5.1 was perceived for 33% sourdough, but was not significantly different than saltiness perception for 0% sourdough, which had an average score of 4.6 (Neither like nor dislike), whereas with 17% sourdough an average score of 3.6 was recorded (Table 21). In the presence of 0.75% sodium chloride, 17% level of sourdough gave a higher saltiness perception with an average score of 6.4 (Like slightly), whereas with 0% and 33% levels of sourdough almost similar scores were recorded with an overall mean of 5.5. At 1.5% sodium chloride in the presence of 3.5% tempe, three levels of sourdough (0, 17 and 33%) gave significantly different saltiness perceptions. It was almost same for 0% and 33% levels of sourdough with an average score of 5.4, but lower for 17% of sourdough with an average score of 4.4. This concluded that, alone, sourdough did not result in a significant saltiness perception but in the presence of 3.5% tempe with 33% level of sourdough the saltiness perception was significantly higher.

3.1.3.2 Sweetness

3.1.3.2.1 ***Effect of Salt***

For 0.75% and 1.5% levels of sodium chloride the same sweetness was perceived with an overall mean of 5.3, but it was significantly different for 0% sodium chloride level with an average score of 4.1 (Appendix III Table 25). In the presence of 3.5% tempe, sodium chloride at 0% and 1.5% gave the same sweetness perception, which was significantly lower, with an average score of 4.1, than for 0.75% level of sodium chloride, which recorded an average score of 4.9. Sourdough at 33% gave the same sweetness perception for 0.75% and 1.5% level of sodium chloride in the presence of 0% tempe, which was significantly different with an average score of 4.9 (Neither like nor dislike) when compared to 0% sodium chloride level, with an average score of 3.7 (Dislike slightly). Sourdough at 17% level in the presence of 0% tempe among three levels of sodium chloride gave the same sweetness perception which was not statistically significant at all, with an overall mean of 4.8 (Neither like nor dislike). Sourdough level at 17% in the presence of 3.5% tempe gave a significantly different sweetness perception at 0.75% level of sodium chloride, with an average score of 5.5, than sodium chloride levels of 0% and 1.5% with an average score of 3.5 (Dislike moderately). Treatment containing sourdough at 33.33% level in the presence of 3.5% tempe gave a significantly different sweetness perception for 0.75% level of sodium chloride, with an average score of 4.5, than sweetness perception at 0% and 1.5% level of sodium chloride with an average score of 3.7.

3.1.3.2.2 ***Effect of Tempe***

In the presence of 0% and 0.75% sodium chloride level tempe at 0% and 3.5% did not make any significant difference for sweetness perception with overall means of 4.1 and 5.1

respectively (Appendix III Table 26). At 1.5% sodium chloride level, tempe at 0 and 3.5% level gave significantly different sweetness perceptions with a recorded average score of 4 with 3.5% tempe, whereas with 0% tempe an average score of 5.3 was recorded for sweetness perception. Sourdough level at 17% in the presence of 0% sodium chloride gave a significant difference in sweetness perception between two levels of tempe. Average scores of 4.6 with 0% tempe and 3.5 with 3.5% tempe were recorded. For 0.75% sodium chloride level, tempe between two levels did not make a significant difference in sweetness perception with an overall mean of 5.2. At 1.5% level of sodium chloride, sourdough at 17% level resulted in a significantly different sweetness perception between two levels of tempe. An average score of 5.1 was recorded with 0% tempe, and an average score of 3.5 was recorded with 3.5% tempe present. Sourdough level at 33% for 0% and 0.75% sodium chloride levels did not make a significant difference in sweetness perception among the two levels of tempe with overall means of 3.7 and 4.7 respectively. At 1.5% level of sodium chloride, sweetness perception was significantly different with 0% of tempe, which recorded an average score of 4.8, when compared with tempe level of 3.5% for the same sodium chloride level, which recorded an average score of 3.7.

3.1.3.2.3 *Effect of Sourdough*

Sourdough among three levels (0, 17 and 33%) with 0% sodium chloride did not affect the sweetness perception significantly, and an overall mean of 4.1 (Dislike slightly) was recorded. In the presence of 0% tempe and 0.75% sodium chloride, the same sweetness perception was recorded when sourdough was compared among three levels (0. 17 and 33%), with an overall mean of 5 (Neither like nor dislike). Similarly, in the presence of 1.5% sodium chloride and 0% tempe the same sweetness was perceived by untrained panelists among three levels of sourdough and an overall mean of 5 (Neither like nor dislike) was reported. Sodium chloride at 0, 0.75 and 1.5% level in the presence of 3.5% tempe resulted in the same, not significant sweetness perception among three levels of sourdough (0, 17 and 33%), and an overall mean of 3.7 (Slightly dislike) was recorded with 0% sodium chloride, and with 0.75% sodium chloride an overall mean of 4.9 (Neither like nor dislike) was recorded. Similarly with 1.5% sodium chloride, an overall mean of 3.7 was recorded (Appendix III Table 27).

3.1.3.3 Sour

3.1.3.3.1 *Effect of Salt*

At three levels of sodium chloride (0%, 0.75% and1.5%), sourness perception was significantly different. Sourness was perceived as the same for 0.75% and1.5% levels of sodium chloride ($P<.0001$), with an average score of 5.5, and with 0% sodium chloride an average score of 3.9 was recorded (Appendix III Table 28). In the presence of 3.5% tempe, sodium chloride among three levels did not result in a significant difference in terms of sourness perception, with an overall mean of 4.6 recorded. Sourdough level at 17% in the presence of 0% tempe gave significantly different sourness perceptions. For 0.75% and 1.5% sodium chloride, the same sourness was perceived with an average score of 5.3, and with 0% sodium chloride an average score of 4 was recorded. The same sourdough level in the presence of 3.5% tempe gave significantly different sourness perceptions. For 0.75% sodium chloride level, an average score of 5.8 was recorded. With 0% and 1.5% sodium chloride level the same sourness was perceived with an average score of 3.3. Sourdough at 33% level with 0% tempe and sodium chloride among three levels (0, 0.75 and 1.5%) made a significant difference in sourness perception. For 1.5% and 0.75% sodium chloride level, the same sourness was perceived with an average score of 4.4, and with 0% sodium chloride level an average score of 3.6 was recorded. The same sourdough level in the presence of 3.5% tempe did not make any significant difference for three levels of sodium chloride, and an average score of 4 was recorded.

3.1.3.3.2 *Effect of Tempe*

In the presence of 0 and 0.75% sodium chloride, tempe between two levels (0, 3.5%) did not make a significant difference in sourness perception with overall means of 4.1 and 5.2 respectively, but for 1.5% sodium chloride level the sourness perception was significantly different between two levels of tempe and an average score of 5.6 was recorded with 0% tempe, and with 3.5% tempe an average score of 4.7 was recorded (Appendix III Table 29). Sourdough at 17% level for 0.75% of sodium chloride did not make any significant difference for sourness perception with an overall mean of 5.6 between two levels of tempe. The same sourdough level at 0% sodium chloride made a significant difference in sourness with an average score of 4 in the presence of 0% tempe, and with 2% tempe an average score of 3.2 was recorded. Sourdough level at 17% with 1.5% sodium chloride between two levels of tempe resulted in a significantly different sourness perception. With 0% tempe an average score of 5.4 was recorded, and with 2% tempe an average score of 3.4 was recorded. Sourdough level at 33% in the presence of 0 and 3.5% of tempe for all three levels of sodium chloride did not make a significant difference in sourness perception. With 0% sodium chloride an overall mean of 3.5 was recorded, whereas with 0.75 and 1.5% of sodium chloride overall means of 4.1 and 4.6 were recorded respectively.

3.1.3.3.3 *Effect of Sourdough*

In the absence of tempe at 0% sodium chloride level, three levels of sourdough did not make a significant difference in sourness perception with an overall mean of 3.8 (Dislike slightly) (Appendix III Table 30). At 0.75% sodium chloride, sourness perception was the same for 0% and 17% sourdough with an average score of 5.3, Sourdough at 33% in the presence of 0.75% sodium chloride gave an average score of 4.1 (Dislike slightly). For sodium chloride level of 1.5% there was no significant difference in sourness perception with overall mean of 5.2. In the presence of 3.5% tempe, sourdough gave significantly different sourness perceptions for the three levels of sodium chloride (0, 0.75 and 1.5%). Sodium chloride at 0% in the presence of 3.5% tempe gave the same sourness perception for 17 and 33% levels of sourdough with an overall mean of 3.3, whereas with 0% sourdough an average score of 4.4 was recorded. At 0.75% sodium chloride in the presence of 3.5% of tempe, 0% and 33% sourdough gave the same sourness perception with an overall mean of 4.5, and with 17% sourdough an average score of 5.8 was recorded. . The same trend was noticed in the presence of 1.5% sodium chloride. 0% and 33% sourdough gave significantly different sourness perceptions with average scores of 4.5, and with 17% sourdough an average score of 3.4 was recorded.

3.1.3.4 Pasteboardy

3.1.3.4.1 ***Effect of Salt***

Three levels of sodium chloride in the presence of 0% tempe and sourdough did not make a significant difference in pasteboardy perception, and an overall mean of 4.4 was recorded (Appendix III Table 31). Tempe level of 3.5% for all three levels of sodium chloride (0, 0.75 and 1.5%) in the presence of 0% sourdough made a significant difference in pasteboardy perception. Sodium chloride at 0.75 and 1.5% gave the same pasteboardy perception and an overall mean of 5.3 was recorded. With 0% sodium chloride an average score of 3.7 was recorded. Sourdough at 17% level in the presence of 0% tempe gave a significantly different pasteboardy perception among three levels of sodium chloride. The same pasteboardy perception was recorded with 0 and 0.75% sodium chloride with an overall mean of 4, and at 1.5% sodium chloride level an average score of 5.8 was recorded. The same level of sourdough in the presence of 3.5% tempe gave significantly different pasteboardy perceptions among three levels of sodium chloride. With 0 and 1.5% sodium chloride the same pasteboardy was perceived with an average score of 4.1, and with 0.75% sodium chloride level an average score of 5.5 was recorded. Sourdough at 33%

level for all three levels of sodium chloride did not make a significant difference in this particular parameter, with an overall mean of 4. The same level of sourdough in the presence of 3.5% tempe gave a significantly different pasteboardy perception among three levels of sodium chloride. The same pasteboardy perception was recorded with 0 and 1.5% sodium chloride level with average score of 3.3, whereas at 0.75% sodium chloride level an average score of 4.8 was recorded.

3.1.3.4.2 ***Effect of Tempe***

Sodium chloride at 0 and 1.5% level in the presence of 0% sourdough between two levels of tempe resulted in the same, not significant pasteboardy perception with overall means of 3.8 and 4.7 respectively (Appendix III Table 32). Sodium chloride at 0.75% gave a significantly different pasteboardy perception between two levels of tempe. An average score of 4.8 was recorded with 0% tempe, and with 3.5% tempe an average score of 5.7 was recorded. Sourdough at 17% level in the presence of 0% sodium chloride between two levels of tempe did not result in a significantly different pasteboardy perception with an overall mean of 4.3. Sodium chloride at 0.75% level with 17% sourdough between two levels of tempe gave a significantly different pasteboardy perception. With 0% tempe an average score of 4 was recorded, and with 3.5% tempe an average score of 5.5 was recorded. Sodium chloride at 1.5% level also resulted in a significantly different pasteboardy perception between two levels of tempe. With 0% tempe an average score of 5.8 was recorded, and with 3.5% tempe an average score of 3.8 was recorded. . Sourdough level at 33% for 0% and 0.75% levels of sodium chloride between two levels of tempe (0, 3.5%) gave no significant difference for pasteboardy perception with overall means of 3.6 and 4.5 respectively, whereas with 1.5% sodium chloride a significantly different pasteboardy perception was perceived between two levels of tempe. With 0% tempe an average score of 4.1 was recorded, and with 3.5% tempe an average score of 3 was recorded.

3.1.3.4.3 *Effect of Sourdough*

Sourdough levels were compared to observe their effectiveness in this particular parameter. At 0% and 0.75% of sodium chloride, sourdough among three levels did not make a significant difference with overall means of 3.9 and 4.3 respectively (Appendix III Table 33). At 1.5% sodium chloride level, sourdough among three levels resulted in significantly different pasteboardy perceptions. The same pasteboardy was perceived with 0 and 33% sourdough with an average score of 4.3, and with 17% sourdough an average score of 5.8 was recorded. In the presence of tempe at 3.5% level, sourdough among three levels resulted in a significantly different pasteboardy perception at 0% sodium chloride. Sourdough at 0 and 33% gave the same pasteboardy perception with an overall mean of 3.6, and with 17% sourdough an average score of 4.5 was recorded. At 0.75% sodium chloride level in the presence of 3.5% tempe did not result in a significant difference for three levels of sourdough (0, 17 and 33%) with an overall mean of 5.3. At 1.5% sodium chloride level in the presence of 3.5% tempe, sourdough among three levels gave significantly different pasteboardy perceptions. Sourdough at 0% gave an average score of 4.9, with 33% sourdough an average score of 3 was recorded, and with 17% sourdough an average score of 3.8 was reported.

3.1.3.5 Aroma

3.1.3.5.1 *Effect of Salt*

Sourdough and tempe at 0% gave significantly different aroma perceptions among three levels of sodium chloride. The same aroma was perceived at 0 and 0.75% sodium chloride level with an average score of 5, and with 1.5% sodium chloride an average score of 6.4 was recorded (Appendix III Table 34). In the presence of 3.5% tempe, sodium chloride among three levels gave no significant difference in aroma with an overall mean of 5 (Neither like nor dislike). Sourdough level at 17% in the presence of 0% tempe did not result in any significant difference with an overall mean of 5.5, but in the presence of 3.5% tempe there was a significant difference in aroma and it had average score of 6.2 at 0.75% level of sodium chloride, and 5 with 0% sodium chloride, whereas with 1.5% sodium chloride a 3.9 average score was recorded. Sourdough level at 33% in the presence of 0% tempe had a significant difference in aroma perception among three levels of sodium chloride. The same aroma was perceived with 0 and 0.75% sodium chloride with an average score of 4.1, whereas with 1.5% sodium chloride level an average score of 5.6 was recorded. In the presence of 3.5% tempe, three levels of sodium chloride (0, 0.75 and 1.5%) had a significant difference in aroma perception. The same aroma was perceived with 0 and 0.75% sodium chloride level an with average score of 4.8, and with 1.5% sodium chloride an average score of 3 was recorded.

3.1.3.5.2 ***Effect of Tempe***

At 0% and 0.75% sodium chloride levels, tempe between two levels (0, 3.5%) did not make a significant difference in aroma with an overall mean of 4.7 and 5.3 respectively (Appendix III Table 35). Sodium chloride at 1.5% level between two levels of tempe gave a significantly different aroma perception. With 0% tempe an average score of 6.4 was recorded, and with 3.5% tempe an average score of 5.1 was recorded. . Sourdough at 17% with 0% sodium chloride gave the same, not significantly different aroma perception with an overall mean of 5.2. The same sourdough level in the presence of 0.75% sodium chloride level gave a significantly different aroma perception between two levels of tempe. An average score of 5.3 was recorded with 0% tempe, and with 3.5% tempe an average score of 6.2 was recorded. Sodium chloride at 1.5% level with 17% sourdough also resulted in a significantly different aroma perception between two levels of tempe. In the presence of 0% tempe an average score of 5.9 was recorded, and with 3.5% tempe present an average score of 3.9 was recorded. . Sourdough at 33% level in the presence of 0% sodium chloride gave the same, not significantly different aroma perception with an overall mean of 4.3. Sodium chloride at 0.75% level in the presence of 33% sourdough resulted in a significantly different aroma perception between two levels of tempe. With 0% tempe an average score of 4.1 was recorded, and with 3.5% tempe level an average score of 5.1 was recorded. The ame sourdough level in the presence of 1.5% sodium chloride level between two levels of tempe resulted in a significantly different aroma perception. With 0% tempe level an average score of 5.6 was recorded, and with 3.5% tempe an average score of 3 was recorded.

3.1.3.5.3 *Effect of Sourdough*

Sodium chloride at 0% in the presence of 0% tempe resulted in a significantly different aroma perception among three levels of sourdough. The same aroma was perceived with 0 and 33% of sourdough with an average score of 4.4, and with 17% sourdough an average score of 5.3 was recorded (Appendix III Table 36). Sodium chloride at 0.75% level with 0% tempe also resulted in a significantly different aroma perception among three levels of sourdough. The same aroma was perceived for 0 and 17% of sourdough with an average score of 5.3, and with 33% sourdough an average score of 4.1 was recorded. In the presence of 3.5% tempe, sodium chloride at 0% among three levels of sourdough resulted in the same, not significantly different aroma perception with an overall mean of 4.7. Sodium chloride at 0.75% level resulted in a significantly different aroma perception among three levels of sourdough in the presence of 3.5% tempe. Sourdough at 0 and 33% gave the same aroma perception with an average score of 5.1, and with 17% sourdough an average score of 6.2 was recorded. Similarly, sodium chloride at 1.5% level resulted in significantly different aroma perceptions in the presence of 3.5% tempe among three levels of sourdough, An average score of 5.1 was recorded with 0% sourdough, and an average score of 3 was recorded with 33% sourdough, whereas with 17% sourdough an average score of 3.9 was recorded.

3.1.3.6 Bitterness

3.1.3.6.1 ***Effect of Salt***

Sourdough at 0% with 0% tempe resulted in significantly different bitterness perceptions among three levels of sodium chloride (0, 0.75 and 1.5%). Average scores of 4 (Dislike slightly), 5.8 (Like slightly) and 4.8 (Neither like nor dislike) were recorded respectively (Table 22). In the presence of 3.5% tempe no significant difference was recorded for all three levels of sodium chloride, and an overall mean of 4.1 was recorded. Sourdough at 17% among three levels of sodium chloride in the presence of 0% tempe resulted in significant difference in bitterness perceptions. The same bitterness was recorded for 0% and 0.75% sodium chloride level with an overall mean of 4.4, but for 1.5% sodium chloride level an average score of 5.3 was recorded. In the presence of 3.5% tempe the same sourdough level gave significantly different bitterness perceptions among three levels of sodium chloride. An average score of 3.3 was recorded with 0 and 1.5% of sodium chloride level, and an average score of 5 was recorded with 0.75% sodium chloride level. Sourdough at 33% level in the presence of 0% tempe resulted in a significantly different bitterness perception among three levels of sodium chloride. The same bitterness perception for 0% and 0.75% levels of sodium chloride was perceived with an average score of 3.9, and with 1.5% sodium chloride level an average score of 5.4 was recorded. The same sourdough level in the presence of 3.5% tempe resulted in significantly different bitterness perceptions among three levels of sodium chloride. An average score of 3.4 was recorded with 0 and 1.5% sodium chloride level, and with 0.75% sodium chloride an average score of 4.5 was recorded.

3.1.3.6.2 *Effect of Tempe*

In the presence of 0% sodium chloride and 0% sourdough, tempe between two levels did not make any significant difference in bitterness perception with an overall mean of 3.8 (Dislike slightly) (Table 23). At 0.75% sodium chloride level tempe between two levels (0, 3.5%) made a significant difference in bitterness perception. With 0% tempe level an average score of 5.8 (Like slightly) was recorded, and with 3.5% tempe an average score of 4.4 (Dislike slightly) was recorded. For 1.5% sodium chloride level, tempe between two levels did not make any significant difference at all and an overall mean of 4.6 (Neither like nor dislike) was recorded. Sourdough at 17% level with 0% sodium chloride between two levels of tempe resulted in significantly different bitterness perceptions and average score of 4.4 (Dislike slightly) with 0% tempe was recorded, and with 3.5% level of tempe an average score of 3.3 (Dislike moderately) was recorded. At 0.75% sodium chloride level, sourdough with 17% resulted in the same, not significantly different bitterness perception with an overall mean of 4.7 (Neither like nor dislike). Sodium chloride level at 1.5% in the presence of 17% sourdough resulted in significantly different bitterness perceptions between two levels of tempe. With 0% tempe an average score of 5.3 (Neither like nor dislike) was recorded, and with 3.5% tempe an average score of 3.4 (Dislike moderately) was recorded. Sourdough at 33% level for 0% and 0.75% sodium chloride levels did not result in a significant bitterness perception between two levels of tempe, and overall means of 3.7 (Dislike slightly) and 4.3 (Dislike slightly) were recorded respectively. At 1.5% sodium chloride level a significantly different bitterness was perceived in the presence of 33% sourdough between two levels of tempe. An average score of 5.4 (Neither like nor dislike) was recorded with 0% tempe, and with 3.5% tempe an average score of 3.5 (Dislike moderately) was recorded.

3.1.3.6.3 ***Effect of Sourdough***

Sourdough levels were compared to observe how sourdough affects the bitterness perception. Sodium chloride at 0% level in the presence of 0% tempe resulted in the same, not significantly different bitterness perception among three levels of sourdough (0, 17 and 33%) with an overall mean of 4 (Dislike slightly). Sodium chloride at 0.75% resulted in a significantly different bitterness perception among three levels of sourdough in the presence of 0% tempe. Sourdough levels of 17 and 33% gave the same bitterness perception with an overall mean of 4.3 (Dislike slightly), whereas with 0% sourdough an average score of 5.8 (Like slightly) was recorded. Sodium chloride at 1.5% gave the same, not significantly different bitterness perception in the presence of 0% tempe among three levels of sourdough and an overall mean of 5.1 (Neither like nor dislike) was recorded. Similarly, sodium chloride at 0 and 0.75% gave the same, not significant bitterness perception in the presence of 3.5% tempe among three levels of sourdough and overall means of 3.5 and 4.6 were recorded respectively. Sodium chloride at 1.5% level in the presence of 3.5% tempe resulted in significantly different bitterness perceptions among three levels of sourdough. At the 17 and 33% levels of sourdough, the same bitterness was perceived with an average score of 3.3, and with 0% sourdough level an average score of 4.4 was recorded (Table 24).

3.1.3.7 Overall Palatability

3.1.3.7.1 ***Effect of Salt***

This parameter was analyzed to study the overall acceptability of each of 18 treatments. Sodium chloride among three levels had a significant difference in overall palatability. In the presence of 0% tempe, sodium chloride levels at 0.75% and 1.5% gave the same overall palatability with an overall mean of 5.5, and with 0% sodium chloride an average score of 4.5 was recorded (Table 25). In the presence of 3.5% tempe and 0% sourdough, sodium chloride also resulted in a significantly different palatability, followed by the same trend as discussed earlier. Sourdough at 17 and 33% gave the same palatability with an average score of 4.7 (Neither like nor dislike), and with 0% sourdough an average score of 3.7 (Dislike slightly) was recorded. Sourdough at 17% in the presence of 3.5% tempe resulted in significantly different palatability among three levels of sodium chloride. With 0% sodium chloride an average score of 3.2 (Dislike moderately) was recorded, and with 0.75% sodium chloride an average score of 5.5 (Neither like nor dislike) was recorded. On the other hand, with 1.5% sodium chloride level an average score of 4 (Dislike slightly) was recorded. This concludes that with 0.75% sodium chloride level, palatability was much more acceptable when compared with the other two levels of sodium chloride. Sourdough at 33% in the presence of 0% tempe resulted in a significant difference in palatability which was similar for 0.75% and 1.5% sodium chloride level with an average score of 4.7 (Neither like nor dislike), and with 0% sourdough an average score of 3.8 (Dislike slightly) was recorded. In the presence of 3.5% tempe the same sourdough level (33%) gave the same, not significantly different palatability among three levels of sodium chloride (0, 0.75 and 1.5%), with an overall mean of 3.8 (Dislike slightly).

3.1.3.7.2 *Effect of Tempe*

Tempe levels were compared to study overall palatability. In the presence of 0% and 1.50% sodium chloride level, tempe between two levels (0, 3.5%) did not make a significant difference in palatability and overall means of 4.1 (Dislike slightly) and 5 (Neither like nor dislike) were recorded respectively. For 0.75% sodium chloride, tempe between two levels made a significant difference in overall palatability. Average scores of 5.7 (Like slightly) with 0% tempe and 4.7 (Neither like nor dislike) with 3.5% tempe were recorded (Table 26). Sourdough at 17% did not result in significant palatability. With 0.75% sodium chloride between two levels of tempe an overall mean of 5 was recorded. The same sourdough level gave a significantly different palatability in the presence of 0 and 1.5% sodium chloride between two levels of tempe. Sodium chloride at 0% gave an average score of 4.2 in the presence of 0% tempe, and with 3.5% tempe an average score of 3.2 was recorded. Similarly sodium chloride at 1.5% level gave an average score of 5.4 in the presence of 0% tempe, and with 3.5% tempe an average score of 4 was recorded. Sourdough level at 33% in the presence of 0 and 0.75% sodium chloride between two levels of tempe gave the same, not significant palatability with overall means of 3.6 and 4.3 respectively. For 1.5% sodium chloride, the same sourdough level between two levels of tempe made a significant difference in overall palatability. An average score of 5 was recorded with 0% tempe, and with 3.5% tempe an average score of 3.7 was recorded.

3.1.3.7.3 ***Effect of Sourdough***

Sourdough levels were compared to study its effect on overall palatability. Sodium chloride at 0% in the presence of 0% tempe resulted in the same, not significantly different palatability among three levels of sourdough with an overall mean of 4.1 (Dislike slightly). Sodium chloride at 0.75% level resulted in a significantly different palatability among three levels of sourdough (0, 17 and 33%) in the presence of 0% tempe. 17 and 33% sourdough gave the same palatability with overall mean of 4.6 (Neither like nor dislike), and with 0% sourdough an average score of 5.7 (Like slightly) was recorded (Table 27). Sodium chloride at 1.5% gave the same, not significantly different palatability among three levels of sourdough with an overall mean of 5.2, and a similar trend was noticed in the presence of 3.5% tempe and with 0% sodium chloride among three levels of sourdough. An overall mean of 3.5 was recorded. Sodium chloride at 0.75% in the presence of 3.5% tempe gave a significantly different palatability among three levels of sourdough. 0 and 33% sourdough gave the same palatability score with an average of 4.5 (Dislike slightly), and with 17% sourdough an average score of 5.5 (Neither like nor dislike) was recorded. Sodium chloride at 1.5% level along with 3.5% tempe resulted in a significantly different palatability among three levels of sourdough. For 17 and 33% sourdough the same palatability score was recorded with an average of 3.8 (Dislike slightly), and with 0% sourdough an average score of 4.8 (Neither like nor dislike) was recorded.

4 Discussion

In the first session of sensory analysis sodium chloride (0.5, 1.5 and 2%) and sourdough (11, 17 and33%) did not affect scores of seven parameters of white bread flavor profile. Tempe (5%) decreased the scores of flavor profile significantly ($P<0.05$). The lower scores of panelists for 5% tempe suggested that the level was too high such that it interfered with expected flavor profile of white bread. Tempe is a fermented product containing wheat and soy beans in equal proportion. According to Shogern (2003) bitter taste was prominent in bread samples baked with no yeast and bread samples containing 40% soy flour which is 35% more than the level used in this study (5%). Soy flour masked the sweet taste of bread samples (Shogren et al, 2003). Thus, 40% soy flour in this study by Shogern et al appeared to be too high since 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 bun was 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 was substituted by soy flour more than 15% it imparted soybean roasted flavor upon baking. One partial explanation of lower scores of bread containing 5% tempe is that during baking auto or enzymatic oxidation of lipids present in soybean released ketones and aldehydes. These aldehydes and ketones had been associated with strong beany flavor which makes soybean flour consumption undesirable (Serrem et al, 2011). One of the previous reports concluded that 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% did not affect the flavor profile thus in the second sensory evaluation session the level was increased.

In the second sensory evaluation session tempe level was decreased from 5 to 2% since it was learned that 5% tempe affected negatively the bread flavor scores. Sodium chloride at 0.75 and 1.5% had similar scores of flavor perception in the presence of 2% tempe which was significantly higher than 0% sodium chloride level in most of the parameters except aroma, which indicated that panelists could not detect difference between flavor profile at 0.75 and 1.5% NaCl. It was reported that wheat breads containing 1.33 and 1.36% sodium chloride were preferred over the bread samples containing higher salt levels (1.5%). At these levels of sodium chloride panelists could not differentiate in other flavor attributes like, sourness, sweetness etc. (Salovaara et al, 1982). It was previously reported that panelists preferred bread samples containing 1.25% of sodium chloride compared to 1.5% NaCl level (Collyer, 1966), which suggests that 0.25% decrease in NaCl level had a significant effect increasing the preference scores. Bread samples with 0% sodium chloride resulted in lower palatability scores as well as dominant pasteboardy flavor attribute (Salovaara et al, 1982). One of the possible partial explanation of getting significantly lower scores with 0% NaCl is that addition of NaCl not only imparts saltiness but it also enhances sweetness perception and hides metallic taste. In the absence of NaCl, food products give a bland and flavorless taste profile which could give a dry mouth feel (pasteboardy), making a food product undesirable. Addition of NaCl enhances the flavor profile of food products and reduces the pasteboardy perception (Miller and Hoseney, 2008). Reduction of sodium to a drastic level or complete exclusion of sodium from food products results in less flavored rather bland food which is not desirable. 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 0.75 and 1.5% increased overall palatability scores compared to 0% sodium chloride, whereas, tempe at 2% decreased the scores of overall palatability significantly.

In third sensory evaluation session the only change was the tempe level, as it was increased from 2 to 3.5%. Tempe at 2% in previous sensory evaluation did not have a 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 with most of treatment combinations including sourdough and tempe. 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 form. Sourdough at 33% in the presence of tempe had similar saltiness perception among three levels of sodium chloride with the scores ranging from "Neither like nor dislike" to "Slightly like". Samples containing 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" which was significantly higher than 1.5% NaCl. One of the possible partial explanations of perceiving higher saltiness at 0.75% NaCl could be that the rate of disposal of aromatic compounds from food product in oral cavity is promoted by NaCl and results in intensifying other flavors of the product. Aromatic compounds are of hydrophobic and hydrophilic in nature. Addition of NaCl increased the concentration of aromatic compounds in vapor phase. NaCl also helps to aggregate gluten proteins, aromatic and flavor compounds bound effectively to gluten proteins in the presence of NaCl hence, resulted in effective release in oral cavity (Guichard, 2002; Thirlby et al, 2006). Sourdough addition made dough viscous which can increase the solubility of NaCl significantly and enhance the saltiness perception even at reduced levels of NaCl (Guichard, 2002). Complex flavors produced by sourdough and tempe can also intensify the flavor perception with low levels of NaCl. It was reported that sourdough bread made with fermented wheat germ gave high scores for acidic flavor, saltiness perception was also higher with score range of 6.8 (Rizzello, 2010). One other possible explanation is that baking changes the food matrix which effects mass transfer and disposal of ions (sodium ions) responsible for saltiness perception. The physical and chemical properties of food constituents (lipids, proteins and carbohydrates) and the manner in which they are arranged in food matrix can have a very pronounced effect on intensity of flavors. It mainly influences the diffusion of aroma compounds throughout the food matrix which affects the stability of flavor profile, flavor release and its persistence in oral cavity (Pozo-Bayón et al, 2006). In summary tempe had 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

Three sensory evaluations were studied containing different levels of NaCl (0, 0.5, 0.75, 1 and 1.5%), tempe (0, 2, 3.5 and 5%) and sourdough (0, 11, 17 and 33%). In the first sensory session bread samples with 0% tempe scored significantly higher on flavor profile (around 6) compared to 5% tempe (around 4-5) on the nine point hedonic scale. The effect of sourdough and NaCl on the flavor profile was not significant. Tempe at 5% resulted in strong beany flavor which was not desirable. In the second sensory session it was concluded that 0.75 and 1.5% NaCl received similar scores for saltiness perception in the presence of 2% tempe which were significantly higher than 0% NaCl ($p < 0.05$). Tempe at 2% reduced the scores of other flavor parameters significantly. From the third sensory session it was concluded that 3.5% tempe did make a significant difference on flavor profile of white bread. 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 were present. This study concluded that addition of fermented products can affect flavor profile of white bread significantly. NaCl can be reduced in white bread formulation as fermented products gave a complex flavor profile and enhanced the overall flavor perception significantly. Combination of fermented products can be used to enhance the saltiness perception even with reduced amounts of NaCl.

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.

Table 2. 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 of treatments block (n=3) ± standard error.

Table 3. 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 of treatments block (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

Table 4. 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 of treatments block (n=3) ± standard error.

Table 5. 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 of treatments block (n=3) ± standard error.

Table 6. 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 of treatments block (n=3) ± standard error.

Table 7. 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 of treatments block (n=3) ± standard error.

Table 8. Effect of tempe (0 and 5%) on 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 (%)	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 of treatments block (n=3) ± standard error.

Table 9. 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 of treatments block (n=3) ± standard error.

Table 10. 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 of treatemnts block (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

Table 11. 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 of treatments block (n=3) ± standard error.

Table 12. 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	±	0.3	
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 of treatments block (n=3) ± standard error.

Table 13**.** 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 of treatments block (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

Table 14. 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 of treatments block (n=3) ± standard error.

Table 15. 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 of treatments block (n=3) ± standard error

Table 16. Effect of NaCl (0.0, 0.75 and 1.5%) on palatability score of white bread at different levels of sourdough (0, 17 and 33%) and tempe (0 and 2%).

Sourdough (%)	Tempe (%)	NaCl (%)	Palatable				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 of treatments block (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

Table 17. Effect of tempe (0 and 2%) on 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 (%)	Palatable	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 of treatments block (n=3) ± standard error.

Table 18. Effect of sourdough (0, 17 and 33%) on 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 (%)	Palatable				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 of treatments block (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

Table 19. 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 (%)	Saltiness				Pvalue
0.0	0.0	0.0	4.0	±	0.34	b	<.0001
0.0	0.0	0.75	4.5	±	0.34	b	
0.0	0.0	1.5	5.8	±	0.25	a	
0.0	3.5	0.0	4.6	±	0.30	b	0.0224
0.0	3.5	0.75	5.7	±	0.27	a	
0.0	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	<.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	<.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 of treatments block (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

Table 20. Effect of tempe (0 and 3.5%) on saltiness 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 (%)	Saltiness	Pvalue
0.0	0.0	0.0	4 ± 0.34	0.1688
0.0	0.0	3.5	4.6 ± 0.30	
0.0	0.75	0.0	4.5 ± 0.34	0.0072
0.0	0.75	3.5	5.7 ± 0.27	
0.0	1.5	0.0	5.8 ± 0.25	0.4021
0.0	1.5	3.5	5.5 ± 0.32	
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	
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	<.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	

[a]Mean of treatments block (n=3) ± standard error.

Table 21. 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 (%)	Saltiness				Pvalue
0.0	0.0	0.0	4	±	0.34	a	0.1648
0.0	0.0	33	3.9	±	0.30	a	
0.0	0.0	17	4.6	±	0.30	a	
0.0	0.75	0.0	4.5	±	0.34	a	0.7347
0.0	0.75	33	4.3	±	0.30	a	
0.0	0.75	17	4.2	±	0.32	a	
0.0	1.5	0.0	5.8	±	0.25	a	0.0814
0.0	1.5	33	5.6	±	0.29	a	
0.0	1.5	17	4.9	±	0.32	a	
3.5	0.0	0.0	4.6	±	0.30	a	0.0007
3.5	0.0	33	5.1	±	0.28	a	
3.5	0.0	17	3.6	±	0.28	b	
3.5	0.75	0.0	5.7	±	0.27	ab	0.0132
3.5	0.75	33	5.2	±	0.24	b	
3.5	0.75	17	6.4	±	0.19	a	
3.5	1.5	0.0	5.5	±	0.32	a	0.0123
3.5	1.5	33	5.4	±	0.29	a	
3.5	1.5	17	4.4	±	0.26	b	

[a]Mean of treatments block (n=3) ± standard error.

Table 22. 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 (%)	Bitterness				Pvalue
0.0	0.0	0.0	4.0	±	0.34	c	<.0001
0.0	0.0	0.75	5.8	±	0.22	a	
0.0	0.0	1.5	4.8	±	0.30	b	
0.0	3.5	0.0	3.6	±	0.26	a	0.0621
0.0	3.5	0.75	4.4	±	0.26	a	
0.0	3.5	1.5	4.4	±	0.31	a	
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	
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	<.0001
17	3.5	0.75	5.0	±	0.31	a	
17	3.5	1.5	3.4	±	0.25	b	

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

Table 23. 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 (%)	Bitterness	Pvalue
0.0	0.0	0.0	4.0 ± 0.34	0.3291
0.0	0.0	3.5	3.6 ± 0.26	
0.0	0.75	0.0	5.8 ± 0.22	0.001
0.0	0.75	3.5	4.4 ± 0.26	
0.0	1.5	0.0	4.8 ± 0.30	0.3291
0.0	1.5	3.5	4.4 ± 0.31	
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	<.0001
33	1.5	3.5	3.2 ± 0.24	
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	<.0001
17	1.5	3.5	3.4 ± 0.25	

[a]Mean of treatments block (n=3) ± standard error.

Table 24. 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 (%)	Bitterness				Pvalue
0.0	0.0	0.0	4.0	±	0.34	a	0.322
0.0	0.0	33	3.8	±	0.31	a	
0.0	0.0	17	4.4	±	0.32	a	
0.0	0.75	0.0	5.8	±	0.22	a	0.0001
0.0	0.75	33	4.1	±	0.29	b	
0.0	0.75	17	4.5	±	0.26	b	
0.0	1.5	0.0	4.8	±	0.30	a	0.3252
0.0	1.5	33	5.4	±	0.27	a	
0.0	1.5	17	5.3	±	0.28	a	
3.5	0.0	0.0	3.6	±	0.26	a	0.5749
3.5	0.0	33	3.7	±	0.29	a	
3.5	0.0	17	3.3	±	0.29	a	
3.5	0.75	0.0	4.4	±	0.26	a	0.3366
3.5	0.75	33	4.5	±	0.30	a	
3.5	0.75	17	5.0	±	0.31	a	
3.5	1.5	0.0	4.4	±	0.31	a	0.0056
3.5	1.5	33	3.2	±	0.24	b	
3.5	1.5	17	3.4	±	0.25	b	

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

Table 25. 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 (%)	Palatability	Pvalue
0.0	0.0	0.0	4.5 ± 0.33 b	0.0056
0.0	0.0	0.75	5.7 ± 0.21 a	
0.0	0.0	1.5	5.3 ± 0.30 a	
0.0	3.5	0.0	3.7 ± 0.25 b	0.0097
0.0	3.5	0.75	4.7 ± 0.24 a	
0.0	3.5	1.5	4.8 ± 0.30 a	
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	
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	<.0001
17	3.5	0.75	5.5 ± 0.29 a	
17	3.5	1.5	4.0 ± 0.32 b	

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

Table 26. 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 (%)	Palatability	Pvalue
0.0	0.0	0.0	4.5 ± 0.33	0.0623
0.0	0.0	3.5	3.7 ± 0.25	
0.0	0.75	0.0	5.7 ± 0.21	0.0109
0.0	0.75	3.5	4.7 ± 0.24	
0.0	1.5	0.0	5.3 ± 0.30	0.2373
0.0	1.5	3.5	4.8 ± 0.30	
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	
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	

[a]Mean of treatments block (n=3) ± standard error.

Table 27. 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 (%)	Palatability	Pvalue
0.0	0.0	0.0	4.5 ± 0.33 a	0.268
0.0	0.0	33	3.8 ± 0.30 a	
0.0	0.0	17	4.2 ± 0.30 a	
0.0	0.75	0.0	5.7 ± 0.21 a	0.0041
0.0	0.75	33	4.4 ± 0.32 b	
0.0	0.75	17	4.8 ± 0.32 b	
0.0	1.5	0.0	5.3 ± 0.3 a	0.5009
0.0	1.5	33	5.0 ± 0.24 a	
0.0	1.5	17	5.4 ± 0.24 a	
3.5	0.0	0.0	3.7 ± 0.25 a	0.4613
3.5	0.0	33	3.5 ± 0.26 a	
3.5	0.0	17	3.2 ± 0.24 a	
3.5	0.75	0.0	4.7 ± 0.24 b	0.0035
3.5	0.75	33	4.2 ± 0.29 b	
3.5	0.75	17	5.5 ± 0.29 a	
3.5	1.5	0.0	4.8 ± 0.30 a	0.0124
3.5	1.5	33	3.7 ± 0.23 b	
3.5	1.5	17	4.0 ± 0.32 b	

Mean of treatments block (n=3) ± standard error. Means followed by different letter are statistically different (P= 0.05).

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CHAPTER IV

ASSESSMENT OF SODIUM CHLORIDE, SOURDOUGH AND TEMPE ON VISCOELASTIC PROPERTIES OF GLUTEN AND ON FERMENTATION PROPERTIES OF WHEAT DOUGH

ABSTRACT

Sourdough and tempe help to improve the nutritional value of wheat bread. Sourdough degrades the gluten as a result amino acids and smaller peptides are liberate and enhances the flavor of bread and affect rheology of gluten and dough, whereas, Tempe serve as a good protein, isoflavons and vitamins source. This study aimed at analyzing the effect of sourdough, tempe and NaCl at different levels on viscoelastic properties of gluten and on fermentation properties of wheat dough, A commercial wheat flour with protein content of 11.5 was treated with sourdough (17 and 33%) tempe (2 and 3.5%) and NaCl (0.75, 1.5 and 2%) using a randomized complete block with three replicates. Gluten viscoelastic properties were determined by using creep recover and compression recovery test, whereas, fermentation properties of dough were determined by using a rheofermentometer. Sourdough and tempe at lower levels (17% sourdough and 2% tempe) in the presence of 1.5% NaCl had a significant effect on viscoelastic properties of gluten as viscosity of gluten increased by 17.4%, whereas, higher levels of sourdough (33% sourdough and 3.5% tempe) in the presence of 1.5% NaCl increased viscosity of gluten by 54.9% and

decreased elastic recovery (large deformation test) by 25%. Fermented products at higher levels (33% sourdough and 3.5% tempe) in the presence of 0.75% NaCl significantly decreased dough development height by 18% compared to lower levels of fermented products (17% sourdough and 2% tempe). Similarly sourdough and tempe together at higher levels (33% sourdough and 3.5% tempe) in the presence of 0.75% NaCl affected the carbon dioxide production, more volume of CO_2 was produced (increased by 31%) compared to lower levels of fermented products but due to softer dough structure more gas was lost from dough 9.3% reduction. Addition of fermented products dilute the gluten content of the flour and interfered with gluten network formation which resulted in increased viscosity of dough, interpreted as weaker dough structure. Fermented products also significantly decrease fermentation properties which are expected to affect bread making quality of dough.

Keywords: Sourdough, tempe, reduced sodium chloride, viscoelasticity, fermentation properties

1 Introduction

Sourdough is the spontaneous fermentation of dough induced by natural microflora present in flour. The changes in structure and rheology of wheat dough as well as the improvement of flavor and nutritional quality of bread have been attributed to sourdough fermentation (Gobbetti et al, 2008; Katina, Arendt, Liukknen, et al, 2005; Kulp and Lorenz, 2003). Cultures of sourdough generally contain mixtures of lactic acid bacteria (LAB) and yeast in addition to other minor types of bacteria. LAB exhibit rapid acidification of carbohydrates, proteins and lipids present in flour (De Vuyst and Vancanneyt, 2007; Di Cagno et al, 2003; Gobbetti et al, 1996). The proteolytic system of LAB produces amino acids and small peptides which help in the growth of microorganisms and produces flavor by serving as precursors of flaovrs (Gobbetti et al, 1996; Schieberle, 1996). The microbial activity in sourdough causes the hydrolysis of protein, which reduces the inter and intramolecular disulfide bonds of high molecular weight-glutenin subunits and low molecular weight-glutenin subunits and makes gluten more vulnerable to further hydrolysis (Shewry and Tatham, 1997; Thiele, 2003). The rheology of wheat dough depends on gluten proteins known as glutenin and gliadin. High molecular weight-glutenin subunits impart elasticity, whereas low molecular weight-glutenin subunits and gliadins are responsible for viscosity (Skerritt et al, 1999; Weegels et al, 1996). Sourdough fermentation degrades gliadins and glutenins through hydrolysis, which results in new, smaller protein fragment bands as appeared on SDS-PAGE after 24 hours of fermentation (Zotta et al, 2006). Degradation of gluten structure in sourdough affects the viscoelasticity of dough; final dough structure depends upon the proportion of sourdough used in the recipe and the extent to which proteins have been degraded (Thiele et al, 2002). Proteolysis in sourdough caused reduction in elasticity by 38.9% along with increased viscosity by 536.1% which results in softer dough with reduced capacity to retain carbon dioxide, whereas increased crumb density was observed in baked sourdough (Pepe et al, 2003). Rapid dough development and increased extensibility was observed in sourdough because of proteolysis (Di Cagno et al, 2003). Wheat bread containing up to 20% sourdough resulted in increased volume (Hui et al, 2003).

Natural sourdough has significantly lower elasticity compared to chemically acidified dough (Clarke et al, 2002). Addition of sourdough preferment up to 20% decreased the elasticity of final dough by 134.8% compared to the control containing no preferment at all; confocal laser scanning micrographs verified there was breakdown in gluten network as larger aggregates of gluten responsible for dough structure integrity were broken down into smaller aggregates, resulting in softer and less elastic dough (Clarke et al, 2004). Wheat dough was chemically acidified by using 0.5 and 1% lactic acid. With 1% lactic acid, higher elasticity and firmness of dough was achieved, which suggests that there is no direct relation between acidity and decreased elasticity (Wehrle et al, 1997). Lactic acid was used at 0.55% to obtain the dough with the same pH as dough with the addition of 20% sourdough preferment. No significant difference in elasticity was recorded with the addition of lactic acid compared to the control containing no additives (Clarke et al, 2002). To study the effect of low pH on structure and fundamental rheological properties of gluten, lactic acid buffer solutions with pH 3.9 and 4.5 were used. Gluten pieces were allowed swelling for 2 h in lactic acid buffer solutions. Rheological tests showed increased softness as well as increased elasticity of gluten pieces with pH 3.9 compared to the control containing only deionized water (Schober et al, 2003).

Tempe is a fermented soybean product produced by the incubation of cooked soybean with a mixture of fungi and bacteria with a predominance of the Rhizopus species. During fermentation, fungal mycelia bind soybeans in a compact structure and the nutritional value of soybeans improves throughout this fermentation process (Nout, 1994; Sudarmadji and Markakis, 1977). Proteolysis, production of vitamins and bioactive compounds during fermentation improve the nutritional value of tempe. Hydrolysis of phytates by microbial enzymes improves the absorption of zinc and iron in tempe (Bruun et al, 2007; Sandberg et al, 1999; Sandberg and Svanberg, 1991). Tempe is an excellent source of vitamins, protein and minerals (Shurtleff and Aoyagi, 1979).

The objective of this study was to analyze the effect of NaCl, sourdough and tempe on viscoelastic properties of gluten and on fermentation properties of wheat dough.

2 Materials and Methods

2.1 Materials

One commercial wheat flour with protein content of 11.5% was obtained from Shawnee Milling Co. (Shawnee, OK). Instant dry yeast was from Lesaffre Yeast Corporation (Milwaukee, WI) and sodium chloride, NaCl from Fisher Scientific (Fair Lawn, NJ). Materials for sourdough and tempe were, commercial all-purpose and whole wheat flour, and soybeans were purchased from a 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). The treatments consisted in NaCl (0, 0.75, 1.5, and 2%), sourdough (17 and 33%), and tempe (2 and 3.5%) w/w based on flour. Preparation of sourdough and tempe is described in chapter III

2.2 Experimental

2.2.1 Gluten preparation

Gluten was obtained from flour containing sourdough and tempe flour treatments. A modification of approved method 38-12.02 (AACCI 2011) was developed. Briefly, the flour with fermented products was mixed one minute and washed for 5 min by using Glutomatic 2200 instrument (Perten Instruments, Ab, Huddinge, Sweden). The concentration of NaCl (w/v) in the washing step matched the respective concentration of each NaCl treatment. For example, for the treatments of 0.75% NaCl the washing solution was 0.75% NaCl. The analysis was conducted t least in triplicates.

2.2.2 Creep and recovery test of gluten

The gluten obtained from the Glutomatic was rolled into a ball shape and was relaxed (2.5 kg top plate and 2.5 mm gap between plates) for an hour at room temperature (25°C). A 25 mm disc of gluten was transferred with the help of a metal die to the lower plate of a constant strain rheometer (AR1000, TA Instrument, New Castle, DE) re-trimmed to fit a 25 mm parallel plate, which was lowered to a 2.5 mm gap. Mineral oil was applied at the edge of gluten to prevent moisture loss. In this test a constant stress of 100 Pa was applied for 100 s which deformed the gluten (viscous response) followed by release of the stress to measure its elastic recovery. The temperature was controlled at 25°C by a peltier. The test was performed in three replicates with a coefficient of variation within 10%. Three responses calculated were: (1) Delta compliance (J-Jr), (2) % Recoverability (RCY), and (3) Maximum % strain and Final % strain.

J-Jr was calculated by subtracting recovery compliance from creep compliance at 100 s. %RCY was calculated by using following formula:

RCY= (creep compliance-recovery compliance/ recovery compliance)*100 at 100 s.

Maximum and final % strains were the last value in creep and recovery compliance at 100 s, respectively. The J-Jr reflects the viscous behavior of the gluten, whereas %RCY reflects the elastic behavior of gluten. Maximum and final % strains reflect the deformation of gluten. A low maximum strain value means the gluten has low (less flow) and high %RCY value means the gluten recovers more and return to its original shape and thus indicated strong gluten compared to high maximum strain and low % RCY.

2.2.3 Compression recovery of gluten

Wet gluten was obtained as mentioned above in Section 2.2.1. The gluten sample was centrifuged for one minute using Perten centrifuge (6000±5 rpm) with the cassette fitted with a plunger and special mesh to shape it into a cylinder. Uniform cylindrical gluten was obtained which can easily be loaded into the lower plate of a Gluten Core analyzer (Perten Instrument Ab, Huddinge, Sweden) by following the procedure of Chapman et al. (2012) in order to determine gluten recovery. The analysis was conducted at room temperature (25°C). The analysis consisted of a compression step at 8 N force for 5 seconds followed by a recovery step for 55 seconds with 0 N of force. The Gluten Core recorded the height of the gluten as a function of time. At least three independent replicates of each treatment were analyzed. This test was suitable for rapid gluten strength test. No oil was applied on the plates because gluten did not stick to the plates.

2.2.4 Dough Preparation

Dough was prepared by following the protocol described by Chopin using a Chopin Alveo Consistograph kneader (Tripette & Renaud, Villeneuve-la-Garenne, France). The dough ingredients were 250 g of flour and 3 g of dry yeast. NaCl (0.75, 1.5, and 2%), sourdough (17 and 33%) and tempe (2 and 3.5%) were added on w/w flour basis. The quantity of deionized water added depended on the moisture content of the flour and the sourdough and tempe levels in the flour. For the control treatment, the deionized water quantity was taken from a table published by the International Association for Cereal Science and Technology (ICC) and also suggested in the reference table given in the Chopin protocol, whereas for other treatments, sourdough and tempe levels dictated the quantity of deionized water to be added based on final dough consistency. All ingredients were mixed in a kneader bowl and water was added progressively during the first minute of mixing. Mixing was stopped after 2 minutes to ensure homogenous hydration and to remove flour sticking to bowl walls. After that, mixing was continued for the next 6 minutes. A sample size of 315 g of dough was used for each treatment.

2.2.5 Fermentation Test

A Rheofermentometer F3 (Chopin, Tripette & Renaud, Villeneuve-la-Garenne, France) was used to study the fermentation properties of the dough. The dough (315 g) was placed in the bottom of an aluminum basket and packed down by hand. The height of the dough sample was leveled out just below the lowest holes. The piston (2000 g) was placed on the top of the dough and temperature was controlled to 28.5°C. The basket was placed in the F3 rheofermentometer bowl. The displacement sensor was placed and the system was tightly closed and test run for 3 h and 5 min. The F3 rheofermentometer analyzed the height of the dough sample placed in the bowl. The piston placed on the dough rises, and the piston is directly linked to the displacement sensor which will calculate the dough height. The rheofermentometer was also linked to a pressure sensor through a pneumatic circuit that measures the pressure increase in the fermenting dough. It also calculatd the speed of carbon dioxide release, volume produced, volume retained in dough, maximum height of dough, height of dough at the end of the test, time to reach maximum height, time to reach maximum gaseous release curve, time to release gas and retention coefficient.

2.2.6 Partial proximate analysis of flour

The protein, moisture and ash contents were determined using the NIR system (FOSS NIR Systems Inc, Laurel, MD 20723). The instrument was used following manufacturer's instructions. Analysis was done in triplicates.

2.2.7 Statistical Analysis

Statistical analysis was done by using SAS 9.3 version (SAS institute, Cary, NC). A factorial design of 2*2*3+1 corresponding to 2 levels of tempe 2 and 3.5%) 2 levels of sourdough (17 and 33%) and 3 levels of NaCl (0.75, 1.5 and 2%) plus one reference was analyzed by Analysis of Variance (ANOVA). The experimental design was randomized and complete block.

3 Results

3.1 Viscoelastic properties

3.1.1 Recoverability (RCY)

3.1.1.1 Effect of Salt

Recoverability measures the elastic recovery of the gluten in creep-recovery test. NaCl at three levels (0.75, 1.5 and 2%) did not have a significant effect ($P>0.05$) in recoverability of gluten at given levels of sourdough and tempe (Table 2). There were four combinations of treatments containing sourdough at 17 and 33% and tempe at 2 and 3.5% level. None of these treatments resulted in any significant effects on recoverability among the three levels of NaCl.

3.1.1.2 Effect of Tempe

For most of the treatment combinations there was no significant effect of tempe on RCY except for two treatment combinations (Table 3). Sourdough at 17% with 3.5% tempe, in the presence of 0.75% sodium chloride, gave lower recoverability by 6.5% when compared with 2% tempe level ($P=0.0284$). Similarly tempe at 3.5% also resulted in lower recoverability in comparison to 2% tempe level by 8.3% with 33% sourdough and 1.5% sodium chloride ($P=0.0066$).

3.1.1.3 Effect of Sourdough

There was no significant effect observed in most of the treatments when sourdough level was increased from 17 to 33% except one treatment combination (Table 4). Treatment containing 33% sourdough gave significantly higher recoverability by 6.5% compared to 17% sourdough level with 2% tempe and 1.5% sodium chloride level ($P=0.0383$).

3.1.2 Delta Compliance (J-Jr)

3.1.2.1 Effect of Salt

J-Jr measures the viscosity of gluten. J-Jr is the difference in creep and recovery compliance at 100 s. Reference control (2% sodium chloride with 0% sourdough and tempe) had average compliance value of 1.0 (1/Pa) and most of the treatment combinations show a trend to higher compliance values compared to the control (Table 5). Sodium chloride levels (0.75, 1.5 and 2%) at a given level of sourdough and tempe resulted in significantly different J-Jr values. Treatments containing 17% sourdough in the presence of 2 and 3.5% tempe decreased J-Jr values as the sodium chloride level was increased from 0.75 to 2%, whereas, with the 33% sourdough level the opposite effect was observed. Treatment containing 17% sourdough in the presence of 2% tempe resulted in a significantly lower J-Jr value by 29.9% when compared to the 0.75% sodium chloride level. Similarly, treatment containing 17% sourdough in the presence of 3.5% tempe gave a significantly lower J-Jr value by 23.8% at 1.5% sodium chloride compared to a lower level of sodium chloride ($P<0.0001$). Treatment containing 33% sourdough showed the opposite effect as J-Jr value increased with the increase in sodium chloride level in the presence of 2 and 3.5% tempe. Sodium chloride at 2% level (with 33% sourdough and 2% tempe) gave a significantly higher J-Jr value by 49.5% when compared to the 0.75% sodium chloride level; similarly, a significantly higher J-Jr value with percentage increase of 54.9% was recorded with the 1.5% sodium chloride level compared to a lower level of salt (in the presence of 3.5% tempe and 33% sourdough) ($P<0.0001$).

3.1.2.2 Effect of Tempe

A significant effect was observed in most of the treatment combinations when the tempe level was increased from 2 to 3.5% (Table 6). General trends indicated an increase in J-Jr values with an increase in tempe level. Treatment containing sourdough at 17% in the presence of 0.75% sodium chloride gave a significantly higher J-Jr value with a percentage increase of 28.5% as tempe level increased from 2 to 3.5% ($P<0.0001$). Similarly, a percentage increase of 52.9% was recorded with a higher level of tempe in the presence of 17% sourdough and 2% sodium chloride ($P<0.0001$). Treatments containing sourdough at 33% in the presence of 0.75 and 1.5% sodium chloride gave a percentage increase by 13.6% and 68.9% respectively, with an increase in tempe levels ($P=0.0001$), whereas, with 2% sodium chloride, no significant difference was recorded in J-Jr values with an increase in tempe levels.

3.1.2.3 Effect of Sourdough

All the treatment combinations showed a significant effect in J-Jr values with an increase in sourdough level (Table 7). Treatments containing 0.75% NaCl showed a decrease in J-Jr values as the sourdough level was increased from 17 to 33%, whereas in treatments containing 2% NaCl, the opposite trend was observed (Table 7). Treatments containing 0.75% sodium chloride in the presence of 2 and 3.5% tempe gave significantly lower J-Jr values with percentage decreases of 19.3 and 28.7%, respectively with increase in sourdough level ($P<0.0001$). Treatments containing 2% sodium chloride in the presence of 2 and 3.5% tempe levels gave significantly higher J-Jr values with percentage increases of 72 and 11.5% as sourdough level was elevated from 17 to 33%. Mixed results were recorded with treatments containing 1.5% sodium chloride. With 2% tempe, it gave a significantly lower J-Jr value with a percentage decrease of 28.4% with an increase in sourdough level ($P<0.0001$), whereas with 3.5% tempe level, this treatment combination gave a significantly higher J-Jr value with a percentage increase of 45.1% as sourdough level increased ($P<0.0001$) (Table 7).

3.1.3 Maximum Percent Strain

3.1.3.1 Effect of Salt

This parameter measures the degree of deformation of gluten at the end of the creep phase. All treatment combinations showed a significant effect in maximum percent strain values among three levels of sodium chloride (0.75, 1.5 and 2%) at a given level of sourdough and tempe (Table 8). Most of the treatments showed a trend to higher maximum percent strain values compared to the reference control (2% sodium chloride with 0% sourdough and tempe), which recorded the value of 32.9% maximum strain. Treatments containing sourdough at 17% in the presence of 2% tempe resulted in similar maximum percent strain values for 0.75 and 1.5% sodium chloride (average 47.2%), but with 2% sodium chloride a significantly lower maximum percent strain value was recorded (31.3%) with a percentage decrease of 30.5% ($P<0.0001$). In contrast, the same sourdough level in the presence of 3.5% tempe gave similar maximum percent strain values (average 46.3%) for 0.75 and 2% sodium chloride value, but with 1.5% sodium chloride level, a significantly lower value was recorded (36.8%) with a percentage decrease of 20.8% ($P<0.002$). Treatments containing 33% sourdough in the presence of 2% tempe gave similar maximum percent strain values (average 37.4%) for 0.75 and 1.5% sodium chloride level, but with 2% sodium chloride level, a significantly higher value was recorded (45.9%) with a percentage increase of 25.9% ($P<0.005$). The same sourdough level (33%) in the presence of 3.5% tempe gave significantly higher values at 1.5 and 2% sodium chloride (average 49.7%) with percentage increases of 39.1 and 31.3%, respectively, when compared to 0.75% sodium chloride level (36.7% maximum strain) ($P<0.0001$).

3.1.3.2 Effect of Tempe

Three out of six total treatment combinations showed a significant effect in maximum percent strain values (Table 9). Two of these treatments indicated higher maximum percent strain values with an increase in tempe levels (Table 9). Treatment containing 17% sourdough in the presence of 2% sodium chloride showed a significantly higher value with a percentage increase of 47.5% as tempe level increased from 2 to 3.5% ($P<0.0001$). Similarly, treatment containing 33% sourdough in the presence of 1.5% sodium chloride gave a significantly higher value with a percentage increase of 33.4% with an increase in tempe level ($P<0.0001$). The opposite trend was observed in treatment containing 17% sourdough in the presence of 1.5% sodium chloride, as the maximum percent strain value decreased significantly by 25.3% with a higher tempe level ($P<0.0001$).

3.1.3.3 Effect of Sourdough

Most of the treatments showed a significant effect in maximum percent strain values with an increase in sourdough level (Table 10). Treatment combinations containing low salt levels (0.75%) showed lower deformation with an increase in sourdough levels but the opposite trend was observed in treatments containing high salt levels (2%). Treatments containing 0.75% sodium chloride in the presence of 2 and 3.5% tempe resulted in significantly lower maximum percent strain values with percentage decreases of 19.1 and 20.9%, respectively, as the sourdough level increased from 17 to 33% ($P<0.005$). Treatments containing 2% sodium chloride level in the presence of 2% tempe gave a significantly higher value with a percentage increase of 46.7% as sourdough level increased from 17 to 33% ($P<0.0001$). Treatment combinations containing 1.5% sodium chloride gave mixed results; a significantly lower maximum percent strain decrease of 22.2% in the presence of 2% tempe as sourdough level increased ($P<0.0005$), but a significantly higher value with a percentage increase of 38.8% was recorded in the presence of 3.5% tempe as the sourdough level increased from 17 to 33% (P<0.0001).

3.1.4 Final Percent Strain

3.1.4.1 Effect of Salt

This parameter measures the final degree of deformation in gluten at the end of recovery phase; a higher value indicates a more deformable character of gluten. All treatments showed a significant effect of sodium chloride at a given level of sourdough and tempe (Table 11). The reference control had the average value of 9.6% final strain and most of the treatments showed a trend to higher value than the control with four treatments similar or lower than reference control. Treatments containing 17% sourdough in the presence of 2% tempe gave significantly different final percent strain values among three levels of sodium chloride (0.75, 1.5 and 2%). Sodium chloride at 1.5% increased final strain (12.5%) by 17.3% when compared to 0.75% NaCl, whereas with 2% sodium chloride reduced final strain (7.4%) by 29.9% compared to 0.75% NaCl (P<0.0001). The same sourdough level in the presence of 3.5% tempe resulted in significantly lower final percent strain values with percentage decreases of 23.8 and 16.9% with 1.5 and 2% salt level, respectively. Treatment combinations containing 33% sourdough with 2 and 3.5% tempe resulted in significantly higher values of deformation with an increase in salt level. Sourdough at 33% in the presence of 2% tempe gave a percentage increase of 49.5% as salt level increased from 0.75 to 2%, whereas with 0.75 and 1.5% sodium chloride levels, similar values were recorded (P<0.0001). The same sourdough level in the presence of 3.5% tempe gave significantly higher final percent strain values with an increase in sodium chloride levels; a percentage increase of 54.8% was recorded for 1.5% salt and a 30.9% increase was recorded for the 2% sodium chloride level (P<0.0001).

3.1.4.2 Effect of Tempe

Most of the treatment combinations showed higher final percent strain values with an increase in tempe levels from 2 to 3.5% (Table 12). Treatments containing sourdough at 17% in the presence of 0.75% sodium chloride showed an increased final strain of 28.4% as tempe level increased from 2 to 3.5% (P<0.0001). The same sourdough level in the presence of 2% sodium chloride increased final strain by 53.1% with an increase in tempe level. Similarly, treatment containing sourdough at 33% in the presence of 1.5% sodium chloride gave a significantly higher value with a percentage increase of 68.8% with an increase in tempe levels (P<0.0001). A comparatively lower percentage increase of 13.7% was recorded with 0.75% sodium chloride level (P<0.0106).

3.1.4.3 Effect of Sourdough

Sourdough has a significant effect on gluten final strain (Table 13). Treatment combinations with a lower salt level showed a significant decrease in final percent strain values with an increase in sourdough levels, and the opposite effect was observed with treatments containing a higher level of salt (Table 13). Treatments containing 0.75% sodium chloride in the presence of 2 and 3.5% tempe gave significantly lower final percent strain values by 19.4 and 28.6% respectively as sourdough level increased from 17 to 33% (P<0.0001). In contrast, treatments containing sodium chloride at 2% with 2 and 3.5% tempe gave significantly higher values with percentage increases of 72.2 and 12% with an increase in sourdough levels (P<0.005). Treatments containing sodium chloride at 1.5% showed mixed results: with 2% tempe, significantly lower values were recorded with a percentage decrease of 28.3% with an increase in sourdough, but in the presence of 3.5% tempe significantly higher values were recorded with a percentage increase of 44.9% with an increase in sourdough level (P<0.0001).

3.1.5 Elastic Recovery

3.1.5.1 Effect of Salt

Two out of four treatment combinations showed a significant effect of NaCl on gluten elastic recovery and only one showed a clear effect of decreasing it with an increase in sodium chloride level (Table 14). The treatment containing sourdough at 33% in the presence of 3.5% tempe decreased elastic recovery with 1.5 and 2% sodium chloride with a percentage decrease of 11.8 and 19.5% (average 15.7%), respectively, in comparison to 0.75% sodium chloride level ($P<0.0006$). The treatment containing sourdough at 17% in the presence of 3.5% tempe gave similar elastic recovery with an increase in sodium chloride level ($P<0.05$). Only 1.5 vs 2% NaCl were different with a decrease of 10.7% elastic recovery with 2% NaCl. The reference control (containing 2% sodium chloride with 0% sourdough and tempe) had an average value of 73.6% elastic recovery and a trend was observed to decreased elastic recovery with all of the treatments compared to the control (Table 14).

3.1.5.2 Effect of Tempe

Half (three out of six) of the treatment combinations gave significant decreasing effect on elastic recovery with an increase in tempe level from 2 to 3.5% (Table 15). The treatment containing 17% sourdough in the presence of 2% sodium chloride gave a significantly lower elastic recovery by 12.6% with an increase in tempe levels ($P<0.005$). Similarly, treatments containing sourdough at 33% in the presence of 1.5 and 2% sodium chloride level gave significantly lower elastic recovery by 11.9 and 25.4%, respectively, with an increase in tempe levels ($P<0.02$).

3.1.5.3 Effect of Sourdough

Three out of six treatment combinations showed significantly lower elastic recovery with an increase in sourdough level (Table 16). Treatments containing sodium chloride at 1.5% in the presence of 2 and 3.5% tempe gave significantly lower elastic recovery by 8.3 and 19.6%, respectively, with an increase in sourdough level ($P<0.05$). Similarly, the treatment containing 2% sodium chloride in the presence of 3.5% tempe gave a significantly lower elastic recovery by 17.9% with an increase in sourdough level ($P=0.0005$).

3.2 Fermentation Properties

3.2.1 Maximum height of dough (Hm)

3.2.1.1 Effect of Salt

Hm is the maximum height of dough development curve from the fermentation test in the rheofermentometer. Most (three out of four) of the treatment combinations gave a significant difference in Hm with increase in salt level (Table 17). Higher Hm values were observed with 1.5% NaCl with the combination treatments of 33% sourdough in the presence of 2 and 3.5% tempe compared to 0.75 and 2% NaCl. Treatment combinations containing 17% sourdough in the presence of 3.5% tempe gave a significantly higher Hm value by 10.1% with 2% sodium chloride, whereas similar Hm values were recorded for 0.75 and 1.5% salt level ($P=0.0205$). Treatment combinations containing 33% sourdough in the presence of 2% tempe gave a significantly higher Hm value by 6.6% with 1.5% salt level, whereas the same Hm values were recorded for 0.75 and 2% salt level ($P=0.0156$). A similar trend was observed with the same sourdough level in the presence of 3.5% tempe ($P=0.0035$). The control had an average value of

40.5 mm, whereas Hm values for treatment combinations ranged from 36.1mm to 48.7mm with few of them showed a trend to higher value than the control. Examples of the latter ones are 17% sourdough with 2% tempe with the three NaCl levels and 33% sourdough with 2% tempe and 1.5% NaCl.

3.2.1.2 Effect of Tempe

All of the treatment combinations showed a significant effect in Hm values with an increase in tempe level. The results indicated a lower Hm value with an increase in tempe level (Table 18). Treatment combinations containing 17% sourdough in the presence of 0.75% sodium chloride gave a significantly lower Hm value by 14.6% with an increase in tempe level from 2 to 3.5% ($P<0.0001$). A similar effect was observed with the same sourdough level in the presence of 1.5 and 2% sodium chloride levels with a decrease of Hm by 11.4 and 9.7%, respectively. The treatment containing sourdough at 33% in the presence of 0.75% sodium chloride gave a significantly lower Hm value by 17.8% with an increase in tempe level ($P<0.0001$). An average decrease of Hm of 12.7% was recorded for 1.5 and 2% salt levels ($P<0.0005$).

3.2.1.3 Effect of Sourdough

Most of the treatment combinations had a significant effect of decreasing Hm values with an increase in sourdough level (Table 19). Treatment combinations containing 0.75% sodium chloride in the presence of 2% tempe gave a significantly lower Hm value by 6.2% with an increase in sourdough level from 17 to 33% ($P<0.05$). Similarly, the treatment containing 2% sodium chloride in the presence of 3.5% tempe also gave a significantly lower Hm value by 15.2% with an increase in sourdough level ($P<0.0001$). The only two treatment combinations that did not affect Hm was 1.5% sodium chloride in the presence of 2 and 3.5% tempe, as increase in sourdough level did not influenced Hm values; a trend to higher values than the control was observed with the 2% tempe.

3.2.2 Height of the dough at the end of the test (h)

3.2.2.1 Effect of Salt

During the fermentation test (3 h 5min), dough rises to its maximum due to a combination of yeast production of CO_2 and gluten expansion, after that gluten breaks down followed by a second dough rising. This parameter measures the height of the dough at the end of the test (h). The general trend indicated a higher h value with an increase in sodium chloride level. Treatment combinations containing 17% sourdough in the presence of 2% tempe gave significantly a higher h value by 35.1 and 72.7% with 1.5 and 2% sodium chloride level respectively ($P<.0001$). Similarly, treatments containing sourdough at 33% in the presence of 2% tempe gave significantly higher h values by 108.5 and 132.8% with 1.5 and 2% sodium chloride levels respectively ($P<.0001$). A similar trend was observed in other treatment combinations. Control treatment (containing 2% NaCl with 0% sourdough and tempe) gave an average value of 40 mm; all treatment combinations show a trend of lower h values (ranging from 13.9mm to 34.9mm) than the control (Table 20).

3.2.2.2 Effect of Tempe

Most treatment combinations showed a significant effect in h value with an increase in tempe levels. The effect was a decrease on h value as tempe level increased from 2 to 3.5% (Table 21). Treatment combinations containing sourdough at 17% in the presence of 0.75% sodium chloride gave a significantly lower h value by 15.6% with an increase in tempe levels ($P<0.05$). Similarly, treatment combinations containing sourdough at 33% in the presence of

1.5% sodium chloride gave a significantly lower h value by 26.4% with an increase in tempe level (P<0.0001). A similar trend was observed for all other treatment combinations except sourdough at 33% in the presence of 0.75% sodium chloride, which did not affect h value with an increase in tempe level (P<0.4173).

3.2.2.3 Effect of Sourdough

Out of six, three treatment combinations gave significantly different h values with an increase in sourdough level (Table 22). Treatments containing the lower salt level (0.75%) gave a significantly lower h value by 21.7% with an increase in sourdough level form 17 to 33% (P<0.005) (Table 22). But as the salt level increased (1.5%), the opposite trend was observed, as treatment containing 1.5% sodium chloride in the presence of 2 and 3.5% tempe gave significantly higher h values by 21.4 and 37.9%, respectively, with an increase in sourdough level (P<0.0005). Although no effect of sourdough was recorded in h values of treatments containing 2% sodium chloride in the presence of 2 and 3.5% tempe levels, a trend to higher h value was observed specifically with 2% tempe levels than with all other treatment combinations discussed above (P>0.05).

3.2.3 Time to reach maximum rise (T1)

3.2.3.1 Effect of Salt

T1 is time to reach maximum height of dough in a fermentation test. The results indicated a higher T1 value with an increase in salt level (Table 23). Treatment combinations containing sourdough at 17% in the presence of 2% tempe gave significantly higher T1 values by 15.3 and 32.8% with 1.5 and 2% salt level, respectively (P<0.0001). Similarly, treatment combinations containing sourdough at 33% in the presence of 2% tempe gave significantly higher T1 values by

51.1 and 68.1% with 1.5 and 2% salt level, respectively (P<0.0001). All other treatment combinations showed the same effect of higher T1 values with an increase in sodium chloride level. The control treatment containing 2% sodium chloride with 0% sourdough and tempe had an average T1 value of 160 min; all treatment combinations showed a trend to lower values ranging from 62 to 113.5 min (Table 23).

3.2.3.2 Effect of Tempe

Only one treatment combination showed a significantly lower T1 value by 13.2% with an increase in tempe level from 2 to 3.5% (P=0.0023) (Table 24). All other treatments showed no significant difference, which means that tempe levels do not make a difference in the time necessary to reach the maximum height of dough.

3.2.3.3 Effect of Sourdough

Four out of six treatment combinations showed a significant difference in T1 values; the general effect indicated a higher T1 value with an increase in sourdough level (Table 25). The treatment combination containing 1.5% sodium chloride in the presence of 2% tempe gave a significantly higher T1 value by 29.1% with an increase in sourdough level (P<0.0001) (Table 25). Similarly, treatment combinations containing 2% sodium chloride in the presence of 2% tempe gave a significantly higher T1 value by 24.7% with an increase in sourdough level (P<0.0001). Similar results were recorded with treatment combinations containing 2.5% tempe. With salt level at 0.75% and in the presence of 2 and 3.5% tempe levels there was no effect on T1 with an increase in sourdough level (P>0.05). The results indicate a trend that at lower salt level with both tempe and sourdough level lower values of T1 were obtained. Lower T1 means the dough develops faster and reaches the maximum height earlier compared to other two higher salt levels. These events are due to yeast activity and structure of the dough, both affected by the treatments.

3.2.4 Maximum height of gaseous release curve (H'm)

3.2.4.1 Effect of Salt

H'm is maximum height of the gaseous release curve in a fermentation test. The reference control treatment containing 2% sodium chloride with 0% sourdough and tempe gave an average value of 46.8 mm; the majority of the treatment combinations gave higher H'm values than the reference control (Table 26). All treatment combinations decrease H'm with an increase in sodium chloride level. Treatment combinations containing sourdough at 17% in the presence of 2% tempe gave significantly lower H'm values by 13.2 and 19.2% with 1.5 and 2% sodium chloride level respectively (P<0.0001). Similarly, treatments containing 33% sourdough in the presence of 2% tempe also gave significantly lower H'm values by 27.4 and 41.2% with 1.5 and 2% of sodium chloride level, respectively (P<0.0001). Other treatment combinations showed the same trend.

3.2.4.2 Effect of Tempe

No significant difference in H'm value was recorded as tempe level increased from 2 to 3.5% level (Table 27).

3.2.4.3 Effect of Sourdough

Five out of six treatment combinations showed a significant effect in H'm value; the general trend indicated a lower H'm value with an increase in sourdough level (Table 28). Treatment combinations containing 0.75% sodium chloride in the presence of 3.5% tempe gave significantly lower H'm values by 6.2% with an increase in sourdough level (P<0.0399). Similarly, treatment combinations containing sodium chloride at 1.5% in the presence of 2% tempe gave significantly lower H'm by 18.5% with increase in sourdough level (P<0.0001). A comparatively higher percentage decrease by 32.1 and 35.9% in H'm value was observed with 2% sodium chloride level in the presence of 2 and 3.5% tempe level as sourdough level increased from 17 to 33% (P<0.0001) .

3.2.5 Time to reach H'm (T'1)

3.2.5.1 Effect of Salt

The reference control treatment had an average value of 180 min (Table 29). Only one treatment combination showed a significant increase with an increase in sodium chloride level; all other treatments showed no significant difference in T'1 value. The treatment containing 33% sourdough in the presence of 2% tempe gave a percentage increase by 106.2% as sodium chloride level was increased from 0.75 to 1.5%; similarly, a percentage increase by 53.4% was recorded as sodium chloride level increased from 0.75 to 2% (P<0.0008).

3.2.5.2 Effect of Tempe

Only the treatment combination containing 33% sourdough in the presence of 0.75% sodium chloride showed a significantly higher value by 98.6% as tempe level increased from 2 to 3.5% (P<0.0004). No other significant differences were recorded (Table 30).

3.2.5.3 Effect of Sourdough

No significant difference was recorded with an increase in sourdough level in any of the treatment combinations (Table 31).

3.2.6 Time of gaseous release (Tx)

3.2.6.1 Effect of Salt

Reference control treatment containing 2% sodium chloride with 0% sourdough and tempe had Tx value of 185 min (Table 32). All other treatment combinations gave average values ranging from 19.5 to 64.5 min. The treatment combination containing 33% sourdough in the presence of 2% tempe gave significantly higher Tx values by 109.5 and 207.1% with 1.5 and 2% sodium chloride, respectively ($P<0.0005$). Similarly, 33% sourdough level in the presence of 3.5% tempe gave the similar Tx value with 0.75 and 1.5% sodium chloride level, whereas a significantly higher Tx value by 158.5% was recorded with 2% sodium chloride ($P<0.0106$). The treatment containing 17% sourdough with 2 and 3.5% tempe level did not give a significant difference in Tx value as sodium chloride level increased ($P> 0.05$).

3.2.6.2 Effect of Tempe

No significant difference on Tx values was recorded with any of the treatment combinations as tempe level increased from 2 to 3.5% (Table 33).

3.2.6.3 Effect of Sourdough

Two out of six treatment combinations gave a significant difference in Tx value with an increase in sourdough level (Table 34). Treatment combinations containing a higher salt level (2% sodium chloride) in the presence of 2 and 3.5% tempe gave significantly higher Tx values by 148.1 and 89.9%, respectively ($P<0.0004$). No other treatment combinations gave any significant difference in Tx value with an increase in sourdough level (Table 34).

3.2.7 Total Volume of Co2 produced (TV)

3.2.7.1 Effect of Salt

This parameter measures the total volume of CO_2 produced during the fermentation test. The general trend indicated a decrease in total volume value with an increase in sodium chloride level. Treatment combinations containing 17% sourdough in the presence of 3.5% tempe gave the same total volume value with 0.75 and 1.5% sodium chloride, but gave a significantly lower total volume by 9.5% with 2% sodium chloride (P<0.0345). A similar trend was observed with the treatment containing 33% sourdough in the presence of 2% tempe (P<0.0001), although treatment combinations containing 33% sourdough with 3.5% tempe gave significantly lower total volume values by 23.8 and 45.3% with 1.5 and 2% sodium chloride respectively (P<0.0001). The control treatment had the average value of 984.3 ml, and all other treatment combinations gave total volumes ranging from 1087.7 to 1991.3 ml, which is quite higher than the control (Table 35).

3.2.7.2 Effect of Tempe

Only the treatment combination containing 33% sourdough in the presence of 0.75% sodium chloride gave a significantly higher total volume by 30.8% as tempe level increased from 2 to 3.5% (P<.0001). No other significant differences were recorded (Table 36).

3.2.7.3 Effect of Sourdough

The general trend indicated a reduction in total volume value with an increase in sourdough level except one treatment combination containing 0.75% sodium chloride in the presence of 3.5% tempe, which gave a higher total volume by 7.4% with an increase in sourdough level (P<0.0447) (Table 37). Treatment combinations containing 1.5% sodium chloride in the presence of 2% tempe gave a significantly lower total volume by 8.6% with an increase in sourdough level (P<0.0294). A similar trend was observed in treatment combinations containing 2% sodium chloride level in the presence of 3.5% tempe, as total volume decreased by 35.2% with an increase in sourdough level (P<0.0001).

3.2.8 Volume lost

3.2.8.1 Effect of Salt

This parameter measures volume loss of CO_2 from dough structure during the fermentation test. The control treatment containing 2% sodium chloride with 0% sourdough and tempe had an average value of 53.3ml; all other treatment combinations gave a range of 60.3ml to 113.7ml, which was quite higher than the control (Table 38). The general trend indicated a lower value of volume lost with an increase in sodium chloride level. Treatment combinations containing 17% sourdough in the presence of 3.5% tempe gave similar volume lost values with 0.75 and 1.5% sodium chloride, but significantly lower volume lost values, recorded at 12.2%, with 2% sodium chloride level (P<0.0425). A similar trend was observed with the treatment containing 33% sourdough in the presence of 2% tempe (P<0.0002), whereas the treatment containing 33% sourdough in the presence of 3.5% tempe gave significantly lower values of volume lost by 28.7 and 46.9% with 1.5 and 2% sodium chloride level respectively (P<0.0001).

3.2.8.2 Effect of Tempe

Two out of six treatment combinations gave significantly higher volume lost values with an increase in tempe level. Treatment combinations containing 17% sourdough in the presence of 0.75% sodium chloride gave a significantly higher volume lost value by 12.2% as tempe level increased from 2 to 3.5% (P<.0348). A similar trend was observed with the treatment containing

33% sourdough in the presence of 0.75% sodium chloride as percentage increase by 30.6% with an increase in tempe level (P<.0001) (Table 39).

3.2.8.3 Effect of Sourdough

Three out of six treatment combinations showed significant decreases in volume lost with an increase in sourdough level. Treatment combinations containing 1.5% sodium chloride level with 3.5% tempe gave significantly lower volume lost values by 20.6% as sourdough level increased from 17 to 33% (P.0004) (Table 40). Similarly, treatments containing 2% sodium chloride in the presence of 3.5% tempe gave significantly lower values by 33.9% with an increase in sourdough level (P<.0001). A similar trend was observed with the same sodium chloride level in the presence of 2% tempe (P<.0001)

3.2.9 Volume Retained

3.2.9.1 Effect of Salt

This parameter measures the volume of CO_2 retained within dough structure in the fermentation test. The control treatment containing 2% sodium chloride in the presence of 0% sourdough and tempe gave an average value of 934.7ml; all treatment combinations gave a range of 1027.3ml to 1878ml, which was quite higher than the control (Table 41). The general trend indicated a decrease in volume retained as sodium chloride level increased. Treatment combinations containing 17% sourdough in the presence of 3.5% tempe gave the same volume retained value with 0.75 and 1.5% sodium chloride, whereas a significantly lower volume retained value by 9.4% was recorded with 2% sodium chloride (P<0.0386). A similar trend was observed in the treatment containing 33% sourdough in the presence of 2% tempe (P<0.0001). The treatment containing 33% sourdough in the presence of 3.5% tempe gave a significantly lower volume retained value by 22.8 and 45.3% with 1.5 and 2% sodium chloride level respectively (P<0.0001).

3.2.9.2 Effect of Tempe

Only the treatment combination containing 33% sourdough in the presence of 0.75% sodium chloride gave a significantly higher volume retained value by 30.9% as tempe level increased from 2 to 3.5% (P<0.0001). No other significant differences were recorded (Table 42).

3.2.9.3 Effect of Sourdough

The general trend indicated a decrease in volume retained value with an increase in sourdough level. Treatment combinations containing 0.75% sodium chloride in the presence of 2% tempe gave a significantly lower value by 14.3% as sourdough level increased from 17 to 33% (P<0.0006) (Table 43). A similar trend was observed in treatment combinations containing 1.5% sodium chloride in the presence of 3.5% tempe as a percentage decrease by 14.3% was recorded with an increase in sourdough level (P<0.0005). Similarly, the treatment containing 2% sodium chloride in the presence of 3.5% tempe gave a percentage decrease by 35.2% with an increase in sourdough level (P<0.0001).

3.2.10 Retention Coefficient (RC)

3.2.10.1 Effect of Salt

RC is the volume retained divided by total gaseous release. Only one treatment combination gave a significant difference with an increase in sodium chloride level. The treatment containing 17% sourdough in the presence of 2% tempe gave the same RC value with 0.75 and 2% sodium chloride level but gave a significantly lower value by 0.53% with 1.5% sodium chloride level (P<0.0417) (Table 44).

3.2.10.2 Effect of Tempe

No significant differences were recorded in RC values with an increase in tempe level (Table 45).

3.2.10.3 Effect of Sourdough

Two out of six combinations of treatment showed significant differences in the RC value with an increase in sourdough level. Treatment combinations containing 0.75% sodium chloride in the presence of 2% tempe gave a significantly lower RC by 0.46% with an increase in sourdough level (P<0.0343). Treatment combinations containing 1.5% sodium chloride in the presence of 3.5% tempe gave a significantly higher RC value by 0.42% with an increase in sourdough level (P<0.048) (Table 46)

4 Discussion

Higher viscosity by 54.9% and lower gluten recovery by 8.3% in the small deformation test (creep recovery test) was observed with 33% sourdough addition in this study, which is in accordance with reported observations of lower elasticity and higher viscosity of gluten with the addition of 20% sourdough in previous work (Clarke et al, 2005). Lower elastic recovery of gluten in large deformation test (compression recovery test) was observed with increase in sourdough level. Treatments containing a lower sourdough level (17%) showed lower viscosity (compared to 33% of sourdough) as the sodium chloride level was increased because a lower sourdough level did not affect the gluten structure as much, and the salt level made a very distinct effect in decreasing viscosity as sodium chloride strengthens the gluten network and makes it less viscous (Beck et al, 2012b). A higher level of sourdough imparts more viscosity as degraded proteins make the gluten structure viscous. An increased viscosity in dough by 536.1% was reported by the addition of lactic acid bacteria to get a cell count of $5*10^7$ cfu/g in pizza dough (Pepe et al, 2003). Sourdough fermentation degrades gliadins and glutenins through hydrolysis, which results in new, smaller protein fragment bands as appeared on SDS-PAGE after 24 hours of fermentation (Zotta et al, 2006). Proteolysis in sourdough degrades high molecular weight glutenin subunits into low molecular glutenin subunits by breaking disulfide bonds and disrupting other inter and intramolecular forces. Laser scanning confocal microscopy revealed that the addition of sourdough changes the dough and gluten structure as gluten fibers were coarser compared to the control; fermentation degrades gluten and causes a reduction in its gas holding capacity (Angioloni et al, 2006; Clarke et al, 2005). To analyze whether the responsible factor of changing gluten network formation from long elastic fibrils to thick coarser fibrils is acidic environment or the hydrolysis of gluten with sourdough addition, there has been a lot of studies emphasizing on artificial chemical acidification of wheat dough and its effect on its rheology. The acidic environment results in electrostatic repulsion forces which unravel the gluten structure and expose its hydrophobic groups, but new bond formation is inhibited by repulsion forces so the gluten structure becomes weak and loses its integrity (Clarke et al, 2002; Clarke et al, 2005; Clarke et al, 2004; Di Cagno et al, 2003). Chemically acidified dough with 1% lactic acid showed an increased firmness and elasticity in dough which suggests that lower pH is not directly related to decreases in the elasticity of wheat dough (Wehrle et al, 1997). A significant decrease in elastic recovery by 26% was observed in this study with the addition of 33% sourdough. Chemical acidification cause gluten to swell in the lactic acid buffer and made it more elastic as well as softer (Schober et al, 2003). Lower elasticity and higher viscosity of gluten was recorded with an increase in tempe level; similar observations were recorded in another study as the increased level of soy proteins cause higher viscosity and lower elasticity in gluten (Roccia et al, 2009). The tempe flour used in this study was a fermented product containing wheat and soy in 1:1 ratio,which has been died and ground. A possible explanation of increase in viscosity and decrease in elasticity with the addition of tempe is that the soy proteins present tempe interfere with gluten network formation as it increases the thiole (SH) group concentration present in soybean and causes a strong association between gluten and soy protein. This stronger affiliation between soy and gluten protein weakens the wheat flour dough (Maforimbo et al, 2006; Maforimbo et al, 2007; Ribotta et al, 2005). The addition of fermented products diluted the gluten content of wheat dough; sourdough addition in wheat dough disrupts the gluten network as degraded proteins from sourdough influence inter and intramolecular bonds in the gluten network (Zotta et al, 2006).

Lower values of dough development height, decreased volume lost from dough structure, and no significant difference in T’1 were recorded with an increase in sourdough level in this study. Similar results of lower Hm and reduced volume lost were recorded in buck wheat batter and wheat dough with the addition of sourdough, as well as a decreased amount of CO2 released from batter, but time to reach maximum gaseous release was reduced with the addition of sourdough, which is contrary to this study as no significant difference was recorded in T’1 (Clarke et al, 2002; Gobbetti et al, 1995; Moroni et al, 2011). Sourdough addition makes dough viscous which resulted in more expansion of the dough, hence more CO_2 volume was retained in treatment combinations containing higher sourdough levels. Lower height of the dough at the end of the test was recorded with 0.75% salt level as sourdough level increased. These observations showed a very pronounced effect of salt level on dough structure as lower salt developed a viscous dough which is interpreted as weaker or softer dough and the sourdough addition made dough softer so it could not recover as much as dough with a 1.5% sodium chloride level. Lower total volume and volume retained values were recorded with an increase in sourdough level; degraded protein structure makes dough soft and entrapment of gas molecules difficult (Gänzle et al, 2008).

5 Conclusion

Fermented products cause significant rheological changes in wheat gluten and dough. Treatment combinations containing higher levels of sourdough (33%) and tempe (3.5%) in the presence of NaCl (0.75, 1.5 and 2%) resulted in significantly lower elasticity and higher viscosity of gluten. Sourdough and tempe addition in flour diluted the gluten content and interfered with gluten network formation. Sourdough addition resulted in hydrolyzed protein, whereas, tempe resulted in soy protein addition. Tempe has fermented soy which interfered with gluten network formation by affiliating with gluten protein and weakening gluten protein interaction among themselves.

Treatment combinations containing higher level of sourdough and tempe had lower values of dough development height, height of the dough at the end of the test, total volume and volume lost in fermentation test, whereas, higher values of time to reach maximum rise (T1) were observed with increase in sourdough level. Fermented product addition increased the viscosity of gluten which in turn resulted in viscous dough interpreted as weak or soft dough. More volume of gas was produced with the addition of fermented products and more gas was lost from dough structure because of weak gluten network.

Thus the presence of sourdough and tempe significantly affected the rheological properties of wheat flour by weakening the gluten structure and resulting in viscous dough.

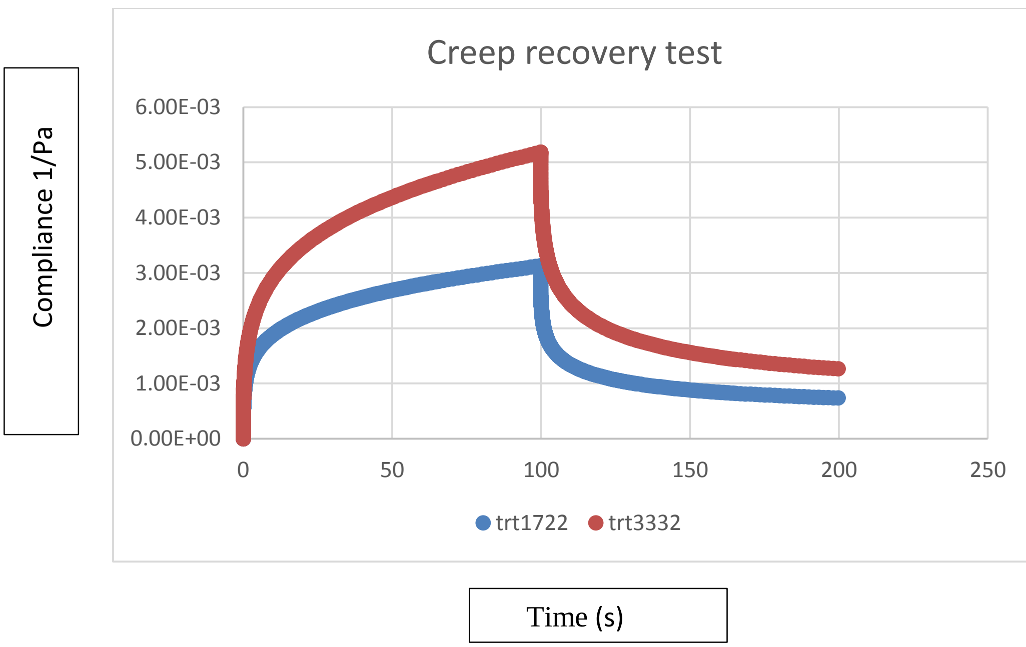
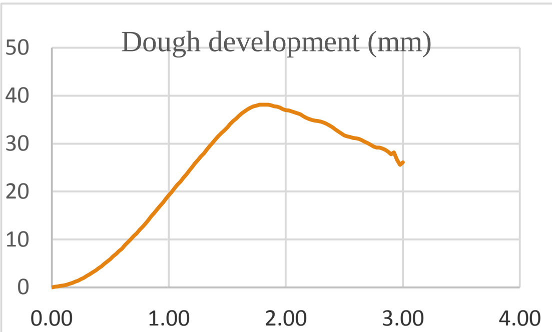


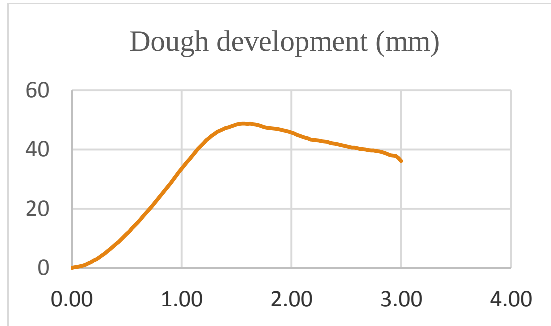
Fig 1. Example of creep recovery tests of samples containing sourdough and tempe

a) Treatment containing 33% sourdough with 3.5% tempe in the presence of 2% NaCl

b) Treatment containing 17% sourdough with 2% tempe in the presence of 2% NaCl



(a)

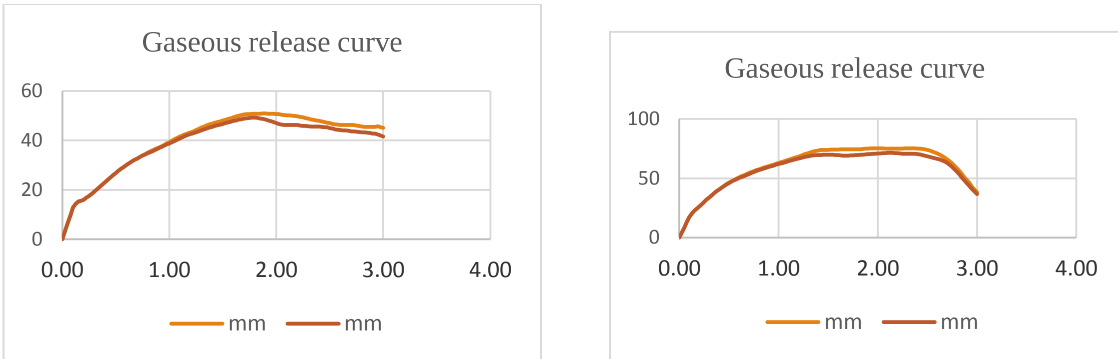


(b)

Fig 2. Examples of dough development height

a) Treatment combinations containing 33% sourdough, 3.5% tempe and 2% NaCl

b) Treatment combination containing 17% sourdough, 2% tempe and 2% NaCl



(a) (b)

Fig 3. Examples of gaseous release curve

a) Treatment combinations containing 33% sourdough, 3.5% tempe and 2% NaCl

b) Treatment combinations containing 17% sourdough, 2% tempe and 2% NaCl

Table 1. Partial proximate analysis of commercial flour

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

Table 2. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on gluten recovery at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Gluten recovery (%)				Pvalue	Percentage change
17	2.0	0.75	76.5	±	0.59	a	0.1108	
17	2.0	1.5	72.3	±	2.97	a		
17	2.0	2.0	76.3	±	0.69	a		
17	3.5	0.75	71.5	±	1.73	a	0.1817	
17	3.5	1.5	72.4	±	2.61	a		
17	3.5	2.0	75.4	±	1.15	a		
33	2.0	0.75	76.6	±	1.23	a	0.0689	
33	2.0	1.5	77.0	±	0.48	a		
33	2.0	2.0	72.3	±	0.76	a		
33	3.5	0.75	74.3	±	1.35	a	0.21	
33	3.5	1.5	70.6	±	0.57	a		
33	3.5	2.0	73.7	±	2.15	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 0% sourdough) gluten recovery = 70.9±0.51; mean (n=3) ± standard error.

Table 3. Effect of tempe (2 and 3.5%) on gluten recovery at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	Gluten recovery (%)	Pvalue	Percentage change
17	0.75	2.0	76.5 ± 0.59	0.0284	
17	0.75	3.5	71.5 ± 1.73		-6.56%
17	1.5	2.0	72.3 ± 2.97	0.9709	
17	1.5	3.5	72.4 ± 2.61		
17	2.0	2.0	76.3 ± 0.69	0.6826	
17	2.0	3.5	75.4 ± 1.15		
33	0.75	2.0	76.6 ± 1.23	0.3135	
33	0.75	3.5	74.3 ± 1.35		
33	1.5	2.0	77.0 ± 0.48	0.0066	
33	1.5	3.5	70.6 ± 0.57		-8.30%
33	2.0	2.0	72.3 ± 0.76	0.5324	
33	2.0	3.5	73.7 ± 2.15		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) gluten recovery = 70.9±0.51; mean (n=3) ± standard error.

Table 4. Effect of sourdough (17 and 33%) on gluten recovery at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	Gluten recovery (%)	Pvalue	Percentage change
0.75	2.0	17	76.5 ± 0.59	0.9847	
0.75	2.0	33	76.6 ± 1.23		
0.75	3.5	17	71.5 ± 1.73	0.1988	
0.75	3.5	33	74.3 ± 1.35		
1.5	2.0	17	72.3 ± 2.97	0.0383	
1.5	2.0	33	77.0 ± 0.48		6.52%
1.5	3.5	17	72.4 ± 2.61	0.4215	
1.5	3.5	33	70.6 ± 0.57		
2.0	2.0	17	76.3 ± 0.69	0.071	
2.0	2.0	33	72.3 ± 0.76		
2.0	3.5	17	75.4 ± 1.15	0.4161	
2.0	3.5	33	73.7 ± 2.15		

Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) gluten recovery = 70.9±0.51; mean (n=3) ± standard error.

Table 5. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on gluten viscosity at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	J-JR (1/Pa)				Pvalue	Percentage change
17	2.0	0.75	1.056	±	0.02	b		
17	2.0	1.5	1.240	±	0.03	a	<.0001	17.41%
17	2.0	2.0	0.740	±	0.01	c		-29.93%
17	3.5	0.75	1.358	±	0.04	a		
17	3.5	1.5	1.034	±	0.01	c	<.0001	-23.84%
17	3.5	2.0	1.132	±	0.02	b		-16.66%
33	2.0	0.75	0.851	±	0.01	b		
33	2.0	1.5	0.888	±	0.05	b	<.0001	4.28%
33	2.0	2.0	1.273	±	0.04	a		49.54%
33	3.5	0.75	0.968	±	0.03	c		
33	3.5	1.5	1.500	±	0.03	a	<.0001	54.95%
33	3.5	2.0	1.262	±	0.05	b		30.34%

[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 0% sourdough) gluten viscosity =1.0±0.03;mean (n=3) ± standard error.

Table 6. Effect of tempe (2 and 3.5%) on gluten viscosity at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	J-JR (1/Pa)	Pvalues	Percentage change
17	0.75	2.0	1.056 ± 0.02	<.0001	
17	0.75	3.5	1.358 ± 0.04		28.56%
17	1.5	2.0	1.240 ± 0.03	<.0001	
17	1.5	3.5	1.034 ± 0.01		-16.60%
17	2.0	2.0	0.740 ± 0.01	<.0001	
17	2.0	3.5	1.132 ± 0.02		52.91%
33	0.75	2.0	0.851 ± 0.01	0.00119	
33	0.75	3.5	0.968 ± 0.03		13.69%
33	1.5	2.0	0.888 ± 0.05	<.0001	
33	1.5	3.5	1.500 ± 0.03		68.95%
33	2.0	2.0	1.273 ± 0.04	0.7899	
33	2.0	3.5	1.262 ± 0.05		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) gluten viscosity =1.0±0.03; mean (n=3) ± standard error.

Table 7. Effect of sourdough (17 and 33%) on gluten viscosity at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	J-JR (1/Pa)	Pvalue	Percentage change
0.75	2.0	17	1.056 ± 0.02	<.0001	
0.75	2.0	33	0.851 ± 0.01		-19.39%
0.75	3.5	17	1.358 ± 0.04	<.0001	
0.75	3.5	33	0.968 ± 0.03		-28.71%
1.5	2.0	17	1.240 ± 0.03	<.0001	
1.5	2.0	33	0.888 ± 0.05		-28.41%
1.5	3.5	17	1.034 ± 0.01	<.0001	
1.5	3.5	33	1.500 ± 0.03		45.03%
2.0	2.0	17	0.740 ± 0.01	<.0001	
2.0	2.0	33	1.273 ± 0.04		72.03%
2.0	3.5	17	1.132 ± 0.02	0.0057	
2.0	3.5	33	1.262 ± 0.05		11.48%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) gluten viscosity =1.0±0.03;mean (n=3) ± standard error.

Table 8. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on maximum strain % at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[a,b].

Sourdough (%)	Tempe (%)	NaCl (%)	Max. Strain (%)	Pvalue	Percentage change
17	2.0	0.75	45.1 ± 1.70 a		
17	2.0	1.5	49.2 ± 3.01 a		9.30%
17	2.0	2.0	31.3 ± 0.72 b	<.0001	-30.54%
17	3.5	0.75	46.5 ± 2.71 a		
17	3.5	1.5	36.8 ± 2.18 b		
17	3.5	2.0	46.2 ± 1.16 a	0.0019	-20.81%
					-0.66%
33	2.0	0.75	36.5 ± 1.46 b		
33	2.0	1.5	38.3 ± 2.35 b		5.08%
33	2.0	2.0	45.9 ± 1.54 a	0.0045	25.95%
33	3.5	0.75	36.7 ± 1.96 b		
33	3.5	1.5	51.1 ± 0.61 a		39.15%
33	3.5	2.0	48.2 ± 2.39 a	<.0001	31.35%

[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 0% sourdough) maximum strain % =32.9±1.73;mean (n=3) ± standard error.

Table 9. Effect of tempe (2 and 3.5%) on maximum strain% at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	Max. Strain (%)	Pvalue	Percentage change
17	0.75	2.0	45.1 ± 1.70	0.6086	
17	0.75	3.5	46.5 ± 2.71		
17	1.5	2.0	49.2 ± 3.01	0.0001	
17	1.5	3.5	36.8 ± 2.18		-25.27%
17	2.0	2.0	31.3 ± 0.72	<.0001	
17	2.0	3.5	46.2 ± 1.16		47.52%
33	0.75	2.0	36.5 ± 1.46	0.9251	
33	0.75	3.5	36.7 ± 1.96		0.71%
33	1.5	2.0	38.3 ± 2.35	<.0001	
33	1.5	3.5	51.1 ± 0.61		33.36%
33	2.0	2.0	45.9 ± 1.54	0.4065	
33	2.0	3.5	48.2 ± 2.39		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) maximum strain % =32.9±1.73; mean (n=3) ± standard error.

Table 10. Effect of sourdough (17 and 33%) on maximum strain% at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	Max. Strain (%)	Pvalue	Percentage change
0.75	2.0	17	45.1 ± 1.70	0.0042	
0.75	2.0	33	36.5 ± 1.46		-19.06%
0.75	3.5	17	46.5 ± 2.71	0.0015	
0.75	3.5	33	36.7 ± 1.96		-20.98%
1.5	2.0	17	49.2 ± 3.01	0.0005	
1.5	2.0	33	38.3 ± 2.35		-22.19%
1.5	3.5	17	36.8 ± 2.18	<.0001	
1.5	3.5	33	51.1 ± 0.61		38.86%
2.0	2.0	17	31.3 ± 0.72	<.0001	
2.0	2.0	33	45.9 ± 1.54		46.75%
2.0	3.5	17	46.2 ± 1.16	0.4565	
2.0	3.5	33	48.2 ± 2.39		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) maximum strain % =32.9±1.73; mean (n=3) ± standard error.

Table 11. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on final strain% at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Final Strain (%)				Pvalue	Percentage change
17	2.0	0.75	10.6	±	0.17	b	<.0001	
17	2.0	1.5	12.5	±	0.28	a		17.35%
17	2.0	2.0	7.4	±	0.07	c		-29.99%
17	3.5	0.75	13.7	±	0.37	a	<.0001	
17	3.5	1.5	10.4	±	0.11	c		-23.82%
17	3.5	2.0	11.4	±	0.23	b		-16.59%
33	2.0	0.75	8.6	±	0.13	b	<.0001	
33	2.0	1.5	8.9	±	0.46	b		4.26%
33	2.0	2.0	12.8	±	0.42	a		49.51%
33	3.5	0.75	9.7	±	0.31	c	<.0001	
33	3.5	1.5	15.1	±	0.27	a		54.82%
33	3.5	2.0	12.8	±	0.41	b		30.95%

[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 0% sourdough) final strain % =9.6±0.35; mean (n=3) ± standard error.

Table 12. Effect of tempe (2 and 3.5%) on final strain% at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	Final Strain (%)	Pvalue	Percentage change
17	0.75	2.0	10.6 ± 0.17	<.0001	
17	0.75	3.5	13.7 ± 0.37		28.45%
17	1.5	2.0	12.5 ± 0.28	<.0001	
17	1.5	3.5	10.4 ± 0.11		-16.61%
17	2.0	2.0	7.4 ± 0.07	<.0001	
17	2.0	3.5	11.4 ± 0.23		53.05%
33	0.75	2.0	8.6 ± 0.13	0.0106	
33	0.75	3.5	9.7 ± 0.31		13.70%
33	1.5	2.0	8.9 ± 0.46	<.0001	
33	1.5	3.5	15.1 ± 0.27		68.83%
33	2.0	2.0	12.8 ± 0.42	0.9027	
33	2.0	3.5	12.8 ± 0.41		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) final strain % =9.6±0.35; mean (n=3) ± standard error

Table 13. Effect of sourdough (17 and 33%) on final strain% at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	Final Strain (%)	Pvalue	Percentage change
0.75	2.0	17	10.6 ± 0.17	<.0001	
0.75	2.0	33	8.6 ± 0.13		-19.40%
0.75	3.5	17	13.7 ± 0.37	<.0001	
0.75	3.5	33	9.7 ± 0.31		-28.65%
1.5	2.0	17	12.5 ± 0.28	<.0001	
1.5	2.0	33	8.9 ± 0.46		-28.38%
1.5	3.5	17	10.4 ± 0.11	<.0001	
1.5	3.5	33	15.1 ± 0.27		44.99%
2.0	2.0	17	7.4 ± 0.07	<.0001	
2.0	2.0	33	12.8 ± 0.42		72.14%
2.0	3.5	17	11.4 ± 0.23	0.0036	
2.0	3.5	33	12.8 ± 0.41		12.01%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) final strain % =9.6±0.35; mean (n=3) ± standard error

Table 14. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on elastic recovery of gluten at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Elastic Recovery (%)				Pvalue	Percentage change
17	2.0	0.75	63.3	±	1.89	a	0.6952	
17	2.0	1.5	63.5	±	2.98	a		
17	2.0	2.0	65.3	±	1.72	a		
17	3.5	0.75	60.6	±	0.55	ab	0.042	
17	3.5	1.5	63.8	±	2.30	a		5.27%
17	3.5	2.0	57.0	±	1.26	b		-5.96%
33	2.0	0.75	62.0	±	1.48	a	0.1793	
33	2.0	1.5	58.2	±	2.23	a		
33	2.0	2.0	62.7	±	1.33	a		
33	3.5	0.75	58.1	±	2.48	a	0.0006	
33	3.5	1.5	51.2	±	2.16	b		-11.81%
33	3.5	2.0	46.8	±	0.56	b		-19.51%

[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 0% sourdough) elastic recovery %

=73.6±1.65; mean (n=3) ± standard error

Table 15. Effect of tempe (2 and 3.5%) on elastic recovery of gluten at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	Elastic Recovery (%)	Pvalue	Percentage change
17	0.75	2.0	63.3 ± 1.89	0.2938	
17	0.75	3.5	60.6 ± 0.55		
17	1.5	2.0	63.5 ± 2.98	0.9045	
17	1.5	3.5	63.8 ± 2.30		
17	2.0	2.0	65.3 ± 1.72	0.0032	
17	2.0	3.5	57.0 ± 1.26		-12.69%
33	0.75	2.0	62.0 ± 1.48	0.136	
33	0.75	3.5	58.1 ± 2.48		
33	1.5	2.0	58.2 ± 2.23	0.011	
33	1.5	3.5	51.2 ± 2.16		-11.97%
33	2.0	2.0	62.7 ± 1.33	<.0001	
33	2.0	3.5	46.8 ± 0.56		-25.46%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) elastic recovery % =73.6±1.65; mean (n=3) ± standard error

Table 16. Effect of sourdough (17 and 33%) on elastic recovery of gluten at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	Elastic Recovery (%)	Pvalue	Percentage change
0.75	2.0	17	63.3 ± 1.89	0.6064	
0.75	2.0	33	62.0 ± 1.48		
0.75	3.5	17	60.6 ± 0.55	0.3313	
0.75	3.5	33	58.1 ± 2.48		
1.5	2.0	17	63.5 ± 2.98	0.0473	
1.5	2.0	33	58.2 ± 2.23		-8.33%
1.5	3.5	17	63.8 ± 2.30	<.0001	
1.5	3.5	33	51.2 ± 2.16		-19.69%
2.0	2.0	17	65.3 ± 1.72	0.3245	
2.0	2.0	33	62.7 ± 1.33		
2.0	3.5	17	57.0 ± 1.26	0.0005	
2.0	3.5	33	46.8 ± 0.56		-17.95%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) elastic recovery % =73.6±1.65;mean (n=3) ± standard error

Table 17. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on Hm at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Hm (mm)				Pvalue	Percentage change
17	2.0	0.75	46.8	±	0.48	a	0.3469	
17	2.0	1.5	47.2	±	1.93	a		
17	2.0	2.0	48.7	±	0.20	a		
17	3.5	0.75	39.9	±	0.97	b	0.0205	
17	3.5	1.5	41.8	±	0.03	ab		4.76%
17	3.5	2.0	44.0	±	0.29	a		10.10%
33	2.0	0.75	43.9	±	0.72	b	0.0156	
33	2.0	1.5	46.8	±	1.21	a		6.68%
33	2.0	2.0	42.8	±	1.43	b		-2.58%
33	3.5	0.75	36.1	±	1.12	b	0.0035	
33	3.5	1.5	40.9	±	0.30	a		13.39%
33	3.5	2.0	37.3	±	0.49	b		3.23%

[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 0% sourdough) Hm =40.5±1.02;mean (n=3) ± standard error

Table 18. Effect of tempe (2 and 3.5%) on Hm at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	Hm (mm)	Pvalue	Percentage change
17	0.75	2.0	46.8 ± 0.48	<.0001	
17	0.75	3.5	39.9 ± 0.97		-14.61%
17	1.5	2.0	47.2 ± 1.93	0.0005	
17	1.5	3.5	41.8 ± 0.03		-11.37%
17	2.0	2.0	48.7 ± 0.20	0.0017	
17	2.0	3.5	44.0 ± 0.29		-9.66%
33	0.75	2.0	43.9 ± 0.72	<.0001	
33	0.75	3.5	36.1 ± 1.12		-17.77%
33	1.5	2.0	46.8 ± 1.21	0.0002	
33	1.5	3.5	40.9 ± 0.30		-12.60%
33	2.0	2.0	42.8 ± 1.43	0.0004	
33	2.0	3.5	37.3 ± 0.49		-12.86%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) Hm =40.5±1.02;mean (n=3) ± standard error

Table 19. Effect of sourdough (17 and 33%) on Hm at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	Hm (mm)	Pvalue	Percentage change
0.75	2.0	17	46.8 ± 0.48	0.0421	
0.75	2.0	33	43.9 ± 0.72		-6.13%
0.75	3.5	17	39.9 ± 0.97	0.0083	
0.75	3.5	33	36.1 ± 1.12		-9.60%
1.5	2.0	17	47.2 ± 1.93	0.7866	
1.5	2.0	33	46.8 ± 1.21		
1.5	3.5	17	41.8 ± 0.03	0.508	
1.5	3.5	33	40.9 ± 0.30		
2.0	2.0	17	48.7 ± 0.20	0.0002	
2.0	2.0	33	42.8 ± 1.43		-12.12%
2.0	3.5	17	44.0 ± 0.29	<.0001	
2.0	3.5	33	37.3 ± 0.49		-15.24%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) Hm =40.5±1.02;mean (n=3) ± standard error.

Table 20. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on height of dough at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	h (mm)				Pvalue	Percentage change
17	2.0	0.75	19.2	±	0.28	c	<.0001	
17	2.0	1.5	25.9	±	1.01	b		35.13%
17	2.0	2.0	33.1	±	1.50	a		72.70%
17	3.5	0.75	16.2	±	0.60	b	<.0001	
17	3.5	1.5	16.8	±	0.46	b		3.71%
17	3.5	2.0	27.7	±	0.93	a		71.34%
33	2.0	0.75	15.0	±	0.67	c	<.0001	
33	2.0	1.5	31.4	±	1.21	b		109.56%
33	2.0	2.0	34.9	±	1.78	a		132.89%
33	3.5	0.75	13.9	±	0.21	c	<.0001	
33	3.5	1.5	23.1	±	1.17	b		66.43%
33	3.5	2.0	27.2	±	0.56	a		95.68%

[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 0% sourdough) height of dough =40.0±1.11; mean (n=3) ± standard error.

Table 21. Effect of tempe (2 and 3.5%) on height of dough at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	h (mm)	Pvalue	Percentage change
17	0.75	2.0	19.2 ± 0.28	0.0338	
17	0.75	3.5	16.2 ± 0.60		-15.65%
17	1.5	2.0	25.9 ± 1.01	<.0001	
17	1.5	3.5	16.8 ± 0.46		-35.26%
17	2.0	2.0	33.1 ± 1.50	0.0005	
17	2.0	3.5	27.7 ± 0.93		-16.31%
33	0.75	2.0	15.0 ± 0.67	0.4173	
33	0.75	3.5	13.9 ± 0.21		
33	1.5	2.0	31.4 ± 1.21	<.0001	
33	1.5	3.5	23.1 ± 1.17		-26.41%
33	2.0	2.0	34.9 ± 1.78	<.0001	
33	2.0	3.5	27.2 ± 0.56		-22.14%

[a]Mean (n=3) ± standard error

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) height of dough =40.0±1.11; mean (n=3) ± standard error.

Table 22. Effect of sourdough (17 and 33%) on height of dough at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	h (mm)	Pvalue	Percentage change
0.75	2.0	17	19.2 ± 0.28	0.0046	
0.75	2.0	33	15.0 ± 0.67		-21.74%
0.75	3.5	17	16.2 ± 0.60	0.1019	
0.75	3.5	33	13.9 ± 0.21		-14.02%
1.5	2.0	17	25.9 ± 1.01	0.0004	
1.5	2.0	33	31.4 ± 1.21		21.36%
1.5	3.5	17	16.8 ± 0.46	<.0001	
1.5	3.5	33	23.1 ± 1.17		37.97%
2.0	2.0	17	33.1 ± 1.50	0.1817	
2.0	2.0	33	34.9 ± 1.78		
2.0	3.5	17	27.7 ± 0.93	0.7108	
2.0	3.5	33	27.2 ± 0.56		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) height of dough =40.0±1.11; mean (n=3) ± standard error.

Table 23. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on T1 at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	T1 (min)				Pvalue	Percentage change
17	2.0	0.75	68.5	±	1.00	c	<.0001	
17	2.0	1.5	79.0	±	2.18	b		15.33%
17	2.0	2.0	91.0	±	4.44	a		32.85%
17	3.5	0.75	62.0	±	0.50	c	<.0001	
17	3.5	1.5	76.5	±	2.29	b		23.39%
17	3.5	2.0	90.0	±	1.73	a		45.16%
33	2.0	0.75	67.5	±	1.73	c	<.0001	
33	2.0	1.5	102.0	±	3.12	b		51.11%
33	2.0	2.0	113.5	±	3.28	a		68.15%
33	3.5	0.75	68.5	±	5.07	c	<.0001	
33	3.5	1.5	88.5	±	2.29	b		29.20%
33	3.5	2.0	110.5	±	2.18	a		61.31%

[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 0% sourdough) T1 =160±3.28; mean (n=3) ± standard error.

Table 24. Effect of tempe (2 and 3.5%) on T1 at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	T1 (min)	Pvalue	Percentage change
17	0.75	2.0	68.5 ± 1.00	0.1162	
17	0.75	3.5	62.0 ± 0.50		
17	1.5	2.0	79.0 ± 2.18	0.5374	
17	1.5	3.5	76.5 ± 2.29		
17	2.0	2.0	91.0 ± 4.44	0.8046	
17	2.0	3.5	90.0 ± 1.73		
33	0.75	2.0	67.5 ± 1.73	0.8046	
33	0.75	3.5	68.5 ± 5.07		
33	1.5	2.0	102.0 ± 3.12	0.0023	
33	1.5	3.5	88.5 ± 2.29		-13.24%
33	2.0	2.0	113.5 ± 3.28	0.4600	
33	2.0	3.5	110.5 ± 2.18		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) T1 =160±3.28; mean (n=3) ± standard error.

Table 25.. Effect of sourdough (17 and 33%) on T1 at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	T1 (min)	Pvalue	Percentage change
0.75	2.0	17	68.5 ± 1.00	0.8046	
0.75	2.0	33	67.5 ± 1.73		
0.75	3.5	17	62.0 ± 0.50	0.1162	
0.75	3.5	33	68.5 ± 5.07		
1.5	2.0	17	79.0 ± 2.18	<.0001	
1.5	2.0	33	102.0 ± 3.12		29.11%
1.5	3.5	17	76.5 ± 2.29	0.0059	
1.5	3.5	33	88.5 ± 2.29		15.69%
2.0	2.0	17	91.0 ± 4.44	<.0001	
2.0	2.0	33	113.5 ± 3.28		24.73%
2.0	3.5	17	90.0 ± 1.73	<.0001	
2.0	3.5	33	110.5 ± 2.18		22.78%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) T1 =160±3.28;mean (n=3) ± standard error.

Table 26. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on H'm at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Hprime (mm)				Pvalue	Percentage change
17	2.0	0.75	99.0	±	1.36	a	<.0001	
17	2.0	1.5	85.9	±	4.94	b		-13.17%
17	2.0	2.0	79.3	±	2.01	c		-19.91%
17	3.5	0.75	100.8	±	1.38	a	<.0001	
17	3.5	1.5	88.0	±	0.76	b		-12.67%
17	3.5	2.0	76.9	±	1.07	c		-23.72%
33	2.0	0.75	96.4	±	1.07	a	<.0001	
33	2.0	1.5	70.0	±	2.51	b		-27.38%
33	2.0	2.0	53.9	±	2.01	c		-44.14%
33	3.5	0.75	94.5	±	2.07	a	<.0001	
33	3.5	1.5	67.1	±	1.39	b		-29.05%
33	3.5	2.0	49.3	±	0.88	c		-47.88%

[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 0% sourdough) H'm =46.8±1.28;mean (n=3) ± standard error.

Table 27. Effect of tempe (2 and 3.5%) on H'm at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	Hprime (mm)	Pvalue	Percentage change
17	0.75	2.0	99.0 ± 1.36	0.5377	
17	0.75	3.5	100.8 ± 1.38		
17	1.5	2.0	85.9 ± 4.94	0.4749	
17	1.5	3.5	88.0 ± 0.76		
17	2.0	2.0	79.3 ± 2.01	0.4125	
17	2.0	3.5	76.9 ± 1.07		
17	0.75	2.0	96.4 ± 1.07	0.5155	
17	0.75	3.5	94.5 ± 2.07		
17	1.5	2.0	70.0 ± 2.51	0.3127	
17	1.5	3.5	67.1 ± 1.39		
17	2.0	2.0	53.9 ± 2.01	0.1225	
17	2.0	3.5	49.3 ± 0.88		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) H'm =46.8±1.28; mean (n=3) ± standard error

Table 28. Effect of sourdough (17 and 33%) on H'm at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	Hprime (mm)	Pvalue	Percentage change
0.75	2.0	17	99.0 ± 1.36	0.3874	
0.75	2.0	33	96.4 ± 1.07		
0.75	3.5	17	100.8 ± 1.38	0.0399	
0.75	3.5	33	94.5 ± 2.07		-6.19%
1.5	2.0	17	85.9 ± 4.94	<.0001	
1.5	2.0	33	70.0 ± 2.51		-18.50%
1.5	3.5	17	88.0 ± 0.76	<.0001	
1.5	3.5	33	67.1 ± 1.39		-23.79%
2.0	2.0	17	79.3 ± 2.01	<.0001	
2.0	2.0	33	53.9 ± 2.01		-32.04%
2.0	3.5	17	76.9 ± 1.07	<.0001	
2.0	3.5	33	49.3 ± 0.88		-35.91%

[a]Mean (n=3) ± standard error

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) H'm =46.8±1.28; mean (n=3) ± standard error

Table 29. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on T'1 at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Tprime (min)				Pvalue	Percentage change
17	2.0	0.75	102.0	±	2.60	a	0.4613	
17	2.0	1.5	117.2	±	6.77	a		
17	2.0	2.0	95.5	±	10.04	a		
17	3.5	0.75	109.0	±	3.28	a	0.4615	
17	3.5	1.5	121.5	±	5.41	a		
17	3.5	2.0	100.0	±	2.00	a		
33	2.0	0.75	72.0	±	2.29	c	0.0008	
33	2.0	1.5	148.5	±	28.50	a		106.25%
33	2.0	2.0	110.5	±	2.78	b		53.47%
33	3.5	0.75	143.0	±	9.50	a	0.1427	
33	3.5	1.5	115.5	±	30.00	a		
33	3.5	2.0	109.0	±	1.80	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 0% sourdough) T'1 =180±0.00; mean (n=3) ± standard error.

Table 30. Effect of tempe (2 and 3.5%) on T'1 at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	Tprime (min)	Pvalue	Percentage change
17	0.75	2.0	102.0 ± 2.60	0.6943	
17	0.75	3.5	109.0 ± 3.28		
17	1.5	2.0	117.2 ± 6.77	0.8076	
17	1.5	3.5	121.5 ± 5.41		
17	2.0	2.0	95.5 ± 10.04	0.8003	
17	2.0	3.5	100.0 ± 2.00		
33	0.75	2.0	72.0 ± 2.29	0.0004	
33	0.75	3.5	143.0 ± 9.50		98.61%
33	1.5	2.0	148.5 ± 28.50	0.0722	
33	1.5	3.5	115.5 ± 30.00		
33	2.0	2.0	110.5 ± 2.78	0.9328	
33	2.0	3.5	109.0 ± 1.80		

[a]Mean (n=3) ± standard error

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) T'1 =180±0.00; mean (n=3) ± standard error.

Table 31. Effect of sourdough (17 and 33%) on T'1 at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	Tprime (min)	Pvalue	Percentage change
0.75	2.0	17	102.0 ± 2.60	0.1004	
0.75	2.0	33	72.0 ± 2.29		
0.75	3.5	17	109.0 ± 3.28	0.0645	
0.75	3.5	33	143.0 ± 9.50		
1.5	2.0	17	117.2 ± 6.77	0.0869	
1.5	2.0	33	148.5 ± 28.50		
1.5	3.5	17	121.5 ± 5.41	0.7361	
1.5	3.5	33	115.5 ± 30.00		
2.0	2.0	17	95.5 ± 10.04	0.4102	
2.0	2.0	33	110.5 ± 2.78		
2.0	3.5	17	100.0 ± 2.00	0.6136	
2.0	3.5	33	109.0 ± 1.80		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) T'1 =180±0.00; mean (n=3) ± standard error.

Table 32. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on Tx at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Tx (min)				Pvalue	Percentage change
17	2.0	0.75	20.5	±	1.00	a	0.5182	
17	2.0	1.5	31.5	±	1.73	a		
17	2.0	2.0	26.0	±	5.77	a		
17	3.5	0.75	19.5	±	0.00	a	0.6369	
17	3.5	1.5	28.0	±	4.77	a		
17	3.5	2.0	26.5	±	7.00	a		
33	2.0	0.75	21.0	±	0.87	c	0.0005	109.52%
33	2.0	1.5	44.0	±	4.77	b		207.14%
33	2.0	2.0	64.5	±	18.79	a		
33	3.5	0.75	19.5	±	0.00	b	0.0106	
33	3.5	1.5	29.5	±	5.29	b		51.28%
33	3.5	2.0	50.3	±	4.84	a		158.12%

[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 0% sourdough) Tx =180±0.00;mean (n=3) ± standard error.

Table 33. Effect of tempe (2 and 3.5%) on Tx at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	Tx (min)	Pvalue	Percentage change
17	0.75	2.0	20.5 ± 1.00	0.9167	
17	0.75	3.5	19.5 ± 0.00		
17	1.5	2.0	31.5 ± 1.73	0.7147	
17	1.5	3.5	28.0 ± 4.77		
17	2.0	2.0	26.0 ± 5.77	0.9583	
17	2.0	3.5	26.5 ± 7.00		
33	0.75	2.0	21.0 ± 0.87	0.8754	
33	0.75	3.5	19.5 ± 0.00		
33	1.5	2.0	44.0 ± 4.77	0.1385	
33	1.5	3.5	29.5 ± 5.29		
33	2.0	2.0	64.5 ± 18.79	0.1474	
33	2.0	3.5	50.3 ± 4.84		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) Tx =180±0.00; mean (n=3) ± standard error.

Table 34. Effect of sourdough (17 and 33%) on Tx at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	Tx (min)	Pvalue	Percentage change
0.75	2.0	17	20.5 ± 1.00	0.9583	
0.75	2.0	33	21.0 ± 0.87		
0.75	3.5	17	19.5 ± 0.00	1.0000	
0.75	3.5	33	19.5 ± 0.00		
1.5	2.0	17	31.5 ± 1.73	0.1989	
1.5	2.0	33	44.0 ± 4.77		
1.5	3.5	17	28.0 ± 4.77	0.8754	
1.5	3.5	33	29.5 ± 5.29		
2.0	2.0	17	26.0 ± 5.77	0.0004	
2.0	2.0	33	64.5 ± 18.79		148.08%
2.0	3.5	17	26.5 ± 7.00	0.0188	
2.0	3.5	33	50.3 ± 4.84		89.94%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) Tx =180±0.00; mean (n=3) ± standard error.

Table 35. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on total volume at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Total Volume (ml)				Pvalue	Percentage change
17	2.0	0.75	1766.3	±	10.27	a	0.4164	
17	2.0	1.5	1738.7	±	67.87	a		
17	2.0	2.0	1680.7	±	9.17	a		
17	3.5	0.75	1854.3	±	17.17	a	0.0345	
17	3.5	1.5	1792.7	±	38.74	ab		-3.33%
17	3.5	2.0	1677.0	±	19.01	b		-9.56%
33	2.0	0.75	1521.3	±	25.14	a	<.0001	
33	2.0	1.5	1589.0	±	75.36	a		4.45%
33	2.0	2.0	1193.3	±	44.41	b		-21.56%
33	3.5	0.75	1991.3	±	73.95	a	<.0001	
33	3.5	1.5	1529.7	±	70.39	b		-23.18%
33	3.5	2.0	1087.7	±	21.09	c		-45.38%

[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 0% sourdough) total volume =984.3±36.20; mean (n=3) ± standard error.

Table 36. Effect of tempe (2 and 3.5%) on total volume at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	Total Volume (ml)	Pvalue	Percentage change
17	0.75	2.0	1766.3 ± 10.27	0.1871	
17	0.75	3.5	1854.3 ± 17.17		
17	1.5	2.0	1738.7 ± 67.87	0.4133	
17	1.5	3.5	1792.7 ± 38.74		
17	2.0	2.0	1680.7 ± 9.17	0.9554	
17	2.0	3.5	1677.0 ± 19.01		
33	0.75	2.0	1521.3 ± 25.14	<.0001	
33	0.75	3.5	1991.3 ± 73.95		30.89%
33	1.5	2.0	1589.0 ± 75.36	0.3693	
33	1.5	3.5	1529.7 ± 70.39		
33	2.0	2.0	1193.3 ± 44.41	0.1158	
33	2.0	3.5	1087.7 ± 21.09		-8.85%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) total volume =984.3±36.20; mean (n=3) ± standard error.

Table 37. Effect of sourdough (17 and 33%) on total volume at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	Total Volume (ml)	Pvalue	Percentage change
0.75	2.0	17	1766.3 ± 10.27	0.0008	
0.75	2.0	33	1521.3 ± 25.14		-13.87%
0.75	3.5	17	1854.3 ± 17.17	0.0447	
0.75	3.5	33	1991.3 ± 73.95		7.39%
1.5	2.0	17	1738.7 ± 67.87	0.0294	
1.5	2.0	33	1589.0 ± 75.36		-8.61%
1.5	3.5	17	1792.7 ± 38.74	0.0004	
1.5	3.5	33	1529.7 ± 70.39		-14.67%
2.0	2.0	17	1680.7 ± 9.17	<.0001	
2.0	2.0	33	1193.3 ± 44.41		-29.00%
2.0	3.5	17	1677.0 ± 19.01	<.0001	
2.0	3.5	33	1087.7 ± 21.09		-35.14%

[a]Mean (n=3) ± standard error

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) total volume =984.3±36.20;mean (n=3) ± standard error.

Table 38. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on volume lost at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	vol.lost (ml)				Pvalue	Percentage change
17	2.0	0.75	92.7	±	2.60	a		
17	2.0	1.5	100.3	±	5.33	a	0.3294	
17	2.0	2.0	95.7	±	4.37	a		
17	3.5	0.75	104.0	±	1.00	a		
17	3.5	1.5	102.0	±	3.51	a	0.0425	-1.92%
17	3.5	2.0	91.3	±	2.91	b		-12.18%
33	2.0	0.75	87.0	±	3.46	a		
33	2.0	1.5	90.3	±	5.36	a	0.0002	3.83%
33	2.0	2.0	67.0	±	3.51	b		-22.99%
33	3.5	0.75	113.7	±	3.71	a		
33	3.5	1.5	81.0	±	3.79	b	<.0001	-28.74%
33	3.5	2.0	60.3	±	1.86	c		-46.92%

[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 0% sourdough) volume lost =53.3±2.96; mean (n=3) ± standard error.

Table 39. Effect of tempe (2 and 3.5%) on volume lost at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	vol.lost (ml)	Pvalue	Percentage change
17	0.75	2.0	92.7 ± 2.60	0.0348	
17	0.75	3.5	104.0 ± 1.00		12.23%
17	1.5	2.0	100.3 ± 5.33	0.745	
17	1.5	3.5	102.0 ± 3.51		
17	2.0	2.0	95.7 ± 4.37	0.4008	
17	2.0	3.5	91.3 ± 2.91		
33	0.75	2.0	87.0 ± 3.46	<.0001	
33	0.75	3.5	113.7 ± 3.71		30.65%
33	1.5	2.0	90.3 ± 5.36	0.0778	
33	1.5	3.5	81.0 ± 3.79		
33	2.0	2.0	67.0 ± 3.51	0.2006	
33	2.0	3.5	60.3 ± 1.86		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) volume lost =53.3±2.96; mean (n=3) ± standard error.

Table 40. Effect of sourdough (17 and 33%) on volume lost at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	vol.lost (ml)	Pvalue	Percentage change
0.75	2.0	17	92.7 ± 2.60	0.2744	
0.75	2.0	33	87.0 ± 3.46		
0.75	3.5	17	104.0 ± 1.00	0.0684	
0.75	3.5	33	113.7 ± 3.71		
1.5	2.0	17	100.3 ± 5.33	0.06	
1.5	2.0	33	90.3 ± 5.36		
1.5	3.5	17	102.0 ± 3.51	0.0004	
1.5	3.5	33	81.0 ± 3.79		-20.59%
2.0	2.0	17	95.7 ± 4.37	<.0001	
2.0	2.0	33	67.0 ± 3.51		-29.97%
2.0	3.5	17	91.3 ± 2.91	<.0001	
2.0	3.5	33	60.3 ± 1.86		-33.94%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) volume lost =53.3±2.96; mean (n=3) ± standard error.

Table 41. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on volume retained at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	vol. retained (ml)				Pvalue	Percentage change
17	2.0	0.75	1673.3	±	8.17	a	0.364	
17	2.0	1.5	1638.3	±	63.40	a		
17	2.0	2.0	1585.3	±	7.22	a		
17	3.5	0.75	1750.3	±	16.38	a	0.0386	
17	3.5	1.5	1690.0	±	35.13	ab		-3.45%
17	3.5	2.0	1586.0	±	16.09	b		-9.39%
33	2.0	0.75	1434.0	±	21.39	a	<.0001	
33	2.0	1.5	1498.7	±	70.44	a		4.51%
33	2.0	2.0	1126.7	±	42.12	b		-21.43%
33	3.5	0.75	1878.0	±	70.44	a	<.0001	
33	3.5	1.5	1448.7	±	67.34	b		-22.86%
33	3.5	2.0	1027.3	±	19.64	c		-45.30%

[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 0% sourdough) volume retained = 934.7±36.15;mean (n=3) ± standard error.

Table 42. Effect of tempe (2 and 3.5%) on volume retained at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	vol. retained (ml)	Pvalue	Percentage change
17	0.75	2.0	1673.3 ± 8.17	0.2189	
17	0.75	3.5	1750.3 ± 16.38		
17	1.5	2.0	1638.3 ± 63.40	0.4056	
17	1.5	3.5	1690.0 ± 35.13		
17	2.0	2.0	1585.3 ± 7.22	0.9914	
17	2.0	3.5	1586.0 ± 16.09		
33	0.75	2.0	1434.0 ± 21.39	<.0001	
33	0.75	3.5	1878.0 ± 70.44		30.96%
33	1.5	2.0	1498.7 ± 70.44	0.4208	
33	1.5	3.5	1448.7 ± 67.34		
33	2.0	2.0	1126.7 ± 42.12	0.1162	
33	2.0	3.5	1027.3 ± 19.64		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) volume retained = 934.7±36.15; mean (n=3) ± standard error.

Table 43. Effect of sourdough (17 and 33%) on volume retained at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	vol. retained (ml)			Pvalue	Percentage change
0.75	2.0	17	1673.3	±	8.17	0.0006	
0.75	2.0	33	1434.0	±	21.39		-14.30%
0.75	3.5	17	1750.3	±	16.38	0.0467	
0.75	3.5	33	1878.0	±	70.44		7.29%
1.5	2.0	17	1638.3	±	63.40	0.0307	
1.5	2.0	33	1498.7	±	70.44		-8.52%
1.5	3.5	17	1690.0	±	35.13	0.0005	
1.5	3.5	33	1448.7	±	67.34		-14.28%
2.0	2.0	17	1585.3	±	7.22	<.0001	
2.0	2.0	33	1126.7	±	42.12		-28.93%
2.0	3.5	17	1586.0	±	16.09	<.0001	
2.0	3.5	33	1027.3	±	19.64		-35.23%

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) volume retained = 934.7±36.15;mean (n=3) ± standard error.

Table 44. Effect of sodium chloride NaCl (0.75, 1.5 and 2%) on coefficient retention at different levels of sourdough (17 and 33%) and tempe (2 and 3.5%)[ab].

Sourdough (%)	Tempe (%)	NaCl (%)	Coefficient retent.	Pvalue
17	2.0	0.75	94.7 ± 0.12 a	0.0417
17	2.0	1.5	94.2 ± 0.15 b	
17	2.0	2.0	94.3 ± 0.23 ab	
17	3.5	0.75	94.4 ± 0.03 a	0.2790
17	3.5	1.5	94.3 ± 0.10 a	
17	3.5	2.0	94.6 ± 0.12 a	
33	2.0	0.75	94.3 ± 0.15 a	0.8695
33	2.0	1.5	94.3 ± 0.15 a	
33	2.0	2.0	94.4 ± 0.23 a	
33	3.5	0.75	94.3 ± 0.09 a	0.0956
33	3.5	1.5	94.7 ± 0.15 a	
33	3.5	2.0	94.4 ± 0.07 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 0% sourdough) coefficient retention =94.8±0.09; mean (n=3) ± standard error.

Table 45. Effect of tempe (2 and 3.5%) on coefficient retention at different levels of NaCl (0.75, 1.5 and 2%) and Sourdough (17 and 33%)[ab]

Sourdough (%)	NaCl (%)	Tempe (%)	coefficient retent.	Pvalue	Percentage change
17	0.75	2.0	94.7 ± 0.12	0.0953	
17	0.75	3.5	94.4 ± 0.03		
17	1.5	2.0	94.2 ± 0.15	0.6072	
17	1.5	3.5	94.3 ± 0.10		
17	2.0	2.0	94.3 ± 0.23	0.1776	
17	2.0	3.5	94.6 ± 0.12		
33	0.75	2.0	94.3 ± 0.15	1.0000	
33	0.75	3.5	94.3 ± 0.09		
33	1.5	2.0	94.3 ± 0.15	0.0681	
33	1.5	3.5	94.7 ± 0.15		
33	2.0	2.0	94.4 ± 0.23	0.7314	
33	2.0	3.5	94.4 ± 0.07		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) coefficient retention =94.8±0.09; mean (n=3) ± standard error.

Table 46. Effect of sourdough (17 and 33%) on coefficient retention at different levels of NaCl (0.75, 1.5 and 2%) and tempe (2 and 3.5%)[ab]

NaCl (%)	Tempe (%)	Sourdough (%)	coefficient retent.	Pvalue	percentage change
0.75	2.0	17	94.7 ± 0.12	0.0334	
0.75	2.0	33	94.3 ± 0.15		-0.46%
0.75	3.5	17	94.4 ± 0.03	0.6072	
0.75	3.5	33	94.3 ± 0.09		
1.5	2.0	17	94.2 ± 0.15	0.494	
1.5	2.0	33	94.3 ± 0.15		
1.5	3.5	17	94.3 ± 0.10	0.048	
1.5	3.5	33	94.7 ± 0.15		0.42%
2.0	2.0	17	94.3 ± 0.23	0.8636	
2.0	2.0	33	94.4 ± 0.23		
2.0	3.5	17	94.6 ± 0.12	0.3939	
2.0	3.5	33	94.4 ± 0.07		

[a]Mean (n=3) ± standard error.

[b]Reference control treatment (2% NaCl, 0% tempe, and 0% sourdough) coefficient retention =94.8±0.09;mean (n=3) ± standard error.

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CHAPTER V

ASSESSMENT OF COMMERCIAL SODIUM CHLORIDE SUBSTITUTES ON VISCOELASTIC PROPERTIES OF GLUTEN AND FERMENTATION PROPERTIES OF WHEAT DOUGH

ABSTRACT

Sodium chloride plays an important role in improving the flavor of bread and rheological properties of wheat flour. Reducing the sodium content interferes with gluten network formation and affects fermentation properties significantly. This study aimed at analyzing the effect of commercial sodium chloride substitutes on viscoelasticity of gluten as well as on fermentation properties of wheat dough. Three commercial wheat flours with different protein contents (9.8, 10.9 and 13.3%) treated with 1 and 2% levels of commercial sodium chloride substitutes using a randomized complete black with three replicates were analyzed. Gluten viscoelastic properties were determined by using small and large deformation tests (creep recovery and compression recovery test), whereas, fermentation properties of wheat dough were determined by using a rheofermentometer. In flour 1 (F1, 9.8% protein) increase in sodium chloride and salt substitutes levels increased the viscosity, whereas, a decrease in viscosity and increase in elasticity of gluten was observed with increase in NaCl and salt substitutes in flour 2 (F2, 10.9% protein). No significant effect in viscoelastic properties of gluten was observed in flour 3 (F3, 13.4% protein).

With lower levels of NaCl and salt substitutes (1%) there was a significant decreases in height of the dough, volume retained and an increase in total volume, volume lost and maximum height of gaseous release curve was observed. Salt substitutes levels (1 and 2%) in comparison to their respective controls C1 (1% NaCl) and C2 (2% NaCl) significantly increased the viscosity of the gluten and decreased its elasticity. A significant increase in height of the dough, time to reach maximum height, total volume and volume lost was observed with salt substitute levels compared to their respective controls.Ssalt substitutes and lower level of NaCl significantly affects the gluten network formation by increasing viscosity and also affected fermentation properties of wheat dough as yeast activity was not controlled as efficiently as with 2% NaCl level.

Keywords: Gluten, commercial sodium chloride substitutes, gluten recovery, creep recovery test, rheofermentometer properties.

1 Introduction

Sodium chloride is used on daily basis to enhance the flavor of food and also to improve the rheological and textural properties of wheat flour dough (Beck et al, 2012a). Increased use of sodium chloride is linked to a higher rate of morbidity, hypertension, renal disorder, diabetes and cardiovascular disease (He and MacGregor, 2008a). There is a desperate need to gradually decrease sodium content from daily consumption. Sodium chloride plays an important role in improving the rheology of wheat gluten, as gluten determines the strength of wheat flour dough by forming a network between its glutenin and gliadin constituents (Belton, 1999). There are many forces involved in making gluten network but disulfide bonds play a very important role (Shewry and Tatham, 1997). Glutenins strengthen the dough by forming cross links with its constituents (MacRitche, 1992). Gluten proteins are hydrophobic in nature and do not dissolve in water (Pareyt et al, 2011). Gliadins provide extensibility in dough (Song and Zheng, 2007). Sodium chloride is added at 2% in flour by weight, its reduction interferes with the gluten network formation and in turn affects the dough strength (Beck et al, 2012b). The gluten network structure is affected mainly by gluten hydration; sodium chloride delays gluten hydration and its network formation. In the presence of salt, gluten forms a fibrous structure and starch granules are embedded in it but, in the absence of salt, gluten forms a thinner honeycomb like structure (McCann and Day, 2013). Gluten is insoluble in water because of the larger molecules and intermolecular interactions. Only glutenins make disulfide bonds with its own molecules and provide elasticity to gluten polymer. Glutenins and gliadins interact with each other non-covalently to form a viscoelastic network (Veraverbeke and Delcour, 2002) Gluten aggregates easily in the presence of salt as salt shields the repulsion between amino acid molecules and allows stronger hydrophobic interactions (Wellner et al, 2003). Sodium chloride changes the secondary conformation of the gluten and allows more aggregation (Ukai et al, 2008). Salt changes the secondary structure equilibrium as aggregated gluten had more β-sheet conformation, whereas the mobile part of gluten has more β-turn conformation (Wellner et al, 2003). Chloride salts draw water molecules and result in more aggregation of gluten proteins. In the presence of calcium chloride gluten forms more disulfide bonds which strengthen the gluten film and increase its elasticity (Balla et al, 1998). High salt concentration helped to separate more protein from the dough. Salt concentration up to 4% gave highest protein yield but levels higher than 4% of salt had a negative effect on protein aggregation as protein aggregates broke down easily (Zalm et al, 2010).

The elasticity of the dough was increased as the salt was added in increased concentration (Larsson, 2002), whereas contradictory results have been reported by (Lynch et al, 2009), which showed that the elasticity of the dough decreases as salt concentration increased This explains why the effect of salt on dough rheology is rather complex and primarily based on the protein content of the flour under study. Sodium chloride affects the fermentation properties of the wheat flour dough by directly controlling the yeast metabolism (Miller, 2008). Higher dough development and higher total volume of carbon dioxide have been reported with decrease in salt (Huang et al, 2008).

The effect of salt on gluten and dough is dependent on the protein content of the flour; lower protein content flour showed more pronounced effects due to salt than higher protein content flours (Ukai et al, 2008).

The objective of this study was to analyze the effect of 1 and 2% levels of commercial sodium chloride substitutes on the viscoelastic properties of gluten as well as on the fermentation properties of wheat dough.

2 Materials and Methods

2.1 Materials

Three commercial flours, two hard red winter wheat and one soft red winter wheat, were obtained from Shawnee Milling (Shawnee, OK) and used to study the rheological properties of commercial sodium chloride substitutes at two levels (1 and 2%). Other materials used were instant dry yeast (Lesaffre Yeast Corporation, Milwaukee, WI), sodium chloride (Fisher Scientific, Fair Lawn, NJ), and five commercial sodium chloride substitutes were from Nu-Tek Food Products, LLC., (Minnetonka, MN).

2.2 Experimental

2.2.1 Gluten preparation

Gluten was obtained from a modified method based on Approved method 38-12.02 (AACC1 2011). A flour sample of 10g containing 1 or 2% salt in solid form was mixed for one minute using the Glutomatic 2200 Instrument (Perten Instruments, Sweden) followed by a 5 min washing with sodium chloride solution with concentration similar to the salt treatment. For example, 1% salt treatment was washed with 1% sodium chloride solution. The analysis was conducted at least in duplicates and within a 10% coefficient of variation.

2.2.2 Creep and recovery test of gluten

The gluten obtained from the Glutomatic was immediately rolled into a ball shape and was relaxed (2.5 kg top plate and 2.5 mm gap between plates) for 60 min at room temperature. A

25 mm disc of gluten was cut with metal die and transferred to the lower plate of the constant stress rheometer (AR1000, TA instrument, New Castle, DE), re-trimmed to fit a 25 mm parallel plate which was lowered to a 2.5mm gap. Mineral oil was applied at the edge of the gluten to prevent moisture loss. In this test, a constant stress of 100 Pa was applied for 100 seconds which deformed the gluten (viscous response), followed by a release of the stress to measure its elastic recovery. The temperature was kept constant at 25ºC. The test was performed in three replicates with a coefficient of variation within 10%. Four responses calculated were: Delta compliance (J-Jr), % Recoverability (RCY), Maximum strain (%) and Final strain (%).

J-Jr delta compliance was calculated by subtracting the recovery compliance from creep compliance at 100 seconds. %RCY was calculated by using following formula:

RCY= (creep compliance-recovery compliance/ recovery compliance)*100 at 100 s.

Maximum and final percent strain were the last values of strain in the creep and recovery phase.

The J-Jr reflects the viscous behavior of the gluten whereas %RCY estimated the elastic recovery. Maximum and final strain (%) measures the deformation of gluten in the creep and recovery phase, respectively.

2.2.3 Compression recovery of gluten

Wet gluten was obtained as described in Section 2.2.1 with a slight modification. After one minute of mixing, the dough was allowed to rest in washing chamber for 5 minutes, with a purpose of giving sufficient time for interaction of the water insoluble salt substitutes to interact with the charged amino acids. Then it was washed with a NaCl solution concentration similar to treatment under study. The wet gluten was shaped by using a specifically designed Perten centrifuge at 6000±5rpm (Perten Instrument Ab, Huddinge, Sweden). Uniform cylindrical gluten was obtained which was loaded to the Gluten Core analyzer. The Gluten Core experiment was conducted at room temperature (23.5ºC). The cylindrical gluten was placed on the Gluten Core bottom plate and was subjected to 8 N force for 5 seconds followed by 55 seconds of recovery with 0 N of force. The Gluten Core recorded the height of the gluten as a function of time. At least three independent replicates of each treatment were analyzed. This test was suitable for rapid gluten strength test. No oil was applied on the plates because gluten did not stick to the plates.

2.2.4 Dough Preparation

Dough was prepared by following the protocol described by Chopin using the Chopin AlveoConsistograph kneader. The ingredients contained 250 g of flour and 3g of dry yeast. Sodium chloride and the commercial sodium chloride substitutes were added at 1 and 2% levels in a dry form. The quantity of deionized water added depended on the moisture content of the flour. The deionized water quantity was taken from a table published by International Association for Cereal Science and also suggested in the reference table given in the Chopin protocol. All ingredients were mixed in the kneader bowl and water was added progressively during the first minute of mixing. Mixing was stopped after 2 minutes to ensure homogenous hydration and to remove flour sticking to bowl walls. After that, mixing was continued for another 6 minutes. A sample size of 315g of dough was used for each treatment.

2.2.5 Fermentation Test

Rheofermentometer F3 (Chopin, Tripette & Renaud, France) was used to study the fermentation properties of the dough. The dough (315 g) was placed in the bottom of an aluminum basket and packed down by hand. The height of the dough sample had to level out just below the lowest holes. A piston with plates summing 2000 g was placed on the top of the dough and temperature was stabilized to 28.5ºC. The basket was placed in an F3 rheofermentometer bowl. A displacement sensor was placed and the whole system was tightly closed and test run for 3h 5 minutes. The F3 rheofermentometer analyzed the height of the dough sample placed in the bowl. As the dough rose, the piston placed on the dough rose accordingly, and the piston was directly linked to the displacement sensor which calculated the dough rising. The rheofermentometer was also linked to a pressure sensor through a pneumatic circuit that measured the pressure increase in the fermenting dough. It also calculated the speed of carbon dioxide release, volume produced, volume retained in dough, maximum height of dough, height of dough at the end of test, T1. H'm, T'1, Tx and coefficient retention.

2.2.6 Partial proximate analysis of flour

The protein, moisture and ash contents were determined using the NIR system (FOSS NIR Systems Inc, Laurel, MD 20723). The instrument was used following manufacturer's instructions. Analysis were done in triplicates.

2.2.7 Statistical Analysis

Statistical analysis was done using SAS 9.3 version. A factorial design of 2*2*3+1 was analyzed by Analysis of Variance (ANOVA). The experimental design used was randomized complete block.

3 Results

3.1 Viscoelastic properties

3.1.1 Recoverability (RCY)

3.1.1.1 Flour 1 (F1)

There was no significant effect observed in gluten recovery among 1 and 2% levels of all commercial sodium chloride substitutes (Table 2). Although with lower protein content (9.81) more distinct recoverability was expected with different levels of NaCl and salt substitute treatments, reduced sodium salt levels did not affect elastic recovery of gluten significantly.

3.1.1.2 Flour 2 (F2)

This flour showed an overall significant effect on gluten recovery of 1 and 2% levels of commercial sodium chloride substitutes with respect to controls. There was no significant effect observed among 1 and 2% levels for most of the commercial sodium chloride substitutes except for S1 ($P<0.0245$) (Table 3). S1 showed a significantly higher gluten recovery by 5.89% as its level increased from 1 to 2%.

Gluten recovery for S1 showed a significantly lower value by 5.1% when compared to C1 (1% sodium chloride). S4 at the 2% level showed a significantly lower gluten recovery by 6% compared to C2 (2% sodium chloride). No other significant effect was observed.

3.1.1.3 Flour 3 (F3)

In flour 3 an overall significant effect in gluten recovery was observed among reduced sodium salt treatments but the controls did not show any significant effect ($P<0.0006$) (Table 4). Only S4 showed a significant increase by 5.7% in gluten recovery as its level increased from 1 to 2%. All other reduced sodium salt treatments did not show any significant difference between the two levels.

Commercial sodium chloride substitutes S2 and S4 were the only reduced sodium salts with a significant difference by 4.5 and 7% respectively in comparison to C1; no general trend was observed. None of the other treatments showed a significant difference compared to C1 and C2.

3.1.2 Delta compliance (J-Jr)

3.1.2.1 Flour 1 (F1)

J-Jr is the difference between creep and recovery compliance at 100 s. All reduced sodium salt treatments in this flour had a significant effect on viscosity among 1 and 2% levels ($P<0.0001$) (Table 5). Controls (NaCl at 1 and 2%) had a significant effect on viscosity. C2 showed a significant increase by 12.9% in comparison to C1, whereas C1 showed a higher percentage increase by 89.7% in comparison to C0. Reduced sodium salt S1 and S2 showed a significant decrease in viscosity by 22.6 and 13.9% respectively with an increase in its levels from 1 to 2%, whereas S3 and S5 showed the opposite effect as significant increases in viscosity by 39.8 and 12.1% were observed with increases in their levels.

Most of the commercial sodium chloride substitutes showed a significant effect in comparison to their respective controls (at the same concentration of NaCl). S3 showed the highest percentage decrease by 37.3% in comparison to C1. All other salts showed significant increases in viscosity compared to C1. S4 showed the highest percentage increase by 16.77% and S1 showed a percentage increase by 13.4%. Reduced sodium salt S1 and S3 showed the highest percentage decreases by 22.2 and 22.4% respectively, whereas S2 showed a percentage decrease by 14.1% in comparison to C2 among all other salts. Higher J-Jr values indicate higher viscosity.

3.1.2.2 Flour 2 (F2)

In flour 2 a significant effect on viscosity was observed as a result of presence of commercial sodium chloride substitutes (P<.0001). Controls showed a significant effect on viscosity. C1 showed a percentage increase by 44.3% compared to C0, whereas C2 showed a percentage decrease by 15.4% in comparison to C2 (Table 6). Commercial sodium chloride substitutes S3 and S5 were the only ones that showed a significant decrease among two levels; S5 showed a decrease by 44.7%, whereas S3 showed a parentage decrease by 31.2% as reduced sodium salt level increased from 1 to 2%.

Most of the commercial sodium chloride substitutes showed a significant effect in comparison to respective controls. Reduced sodium salt S1 showed a percentage increase by 36.3%, whereas S5 showed the highest percentage increase by 85.5% in comparison to C1. S4 showed the lowest percentage increase by 18.7% in comparison to C1. Reduced sodium salt S1 showed a percentage increase by 48.6% and S5 showed a percentage increase by 21.2% compared to C2. The highest percentage increase was observed for S4 by 52.1% in comparison to C2.

3.1.2.3 Flour 3 (F3)

An overall significant effect in viscosity among 1 and 2% levels of all reduced sodium salt treatments was observed (P<0.0001) (Table 7). C1 showed a significant increase by 41.4% in comparison to C0, whereas C2 showed a significant decrease by 39.2% compared to C1. Commercial sodium chloride substitutes S1, S4 and S5 had a significant effect in viscosity as level increased from 1 to 2%. S4 showed the highest percentage decrease by 21.2%. Commercial sodium chloride substitutes S1 and S4 at 1% showed a significantly higher viscosity when compared to 2% levels, but S5, potassium based salt, showed a reverse trend between the two levels and showed a percentage increase by 39.2%.

Most of the commercial sodium chloride substitutes showed a significant increase in viscosity when compared to respective controls except S2 and S5, which at 1% showed a significant decrease compared to C1 by 30.6% and 29.7% respectively. Reduced sodium salt S5 showed a percentage increase by 60.1% and S4 showed a percentage increase by 55.1% compared to C2. S3 showed the highest percentage increase in viscosity by 72.6% in comparison to C2.

3.1.4 Maximum strain (%)

3.1.4.1 Flour 1 (F1)

Maximum strain (%) measures the percent deformation degree of gluten under constant stress of 100S in creep phase. An overall significant effect was observed for all the treatments in this flour (P<.0001). C1 showed a significant increase by 77.3% in comparison to C1, whereas C2 showed a percentage increase by 18.7% in comparison to C2 (Table 8). A higher value of maximum creep strain (%) indicates greater deformation. No general trend was observed among commercial sodium chloride substitutes. S1 and S3 showed significantly lower maximum strain (%) values by 27.1and 25.1% respectively at 2% level compared to 1% level, whereas S2 and S5 demonstrated the reverse trend and showed a percentage increase by 40.2 and 12.8% respectively with an increase in level.

Most of the commercial sodium chloride substitutes showed a significant increase in maximum strain (%) value compared to C1. Reduced sodium salt S2 showed a percentage decrease by 27.2%, whereas S3 showed the highest percentage increase by 24.4% among all other salts. The lowest percentage increase by 16.9% was observed in S4. In comparison to C2, commercial sodium chloride substitutes showed a significant decrease in maximum strain (%) values. Reduced sodium salt S3 showed a percentage decrease by 21.4%. S1 showed the highest percentage decrease by 27.8% among all other salts. The lowest percentage decrease, 14%, was observed in S2.

3.1.4.2 Flour 2 (F2)

An overall significant effect was observed for all the treatments in this flour (P<.0001). The general trend indicated lower values of maximum strain (%) at 2% salt levels (Table 9). C1 showed a significant decrease by 14.5% in comparison to C2, whereas C1 showed a higher percentage increase by 58.3% in comparison to C0. S5 showed a percentage decrease by 21.1% with an increase in its level. S2 showed the highest percentage decrease by 25.6% among all other salts. The lowest percentage decrease of 9.01% was observed in S1 with an increase in its level.

All commercial sodium chloride substitutes showed a significant increase in comparison to respective controls. Reduced sodium salt S5 showed a percentage increase by 14.9%, whereas S4 showed the highest percentage increase by 21.4% in comparison to C1, and S2 showed the lowest percentage increase by 14.3% in comparison to C1. S1 showed the highest percentage increase by 38.8% in comparison to C2, and the lowest percentage increase of 21.5% was recorded for S4.

3.1.4.3 Flour 3 (F3)

An overall significant effect was observed for all the treatments flour 3 (P<.0001) (Table 10). The general trend indicated a higher value of maximum strain (%) at 1% salt levels, except S5 which showed a percentage increase by 21.9% as its level increased from 1 to 2%. C1 showed a significant increase by 45.9% in comparison to C0, whereas C2 showed a significant decrease by 38.3% in comparison to C1. S2 showed a percentage decrease by 13.3% with an increase in its level.

Commercial sodium chloride substitutes showed a significant decrease in comparison to C1. S5 showed the highest percentage decrease by 26.1%, and the lowest percentage decrease by 16.5% was observed for S2. In comparison to C2, commercial sodium chloride substitutes showed a significant increase: S4 and S5 showed a percentage increase by 44.8 and 45.9% respectively in comparison to C2. S3 showed the highest percentage increase by 56.3%, and S2 showed the lowest percentage increase by 17.2% among all other salts.

3.1.3 Final Strain (%)

3.1.3.1 Flour 1 (F1)

Final strain (%) measures the final deformation of gluten after the removal of constant stress in 100S of recovery phase. A higher value indicates a more flowable character for the gluten. This flour had an overall significant effect on final strain % value for all reduced sodium salt treatments ($P<.0001$). C1 showed a significantly higher final strain value by 89.8% in comparison to C0, whereas C2 showed a percentage increase by 12.9% in comparison to C1 (Table 11). No general trend was observed. S3 showed a percentage increase by 38.8% and S1 showed a percentage decrease by 22.6% with increases in their level.

Most of the commercial sodium chloride substitutes showed a significant increase in comparison to C1 except S3 which showed a percentage decrease by 37.3%. S4 showed the highest percentage increase by 16.7% and S1 showed a percentage increase by 13.3%. Commercial sodium chloride substitutes showed a significant decrease in comparison to C2, as expected. S1 and S2 showed a percentage decrease by 22.3 and 14.2% respectively, and the highest percentage decrease was recorded for S3 by 22.4%.

3.1.3.2 Flour 2 (F2)

There was an overall significant effect in final strain (%) for all the reduced sodium salt treatments in this flour (P<.0001) (Table 12). The general trend indicated a lower final strain (%) at 2% level compared to 1% level. Controls showed a significant effect on final strain (%). C1 showed a significant increase by 48.5% in comparison to C0, whereas C2 showed a significant decrease by 18.1% in comparison to C2. S3 and S5 showed a percentage decrease by 30.3 and 44.9% respectively with an increase in their levels.

All commercial sodium chloride substitutes showed a significant increase in comparison to their respective control. S1 showed a percentage increase by 31.8%. S5 showed the highest percentage increase by 79.5% and the lowest percentage increase by 14.8% was recorded for S4 in comparison to C1. Reduced sodium salt S1 showed a percentage increase by 48.2%. S4 showed the highest percentage increase by 51.5% and the lowest percentage increase of 20.5% was recorded for S5 in comparison to C2 among all other salts. In this flour, commercial sodium chloride substitutes showed more elastic recovery than control.

3.1.3.3 Flour 3 (F3)

An overall significant effect was observed for all the treatments in this flour (P<.0001) (Table 13). The general trend indicated lower final strain (%) values at 2% salt levels compared to 1% level except for S5, which showed the reverse trend. C1 showed a significant increase by 41.5% compared to C0, whereas C2 showed a significant decrease by 39.1% in comparison to C1. S1 and S4 showed a percentage decrease by 13.04 and 21.1% respectively as the level increased from 1 to 2%. The opposite trend was observed in S5 as it showed a percentage increase by 39.2% with an increase in its level.

Most commercial sodium chloride substitutes showed a significant increase in comparison to respective controls except S2 and S5 which showed a significant decrease by 30.6 and 29.7% respectively. On the other hand, S4 showed a percentage increase by 19.6% in comparison to C1. S4 and S5 showed a percentage increase by 55.1 and 60.8% respectively in comparison to C2. S3 showed the highest percentage increase by 72.6% and the lowest percentage increase of 33.8% was recorded for S1 in comparison to C2.

3.2 Elastic Recovery

3.2.1 Flour 1 (F1)

There was an overall significant effect in elastic recovery for this flour ($P<.0001$). Controls did not show any significant effect (Table 14). No general trend was observed. Commercial sodium chloride substitutes S1 and S4 were the only ones with a significant difference by 23.3 and 15.2% respectively among 1 and 2% levels.

All reduced sodium salt treatments of 1 and 2% levels were compared with respective controls. S4 and S5 showed a significantly lower elastic recovery by 18.5 and 19.5% respectively in comparison to C1. Most of the reduced sodium salt showed a significantly higher elastic recovery in comparison to C2. S1 and S4 showed a percentage increase by 26.4 and 27.4% respectively in comparison to C2. The highest percentage increase by 30.2% was observed for S3, whereas the lowest percentage increase by 16.8% was recorded for S5 compared to C2.

3.2.2 Flour 2 (F2)

There was an overall significant effect observed for all the treatments in this flour ($P<0.0002$) (Table 15). C1 showed a significantly higher elastic recovery by 6.1% in comparison to C0, whereas C2 showed a percentage increase by 5.5% in comparison to C1. Reduced sodium salt S2 was the only significant increase by 11.5% as its level increased from 1 to 2%.

No significant differences were observed in comparison to C1. Reduced sodium salt S1 was the only one which showed a significantly lower elastic recovery by 6.4% in comparison to C2. No other significant differences were recorded.

3.2.3 Flour 3 (F3)

In this flour, controls and commercial sodium chloride substitutes did not show any significant difference among 1 and 2% levels ($P<0.0353$) (Table 16).

The only significant difference recorded was of S1 at 2% level, which showed higher elastic recovery by 11.7% in comparison to C2.

3.3 Fermentation properties

3.3.1 Maximum height of dough (Hm)

3.3.1.1 Flour 1 (F1)

Hm is the maximum height of the dough development curve in the fermentation test. There was an overall significant effect observed in Hm for salt treatments ($P<0.0188$) (Table 17). Only controls showed a significant effect as level increased from 1 to 2%. C2 showed a percentage increase by 9.1% in comparison to C1. No other significant difference was observed among commercial sodium chloride substitutes.

Commercial sodium chloride substitutes showed a significant increase in Hm value in comparison to C1. S1 showed a percentage increase by 10.7%, whereas S2 resulted in the highest percentage increase by 13.1% and the lowest percentage increase of 7.9% was recorded for S5. No significant difference was recorded in comparison to C2

3.3.1.2 Flour 2 (F2)

An overall significant effect on Hm value was observed for this flour (P<.0001). The general trend indicated a lower Hm value at the 2% level (Table 18). C1 showed a significant increase by 15.7% compared to C0. C2 showed a percentage decrease by 5.7% compared to C1. S1 showed a percentage decrease by 5.3% and S2 showed a higher percentage decrease with an increase in its level by 6.8%.

Commercial sodium chloride substitutes showed a significant increase in comparison to respective controls. Reduced sodium salt S1 showed a percentage increase by 6.2% in comparison to C1. S5 showed the highest percentage increase by 7.4% and the lowest percentage increase of 5.4% was recorded for S2 in comparison to C1. S4 showed a percentage increase by 6.8%, S5 showed the highest percentage increase by 10.7%, and the lowest percentage increase of 6.6% was observed for S1 in comparison to C2.

3.3.1.3 Flour 3 (F3)

An overall significant effect on Hm value for all the treatments was observed for this flour (P<.0001). The general trend indicated a higher Hm value at 2% salt level. C2 showed a significantly higher Hm value by 9.6% in comparison to C1 (Table 19). S4 showed a percentage increase by 5.7% and S5 showed the highest percentage increase by 11% with an increase in its level.

Reduced sodium salt S5 showed a significant decrease at 1 and 2% levels in comparison to C1 and C2 by 6.2% and 5% respectively, whereas S1 and S2 showed a significant increase by 9.7 and 7.8% respectively in comparison to C1. No other salts showed any significant difference.

3.3.2 Height of the dough (h)

3.3.2.1 Flour 1 (F1)

During the fermentation test, dough rises to its maximum until gluten expands to its full capacity; afterwards, it breaks down and the flattened dough rises again. The height of the dough development at the end of the test is represented by "h". An overall significant effect was observed in the height of the dough at the end of the fermentation test in this flour ($P<.0001$) (Table 20). The general trend indicated a higher value at 2% salt level. C1 showed a significant increase by 20.1% in comparison to C0, whereas C2 showed a percentage increase by 73.6% in comparison to C1. Reduced sodium salt S3 showed a percentage increase by 61.9% with an increase in its level. S1 showed the highest percentage increase by 67.6%, and the lowest percentage increase of 31.8% was observed for S2 with an increase in its level from 1 to 2%.

Commercial sodium chloride substitutes showed a significant decrease in h value in comparison to respective controls except S2 which resulted in a significant increase at 1 and 2% level in comparison to C1 and C2 by 42.7% and 8.3% respectively. All other commercial sodium chloride substitutes showed significantly lower h values compared to respective controls. S1 showed a percentage decrease by 17.8% at 1% level in comparison to C1, whereas S1 and S4 at 2% level showed a percentage decrease by 20.7 and 20.8% respectively in comparison to C2.

3.3.2.2 Flour 2 (F2)

An overall significant effect was observed in h value for all the treatments in this flour ($P<0.0003$) (Table 21). C1 showed a significant increase by 23.1% in comparison to C0. No significant effect was observed among C2 and C1. Reduced sodium salt S5 was the only one with a significant increase by 8.1% as its level increased from 1 to 2%.

No significant difference was observed in any of reduced sodium salt levels compared to respective controls.

3.3.2.3 Flour 3 (F3)

An overall significant effect in h value was observed for this flour (P<.0001) (Table 22). The general trend indicated a higher h value at 2% salt levels compared to 1% levels C1 showed a significant increase by 6% in comparison to C0, and C2 showed a percentage increase by 9.8% compared to C1. Commercial sodium chloride substitutes S4 and S5 showed a significant increase by 6.1 and 10.9% respectively with an increase in its levels from 1 to 2%.

Commercial sodium chloride substitutes S1 and S2 showed a significant increase in comparison to C1, whereas S5 showed a significant decrease by 6%. S1 showed the highest percentage increase by 9.5% in comparison to C1. These results can be explained by the low sodium content of salt not affecting yeast metabolism properly and resulting in higher values of h. No significant difference was recorded for reduced sodium salt levels in comparison to C2.

3.3.3 Time of maximum rise (T1)

3.3.3.1 Flour 1 (F1)

T1 is the time taken by the dough to reach maximum height during dough development in the fermentation test. This flour showed a significant effect overall in all the treatments (P<.0001) (Table 23). The general trend indicated that 2% level of sodium chloride and all other commercial sodium chloride substitutes gave higher T1 values compared to 1% level. C1 showed a 27.7% increase compared to C0, whereas C2 showed a percentage increase of 25% in comparison to C1. Commercial sodium chloride substitutes S1, S2, S3, S4 and S5 showed similar trends of higher T1 values at 2% compared to 1% levels. S5 showed a percentage increase of 28% with an increase in its level. The highest percentage increase of 29.5% was observed for S4, whereas the lowest percentage increase of 23.4% was observed for S1 with an increase in its level from 1 to 2%.

All reduced sodium salt levels were compared with respective controls. Commercial sodium chloride substitutes S3, S4 and S5 showed significantly lower T1 values compared to C1 (1% sodium chloride). S3 and S5 showed a percentage decrease of about 14.6%, but lower percentage decreases of 9.7% were recorded with S4. Similarly, commercial sodium chloride substitutes S3 and S5 showed significantly lower T1 values compared to C2 (2% sodium chloride) with percentage decreases of 12.7%.

3.3.3.2 Flour 2 (F2)

There was an overall significant effect in all the treatments observed for this flour (P<.0001) (Table 24). A similar general trend was observed here. 2% salt levels increased dough development time significantly compared to 1% levels. C2 showed a significantly higher value of T1 by 25.2% compared to C1. Commercial sodium chloride substitutes S1, S2, S3 and S5 showed significantly higher dough development times at 2% level compared to 1% level. S3 showed a percentage increase by 38.1%. The highest percentage increase of 47.3% was observed in S2, whereas the lowest percentage increase of 23.4% was observed in S5.

In comparison to C1, commercial sodium chloride substitutes S3, S4 and S5 showed significantly lower T1 values. S5 showed a percentage decrease by 17.5% and the highest percentage decrease of 20% was recorded for S3. In comparison to C2, commercial sodium chloride substitutes S4 and S5 showed significantly lower dough development times with percentage decreases of 21.5 and 18.7% respectively.

3.3.3.3 Flour 3 (F3)

There was no significant effect observed in this flour (P>0.05) (Table 25) which indicates that hard red winter wheat with a higher protein content of 13.3% showed no significant difference in dough development time as salts did not make any pronounced difference.

3.3.4 Maximum height of the gaseous curve (H´m)

3.3.4.1 Flour 1 (F1)

H'm is the maximum height of the gaseous release curve in the fermentation test. There was an overall significant effect on H'm for this flour (P<.0001) (Table 26). The general trend showed a decrease in H'm values at 2% salt levels compared to 1% level. C1 showed a significantly lower H'm with a percentage decrease of 12% compared to C0. C2 showed a percentage decrease by 13.9% compared to C1. S1 showed a percentage decrease by 10.7% with an increase in its level. Reduced sodium salt S4 showed the highest percentage decrease of 14.7% and S5 showed the lowest percentage decrease by 8.4% with an increase in its level from 1 to 2%.

Commercial sodium chloride substitutes S1, S4 and S5 showed significantly higher H'm values compared to C1. S4 showed the highest percentage increase by 13.3% and S1 showed the lowest percentage increase by 7.2% compared to C1. S3 showed a percentage increase by 17.1%. S5 showed the highest percentage increase by 18.2% and S2 showed the lowest percentage increase by 8.4% in comparison to C2 All other commercial sodium chloride substitutes showed significantly higher H'm values compared to C2.

3.3.4.2 Four 2 (F2)

There was an overall significant effect on H'm in all the treatments for this flour (P<.0001) (Table 27). A similar general trend of lower H'm values with 2% salt levels compared to 1% was observed. C0 showed a percentage decrease by 14.7% compared to C1, whereas C2 showed a percentage decrease of 28.5% compared to C1. Reduced sodium salt S1 showed a percentage decrease by 14.2%. S2 showed the highest percentage decrease of 17.9% and the lowest percentage decrease of 8.2% was observed in S3 with an increase in level from 1 to 2%.

All commercial sodium chloride substitutes showed a significant percentage increase of H'm in comparison to respective controls. S3 and S5 showed a percentage increase by 11.3 and 11.9% respectively, and the highest percentage increase by 12.2% was observed for S1 in comparison to C1. Similarly, all salts showed significantly higher H'm values compared to C2. S4 and S5 showed a percentage increase by 33.7 and 42.5% respectively in comparison to C2. S3 showed the highest percentage increase by 42.8%, and S2 showed the lowest percentage increase by 25.6% compared to C2.

3.3.4.3 Flour 3 (F3)

There was an overall significant effect observed for all the treatments in this flour ($P<.0001$) (Table 28). The general trend was similar to F1 and F2. C1 showed a percentage decrease of 16.8% compared to C0, whereas a percentage decrease of 34% was observed for C2 in comparison to C1. Reduced sodium salt S4 showed a percentage decrease by 10.6% with an increase in its level. S2 showed the highest significant decrease by 18% as its level increased from 1 to 2%.

All commercial sodium chloride substitutes showed significantly higher values of H'm compared to C1 and C2. Reduced sodium salt S1 showed the highest percentage increase by 14.4% and the lowest percentage increase by 5.1% was recorded for S4 compared to C1. Commercial sodium chloride substitutes S1 and S5 gave percentage increases by 49.5 and 49.3% respectively in comparison to C2. S3 showed the highest percentage increase by 58.7% and S2 showed the lowest percentage increase by 34.1% compared to C2.

3.3.5 Time of maximum rise (T'1)

3.3.5.1 Flour 1 (F1)

T'1 measures the time taken to reach maximum rise during the gaseous release phase. An overall significant effect was observed for all treatments in this flour (P<.0001) (Table 29). The general trend indicated an increase in T'1 value with an increase in salt levels from 1 to 2%. C1 showed a significantly higher T'1 value by 17.8% compared to C0. C2 showed a percentage increase by 16.3% in comparison to C1. Commercial sodium chloride substitutes S1, S2 and S3 showed higher T'1 values at the 2% level compared to the 1% level, whereas S4 showed the opposite trend with a percentage difference of15.2%. The highest percentage increase of 46.2% was observed in S2 with an increase in its level.

Commercial sodium chloride substitutes did not show any significant difference in comparison to C1. Commercial sodium chloride substitutes S1 and S2 showed significantly higher T'1 values by 23.7 and 22% respectively compared to C2. The only significantly lower value in comparison to C2 was recorded for S3 with a percentage decrease of 13.4%.

3.3.5.2 Flour 2 (F2)

The only significant difference recorded was for controls in this flour (P<0.0072) (Table 30). C1 had a significantly higher value of T'1 with a percentage increase of 12.1% compared to C1, whereas C2 showed a percentage increase of 11.1% in comparison to C1. No other treatments showed any significant difference in T'1 value.

3.3.5.3 Flour 3 (F3)

There was an overall significant effect observed for all treatments in this flour (P<.0001) (Table 31). The general trend showed higher T'1 values at 2% salt level compared to 1% levels.

C1 showed a significantly higher value by 24.1% in comparison to C0, whereas a percentage increase of 10.7% was observed for C2 in comparison to C1. Commercial sodium chloride substitutes S1 and S2 showed a percentage increase by 15.8%. S5 showed the significantly highest percentage increase of 20.2% with an increase in its level from 1 to 2%.

Commercial sodium chloride substitutes S1 and S5 only showed significantly lower T'1 values compared to C1, with a percentage decrease of 6.7 and 8.9% respectively. No significant differences were observed for any treatments in comparison to C2.

3.3.6 Time to release gas from dough (Tx

3.3.6.1 Flour 1 (F1)

Tx is the time when gas starts to release from the dough during the fermentation test. An overall significant effect was observed for all the treatments in this flour ($P<.0001$) (Table 32). C1 showed a significantly higher Tx value by 75.5% in comparison to C0, whereas C2 showed a significant decrease by 22.4% compared to C1. Reduced sodium salt S3 was the only salt which showed a significantly lower Tx value at 2% level by 52.1% compared to its 1% treatment level.

Reduced sodium salt treatments with 1 and 2% levels showed significantly lower TX values compared to respective controls. Commercial sodium chloride substitutes S1 and S2 showed a percentage decrease by 51.5 and 50.7% respectively in comparison to C1. S5, potassium based salt, showed the highest percentage decrease of 54.6% in comparison to C1; similarly, S3 and S5 showed the highest percentage decrease by 41.5% among all other commercial sodium chloride substitutes in comparison to C2. Since commercial sodium chloride substitutes contain less sodium, they could not form a stronger gluten network which results in an earlier escape of gas molecules from the dough structure. Sodium chloride masks the repulsion forces among gluten molecules and helps to strengthen the elastic and the network formation.

3.3.6.2 Flour 2 (F2)

An overall significant effect was observed for all treatments in this flour (P0.0135) (Table 33). The general trend indicated more time taken by the dough to release gas at 2% salt levels compared to 1% levels. C2 showed a significantly higher Tx value compared to C1 by 56.5%. Reduced sodium salt S5 showed a percentage increase by 79.7% as its level increased from 1 to 2%. S3 showed the highest percentage increase of 123.1% with an increase in its level.

No significant difference was observed in comparison to C1, whereas S1 and S4 showed significantly lower Tx values compared to C2. S4 showed the highest percentage decrease by 44.4% in comparison to C2 and S1 showed a percentage decrease by 35.1%.

3.3.6.3 Flour 3 (F3)

An overall significant effect was observed for this flour (P<.0001). The general trend was similar to F2, an increase in Tx value with an increase in salt level (Table 34). C1 showed a significantly higher Tx value with a percentage increase of 136.8% in comparison to C0, whereas C2 showed a percentage increase by 37% compared to C1. Reduced sodium salt S2 showed a percentage increase by 58.4% with an increase in its level. S1 showed the highest percentage increase by 190.9% with an increase in its level from 1 to 2%.

Most of reduced sodium salt levels showed a significant difference in Tx values compared to respective controls. S1 and S3 showed a percentage decrease by 54.3 and 53.9% respectively in comparison to C1. S5 showed the highest percentage decrease by 55.3%, and the lowest percentage decrease of 38.4% was recorded for S2 in comparison to C1.Commercial sodium chloride substitutes S3 and S4 showed a percentage decrease by 32.1 and 30.3% respectively compared to C2. S5 also showed the highest significant decrease by 69.2%, and S2 showed the lowest percentage decrease by 28.7% in comparison to C2.

3.3.7 Total volume (TV)

3.3.7.1 Flour 1 (F1)

Tv is the total volume of the gas produced during the fermentation test. An overall significant effect for all the treatments was observed in this flour (P<.0001) (Table 35). No significant effect in total volume was observed among controls. Commercial sodium chloride substitutes S2 and S4 showed a significant difference by 3.9% with an increase in their level.

Most reduced sodium salt levels showed significantly higher Tv values compared to respective controls. Because of the high metabolism of yeast, the reduced sodium content of the salt could not inhibit yeast metabolism. Reduced sodium salt S3 showed a percentage increase by 7.1%, S5 showed the highest percentage increase by 8.2%, and the lowest percentage increase of 6.3% was recorded for S1 compared to C1. S2 and S3 showed a percentage increase by 8.5 and 7.9% respectively in comparison to C2. S1 showed the highest percentage increase by 11.3% and the lowest percentage increase of 5.1% was recorded for S4 compared to C2.

3.3.7.2 Flour 2 (F2)

An overall significant effect was observed in this flour (P<.0001) (Table 36). The general trend indicated lower Tv values at 2% compared to 1% level. C1 showed a significantly lower Tv value by 12.6% compared to C0, whereas C2 showed a percentage decrease by 33.2% compared to C1. Reduced sodium salt S1 showed a percentage decrease by 16% with an increase in its level from 1 to 2%. S2 showed the highest percentage decrease by 20.1%.

Reduced sodium salt levels showed a significant difference in comparison to respective controls. S5 showed the highest percentage increase by 8.4% and a percentage increase of 7.8% was observed for S1, S2 and S3 in comparison to C1. Reduced sodium salt S5 showed a percentage increase by 40.1%. S3 showed the highest percentage increase by 45.3% and the lowest percentage increase of 29% was observed for S2 in comparison to C2 among all commercial sodium chloride substitutes.

3.3.7.3. Flour 3 (F3)

An overall significant effect was observed for all the treatments in this flour (P<.0001) (Table 37). The general trend indicated a decrease in total volume value with an increase in salt level. C1 showed a significantly lower Tv value by 22.4% in comparison to C0, whereas C2 showed a percentage decrease by 33.9% compared to C1. Reduced sodium salt S1 showed a percentage decease by 21.2% and S2 showed the highest percentage decrease by 24.1% with an increase in its level.

All commercial sodium chloride substitutes showed significantly higher Tv values compared to respective controls. Reduced sodium salt S5 showed a percentage difference by 10.6% compared to C1. S1 showed the highest percentage increase by 17.5% and the lowest percentage increase of 9% was recorded for S3 in comparison to C1. Reduced sodium salt S1 showed a percentage increase by 40.2% in comparison to C2, whereas S3 showed the highest percentage increase by 48.4% and the lowest percentage increase by 25.5% was recorded for S2 in comparison to C2.

3.3.8 Volume lost (VL)

3.3.8.1 Flour 1 (F1)

No significant effect was observed in any of the treatments for this flour (Table 38).

3.3.8.2 Flour 2 (F2)

An overall significant effect was observed for all the treatments in this flour (P<.0001) (Table 39). The general trend indicated that treatments with 1% salt lost more volume compared to 2% salt levels. C1 showed a significantly lower VL value by 17.2% in comparison to C0, whereas C2 showed a percentage decrease by 33.8% in comparison to C1. Reduced sodium salt S1 showed a percentage decrease by 18.9% with an increase in its level. S2 showed the highest percentage decrease by 22.8% among all other salts with an increase in its level.

No significant difference was observed in comparison to C1. All commercial sodium chloride substitutes showed significantly higher VL values compared to C2. S1 and S4 showed a percentage increase by 28.7%, S3 showed the highest percentage increase by 43.5%, and the lowest percentage increase of 22.4% was observed for S2 in comparison to C2.

3.3.8.3 Flour 3 (F3)

An overall significant effect was observed for all the treatments in this flour as well (P<.0001) (Table 40). The general trend indicated higher values of VL at 1% compared to 2% salt level. C1 showed a significantly lower VL value by 25.8% in comparison to C0, whereas C2 showed a higher percentage decrease by 39.4% in comparison to C1. The general trend indicated a decrease in volume lost values with an increase in salt level. S1 and S3 showed a percentage decrease by 21.5 and 20.6% respectively with an increase in their levels from 1 to 2%. S2 showed the highest percentage decrease by 24.4% among all other salts.

Most reduced sodium salt treatments showed significantly higher VL values in comparison to respective controls. 2% level treatments showed a more drastic significant increase in respect to C2. Reduced sodium salt S3 showed a percentage increase by 19.5% and S1 showed the highest percentage increase by 20.4% in comparison to C1. S1 and S5 showed a percentage increase by 561%, S3 showed the highest percentage increase by 56.6%, and the lowest percentage of 33.8% was observed for S2 in comparison to C2.

3.3.9 Volume Retained (VR)

3.3.9.1 Flour 1 (F1)

This is the volume of carbon dioxide retained in the dough at the end of the test. An overall significant effect was observed for the treatments in this flour (P<.0001) (Table 41). Controls were not significantly different among 0, 1 and 2% levels. No general trend was observed. Commercial sodium chloride substitutes S2 and S4 were the only ones with significant differences by 4 and 3.6% respectively with an increase in their levels.

Most commercial sodium chloride substitutes showed a significant increase in comparison to respective controls. S3 and S4 showed a percentage increase by 6.8 and 6.2% respectively in comparison to C1. S5 showed the highest percentage increase by 7.9% and the lowest percentage increase by 6% was observed for S1 in comparison to C1 among other salts. S5 showed a percentage increase by 9.8%, S1 showed the highest percentage increase by 11%, and the lowest percentage increase by 5.4% was observed for S4 in comparison to C2.

3.3.9.2 Flour 2: (F2)

An overall significant effect was observed for this flour (P<.0001) (Table 42). The general trend indicated higher VR values at 1% compared to 2% level. C1 showed a significant decrease by 12.3% in comparison to C0, whereas C2 showed a percentage decrease by 33.1% in comparison to C1. Reduced sodium salt S1 showed a percentage decrease by 15.8%, whereas S2 showed the highest percentage decrease by 19.9% with an increase in its level from 1 to 2% among all other salts.

A significant increase in VR values was observed for reduced sodium salt treatment in comparison to respective controls. S1 and S2 showed a percentage increase by 8.1 and 8% respectively in comparison to C1. The highest percentage increase by 8.6% was observed for S5 in comparison to C1. A more drastic significant increase was observed in 2% salt levels in comparison to C2. S5 showed a percentage increase by 40.5%. S3 showed the highest percentage increase in VR values by 45.3% and the lowest percentage increase by 29.4% was observed for S2 in comparison to C2.

3.3.9.3 Flour 3 (F3)

An overall significant effect was also observed in this flour (P<.0001) (Table 43). The general trend indicated a decrease in volume retained value with an increase in salt level. C1 showed a significant decrease by 22.2% in comparison to C0, whereas C2 showed a percentage decrease by 33.6% in comparison to C1. Reduced sodium salt S1 showed a percentage decrease by 21.1% and S2 showed the highest percentage decrease by 24% with an increase in its level from 1 to 2%.

Reduced sodium salt treatments showed a significant increase in VR values in comparison to respective controls. S5 showed a percentage increase by 10.5% in comparison to C1. The highest percentage increase was observed for S1 by 17% and the lowest percentage increase of 8.9% was observed for S3 comparison to C1. S1 showed a percentage increase by 39.5%, and S3 showed the highest percentage increase by 48%. The lowest percentage increase of 25.2% was observed for S2 in comparison to C2.

3.3.10 Retention Coefficient (RC)

3.3.10.1 Flour 3 (F3):

RC is the retained volume of CO_2 divided by total CO_2 released from the dough. F1 and F2 did not show any significant difference in treatments (Table 44 &45). F3 showed an overall significant effect in all the treatments (Table 46). Controls and S3 were the only ones that showed significant differences in 1 and 2% levels. The treatment containing 2% salt showed a higher RC compared to 1% level. C2 showed a significant increase by 0.4% in comparison to C1.No significant difference was observed for any treatments in comparison to C1. Commercial sodium chloride substitutes S1, S4 and S5 showed significant decreases by 0.5 and 0.6% respectively in comparison to C2. S5 gave the highest percentage decrease by 0.6% among all other salts.

4 Discussion

Reduced gluten recovery values in the creep recovery test with commercial sodium chloride substitutes compared to sodium chloride were recorded. Sodium chloride helps to reduce the electrostatic repulsion between positively charged proteins and makes a stronger network (Galal et al, 1978b; Mirsaeedghazi et al, 2008; Wellner et al, 2003). Chloride ions draw water and help forming a stronger association of gluten thus a stronger network (Kinsella and Hale, 1984). The reduced sodium content of salts do not mask the electrostatic repulsion as effectively as NaCl, thus affecting gluten strength and eventually decreasing elasticity. A significant increase in the elastic modulus of the dough with 2% NaCl was reported by several authors (Larsson, 2002; Lynch et al, 2009; Wehrle et al, 1997). No significant effect in the elastic recovery of gluten was recorded among controls of F3 and most of the other sodium chloride substitutes and this is partially explained by the higher protein content of the F3 compared to F1 and F2. The hypothesis, that salts do not affect aggregation of gluten in high protein flours, was suggested by Ukai and collaborators (Ukai et al, 2008). There was no significant difference recorded in the gluten recovery of F1 for any of the treatments, thus there is no effect of the treatments when visco-elastic are tested with small deformation test. C2 (2% sodium chloride) had higher viscosity than C1 and C0 in F1, which can be explained by the phenomenon of different effects of salt attributed primarily to the protein content of flour. 2% NaCl results in a more aligned and close knitted gluten structure in flours with low protein content because of changes in the secondary structure conformation i.e., more β sheet formation due to increased hydrogen and hydrophobic interactions. These β sheets work as an extensive structure which under small strain gives more viscosity to the gluten network (Tuhumury et al, 2014). Sodium chloride has a different effect on the gluten network which is dependent on the protein content of the flour.

Sodium chloride facilitates aggregation of gluten, hence the increased elasticity of gluten in F2 and F3 can be partially explained by the arguments of elongated gluten fibrous network formation and lower viscosity observed with the increase in salt level (Lynch et al, 2009; McCann and Day, 2013). Commercial sodium chloride substitutes gave higher viscosity values at 2% levels because the reduced sodium content of the salts could not facilitate the stronger gluten network formation but resulted in higher viscosity values.

Higher maximum strain (%) values at 1% salt treatment indicate higher deformation compared to 2% level of salts. This can be explained by improved gluten aggregation with higher salt treatment. Higher levels of salt (2%) reduce the repulsion forces between gluten molecules which results in effective interaction of gluten molecules. Lower deformation with 2% salt levels can be partially explained by increased cross linking of gluten due to increased hydrophobic and hydrogen bonding which makes it resistant to deformation so less deformation was observed with 2% salt treatments (Balla et al, 1998).

Gluten elasticity of any flour depends on the gluten strength (Chapman et al, 2012). F3 contains higher protein content (13.4%) compared to other two flours F1 and F2, thus most of commercial salt substitute treatments including the controls did not make a significant improvement to the elastic recovery of the gluten.

The dough development height (Hm) decreased with an increase in NaCl and commercial salt substitutes levels. These observations are in accordance with previous reports (Beck et al, 2012b; Huang et al, 2008; Lynch et al, 2009), which explains that the dough development height (Hm) increases with a decrease in sodium chloride levels. Insufficient amount of salt leads to excessive fermentation and results in acidic dough (Matz, 1992). Higher values of height of the dough (h) were observed with an increase in NaCl and commercial salt substitutes level which is not in accordance with previous reports (Beck et al, 2012b; Gujral and Singh, 1999; Huang et al, 2008), in which the height of the dough at the end of the test, "h", increased significantly when sodium chloride was reduced from 2 to 1% level. Lower time to reach maximum height of the dough (T1) values were observed with an increase in salt level. This observation is in accordance with previous work (Beck et al, 2012b; Huang et al, 2008), which explains that T1 is lower for dough with reduced NaCl because dough is not strong enough to hold the gas. NaCl at 2% level increases the dough development time significantly since salt makes a stronger gluten network. A reduction in its leel results in a weaker gluten network which cannot hold gas molecules, thus a higher volume lost at 1% salt was observed (Lynch et al, 2009). More gas was produced with lower salt levels in the fermentation test. Sodium chloride plays an important role not only in gluten network formation but also in inhibiting yeast metabolism (Miller, 2008). With decreases in sodium content, yeast metabolism accelerates and results in more gas production by yeast. The total volume of gas produced was lower with an increase in salt level.

5 Conclusion

Commercial sodium chloride substitutes affect the rheology of wheat gluten as well as the fermentation properties of wheat dough significantly. In this study three flours with different protein contents (9.8, 10.9 and 13.4%) were used. At higher levels of NaCl (2%) and salt substitutes, increase in viscosity of gluten was observed in F1 (9.8%). Higher elasticity and lower viscosity were observed with an increase in commercial salt substitute's levels in F2 (10.9% protein). Similarly higher deformation of gluten was observed with commercial sodium chloride substitutes levels (1 and 2%) compared to controls (C1 and C2). No significant effect in viscoelastic properties of gluten was observed with increase in NaCl and salt substitute's levels in

F3 (protein=13.4%). Effect of salt on gluten primarily depends on protein content and type of flour.

Commercial salt substitutes resulted in more gas production in the fermentation test as insufficient salt concentration resulted in excessive fermentation and also a weaker gluten network which could not hold gas molecules. Take home message of this study is that reduction in sodium chloride level increases the viscosity of gluten which leads to viscous dough usually interpreted as soft dough. Reduction in sodium chloride (1%) could not control the yeast activity as effectively as higher level of NaCl (2%), resulted in more volume of gas produced within dough structure and also higher volume lost. Salt substitutes could not reduce repulsion forces between gluten molecules as effectively as NaCl, thus gluten network formation was poor compared to NaCl which resulted in increase in viscosity and decrease in elasticity of the gluten. Similarly salt substitutes could not retard yeast activity as effectively as NaCl which resulted in more gas production and less volume retained within dough structure. Lower dough height at the end of the test was observed with salt substitutes compared to NaCl.

Table 1. Proximate analysis of commercial 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 deviation.

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 Gluyen recovery of soft red winter wheat (F1) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Gluten recovery %				I	II	III	Pvalue
F1	C	0	76.8	±	0.70	a				0.7051
F1	C	1	75.2	±	1.11	a				
F1	C	2	76.3	±	2.56	a				
F1	S1	1	76.1	±	0.04	a				
F1	S1	2	75.5	±	1.88	a				
F1	S2	1	77.6	±	0.95	a				
F1	S2	2	74.2	±	1.89	a				
F1	S3	1	78.7	±	0.99	a				
F1	S3	2	77.4	±	2.43	a				
F1	S4	1	75.3	±	0.93	a				
F1	S4	2	76.1	±	0.61	a				
F1	S5	1	77.1	±	1.89	a				
F1	S5	2	77.5	±	0.40	a				

[a]Mean (n=3) ± standard error.

[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 Gluyen recovery of hard red winter wheat (F2) [abcde].

							Percentage change			
Flour	Salt	Level (%)	Gluten recovery %				I	II	III	Pvalue
F2	C	0	78.1	±	1.29	abcde				0.0245
F2	C	1	78.6	±	1.38	abcd				
F2	C	2	80.4	±	0.82	abc				
F2	S1	1	74.5	±	2.71	e		-5.15%		
F2	S1	2	78.9	±	1.33	abcd	5.89%			
F2	S2	1	80.0	±	1.05	abc				
F2	S2	2	81.3	±	1.26	a				
F2	S3	1	77.7	±	0.78	abcde				
F2	S3	2	80.7	±	0.65	ab				
F2	S4	1	77.7	±	1.26	abcde				
F2	S4	2	75.5	±	0.76	de				
F2	S5	1	77.0	±	0.52	cde				
F2	S5	2	77.5	±	1.04	bcde				

[a]Mean (n=3) ± standard error. Means followed by different letter 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 Gluyen recovery of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Gluten recovery %				I	II	III	Pvalue
F3	C	0	77.2	±	1.28	c				0.0006
F3	C	1	78.0	±	0.59	bc				
F3	C	2	79.0	±	2.28	abc				
F3	S1	1	78.4	±	0.44	abc				
F3	S1	2	78.7	±	0.81	abc				
F3	S2	1	81.5	±	1.21	a		4.55%		
F3	S2	2	80.4	±	0.19	ab				
F3	S3	1	76.7	±	0.46	c				
F3	S3	2	76.0	±	0.19	c				
F3	S4	1	72.5	±	0.62	d		-7.06%		
F3	S4	2	76.6	±	0.80	c	5.75%			
F3	S5	1	79.0	±	1.23	abc				
F3	S5	2	75.9	±	1.65	c				

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 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 gluten viscosity of soft red winter wheat (F1) [abcde].

							Percentage change			
Flour	Salt	Level (%)	j-jr (1/pa)				I	II	III	Pvalue
										<.0001
F1	C	0	0.547	±	0.02	f				
F1	C	1	1.038	±	0.01	c	89.73%			
F1	C	2	1.172	±	0.05	ab	12.90%			
F1	S1	1	1.177	±	0.03	ab		13.40%		
F1	S1	2	0.911	±	0.03	d	-22.63%		-22.29%	
F1	S2	1	1.168	±	0.02	ab		12.58%		
F1	S2	2	1.005	±	0.05	cd	-13.95%		-14.19%	
F1	S3	1	0.650	±	0.04	e		-37.34%		
F1	S3	2	0.909	±	0.01	d	39.80%		-22.41%	
F1	S4	1	1.212	±	0.06	ab		16.77%		
F1	S4	2	1.266	±	0.04	a				
F1	S5	1	1.039	±	0.03	c				
F1	S5	2	1.165	±	0.03	b	12.09%			

[a]Mean (n=3) ± standard error. Means followed by different letter 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 gluten viscosity of hard red winter wheat (F2) [abcde]

							Percentage change			
Flour	Salt	Level (%)	j-jr (1/pa)				I	II	III	Pvalue
F2	C	0	0.374	±	0.02	g				<.0001
F2	C	1	0.540	±	0.02	d	44.32%			
F2	C	2	0.456	±	0.01	ef	-15.46%			
F2	S1	1	0.736	±	0.03	b		36.31%		
F2	S1	2	0.678	±	0.03	bc			48.64%	
F2	S2	1	0.531	±	0.03	de				
F2	S2	2	0.455	±	0.02	ef				
F2	S3	1	0.648	±	0.03	c		19.96%		
F2	S3	2	0.445	±	0.02	fg	-31.21%			
F2	S4	1	0.641	±	0.01	c		18.74%		
F2	S4	2	0.694	±	0.04	bc			52.11%	
F2	S5	1	1.002	±	0.04	a		85.55%		
F2	S5	2	0.553	±	0.02	d	-44.77%		21.21%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 gluten viscosity of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	j-jr (1/pa)				I	II	III	Pvalue
F3	C	0	0.718	±	0.03	e				<.0001
F3	C	1	1.016	±	0.06	bc	41.44%			
F3	C	2	0.618	±	0.02	e	-39.17%			
F3	S1	1	0.953	±	0.02	c				
F3	S1	2	0.827	±	0.02	d	-13.17%		33.90%	
F3	S2	1	0.705	±	0.01	e		-30.62%		
F3	S2	2	0.653	±	0.04	e				
F3	S3	1	1.097	±	0.03	b				
F3	S3	2	1.067	±	0.06	b			72.67%	
F3	S4	1	1.216	±	0.04	a		19.73%		
F3	S4	2	0.959	±	0.01	c	-21.17%		55.17%	
F3	S5	1	0.714	±	0.02	e		-29.71%		
F3	S5	2	0.994	±	0.05	bc	39.25%		60.90%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 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 maximum strain % of soft red winter wheat (F1) [abcde]

Flour	Salt	Level (%)	Max.Strain (%)				Percentage change I	Percentage change II	Percentage change III	Pvalue
F1	C	0	23.7	±	1.15	g				<.0001
F1	C	1	42.0	±	1.82	cd	77.36%			
F1	C	2	49.8	±	2.93	ab	18.70%			
F1	S1	1	49.3	±	1.26	ab		17.58%		
F1	S1	2	36.0	±	2.10	e	-27.10%		-27.78%	
F1	S2	1	30.5	±	0.59	f		-27.23%		
F1	S2	2	42.8	±	2.67	cd	40.27%		-14.01%	
F1	S3	1	52.2	±	1.64	a		24.40%		
F1	S3	2	39.1	±	2.02	de	-25.08%		-21.48%	
F1	S4	1	49.1	±	1.22	ab		16.96%		
F1	S4	2	53.0	±	0.55	a				
F1	S5	1	45.8	±	2.27	bc				
F1	S5	2	51.7	±	0.82	a	12.86%			

[a]Mean (n=3) ± standard error. Means followed by different letter 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 maximum strain % of hard red winter wheat (F2) [abcde].

Flour	Salt	Level (%)	Max.Strain (%)				Percentage change I	Percentage change II	Percentage change III	Pvalue
F2	C	0	17.2	±	0.55	g				<.0001
F2	C	1	27.2	±	0.54	d	58.35%			
F2	C	2	23.3	±	0.36	f	-14.53%			
F2	S1	1	29.6	±	1.67	bc		8.83%		
F2	S1	2	32.3	±	0.72	a	9.01%		38.81%	
F2	S2	1	31.1	±	0.67	ab		14.35%		
F2	S2	2	23.1	±	0.81	f	-25.68%			
F2	S3	1	26.0	±	0.40	de				
F2	S3	2	23.5	±	1.36	f	-9.56%			
F2	S4	1	33.1	±	0.36	a		21.42%		
F2	S4	2	28.3	±	0.82	cd	-14.43%		21.57%	
F2	S5	1	31.3	±	0.63	ab		14.95%		
F2	S5	2	24.7	±	0.86	ef	-21.14%			

[a]Mean (n=3) ± standard error. Means followed by different letter 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 (Control, C) on maximum strain % of hard red winter wheat (F3) [abcde]
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Flour	Salt	Level (%)	Max.Strain (%)				Percentage change I	Percentage change II	Percentage change III	Pvalue
										<.0001
F3	C	0	31.6	±	1.27	fg				
F3	C	1	46.0	±	1.99	ab	45.92%			
F3	C	2	28.4	±	1.53	g	-38.36%			
F3	S1	1	44.1	±	1.37	abc				
F3	S1	2	39.0	±	1.92	d	-11.70%		37.37%	
F3	S2	1	38.4	±	2.33	de		-16.57%		
F3	S2	2	33.3	±	1.69	f	-13.38%		17.24%	
F3	S3	1	47.0	±	0.88	a				
F3	S3	2	44.4	±	2.43	abc			56.37%	
F3	S4	1	44.2	±	1.09	abc				
F3	S4	2	41.1	±	1.27	cd			44.80%	
F3	S5	1	34.0	±	2.01	ef		-26.19%		
F3	S5	2	41.4	±	1.05	bcd	21.90%		45.96%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 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 final strain % of soft red winter wheat (F1) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Final strain (%)				I	II	III	Pvalue
										<.0001
F1	C	0	5.5	±	0.21	e				
F1	C	1	10.4	±	0.09	b	89.83%			
F1	C	2	11.8	±	0.54	a	12.94%			
F1	S1	1	11.8	±	0.29	a		13.39%		
F1	S1	2	9.2	±	0.30	c	-22.61%		-22.31%	
F1	S2	1	11.8	±	0.24	a		12.58%		
F1	S2	2	10.1	±	0.50	bc	-13.98%		-14.26%	
F1	S3	1	6.5	±	0.41	d		-37.35%		
F1	S3	2	9.2	±	0.10	c	39.85%		-22.43%	
F1	S4	1	12.2	±	0.56	a		16.74%		
F1	S4	2	12.7	±	0.40	a				
F1	S5	1	10.5	±	0.32	b				
F1	S5	2	11.7	±	0.28	a	12.15%			

[a]Mean (n=3) ± standard error. Means followed by different letter 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 final strain % of hard red winter wheat (F2) [abcde]

Flour	Salt	Level (%)	Final strain (%)				Percentage change I	Percentage change II	Percentage change III	Pvalue
F2	C	0	3.8	±	0.22	g				<.0001
F2	C	1	5.6	±	0.19	d	48.59%			
F2	C	2	4.6	±	0.16	ef	-18.01%			
F2	S1	1	7.4	±	0.28	b		31.83%		
F2	S1	2	6.8	±	0.34	bc			48.22%	
F2	S2	1	5.3	±	0.27	de				
F2	S2	2	4.6	±	0.20	ef				
F2	S3	1	6.5	±	0.33	c		15.95%		
F2	S3	2	4.5	±	0.24	fg	-30.31%			
F2	S4	1	6.4	±	0.09	c		14.83%		
F2	S4	2	7.0	±	0.41	bc			51.55%	
F2	S5	1	10.1	±	0.39	a		79.52%		
F2	S5	2	5.5	±	0.18	d	-44.95%		20.53%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 final strain % of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Final strain (%)				I	II	III	Pvalue
F3	C	0	7.2	±	0.25	e				<.0001
F3	C	1	10.2	±	0.60	bc	41.52%			
F3	C	2	6.2	±	0.22	e	-39.19%			
F3	S1	1	9.6	±	0.21	c				
F3	S1	2	8.3	±	0.24	d	-13.04%		33.89%	
F3	S2	1	7.1	±	0.10	e		-30.69%		
F3	S2	2	6.6	±	0.39	e				
F3	S3	1	11.0	±	0.34	b				
F3	S3	2	10.7	±	0.65	b			72.67%	
F3	S4	1	12.2	±	0.43	a		19.62%		
F3	S4	2	9.6	±	0.09	c	-21.15%		55.12%	
F3	S5	1	7.2	±	0.21	e		-29.76%		
F3	S5	2	10.0	±	0.51	bc	39.23%		60.84%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 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 elastic recovery of soft red winter wheat (F1) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Elastic reocvery (%)				I	II	III	Pvalue
F1	C	0	65.5	±	2.96	a				<.0001
F1	C	1	63.1	±	3.31	ab				
F1	C	2	59.6	±	2.08	abc				
F1	S1	1	58.6	±	0.21	bc				
F1	S1	2	47.5	±	1.30	e	-18.85%		-20.24%	
F1	S2	1	58.5	±	2.15	bc				
F1	S2	2	60.1	±	1.66	abc				
F1	S3	1	61.5	±	1.06	abc				
F1	S3	2	61.9	±	3.62	ab				
F1	S4	1	51.5	±	2.58	de		-21.37%		
F1	S4	2	60.6	±	1.95	abc	17.68%			
F1	S5	1	50.9	±	0.95	de		-22.31%		
F1	S5	2	55.5	±	1.11	cd				

[a]Mean (n=3) ± standard error. Means followed by different letter 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 elastic recovery of hard red winter wheat (F2) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Elastic reocvery (%)				I	II	III	Pvalue
F2	C	0	75.4	±	1.82	f				0.0002
F2	C	1	80.0	±	0.95	cde	6.09%			
F2	C	2	84.4	±	1.22	ab	5.53%			
F2	S1	1	79.3	±	0.73	de				
F2	S1	2	79.1	±	0.49	def			-6.37%	
F2	S2	1	78.4	±	1.17	ef				
F2	S2	2	87.5	±	1.34	a	11.58%			
F2	S3	1	78.5	±	1.13	ef				
F2	S3	2	81.2	±	1.13	bcde				
F2	S4	1	80.6	±	1.59	bcde				
F2	S4	2	83.5	±	1.70	bc				
F2	S5	1	81.0	±	2.43	bcde				
F2	S5	2	82.6	±	0.13	bcd				

[a]Mean (n=3) ± standard error. Means followed by different letter 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 elastic recovery of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Elastic reocvery (%)				I	II	III	Pvalue
F3	C	0	73.6	±	0.47	abc				0.0353
F3	C	1	70.7	±	0.97	bcd				
F3	C	2	69.2	±	1.08	bcd				
F3	S1	1	74.7	±	0.91	ab				
F3	S1	2	77.3	±	1.19	a			11.72%	
F3	S2	1	71.8	±	1.55	abcd				
F3	S2	2	66.7	±	2.72	d				
F3	S3	1	70.0	±	3.32	bcd				
F3	S3	2	67.7	±	3.37	d				
F3	S4	1	70.6	±	1.84	bcd				
F3	S4	2	69.5	±	1.14	bcd				
F3	S5	1	68.7	±	2.58	cd				
F3	S5	2	68.7	±	1.28	cd				

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 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 Hm of soft red winter wheat (F1) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Hm (mm)				I	II	III	Pvalue
F1	C	0	41.8	±	2.48	d				0.0188
F1	C	1	41.7	±	1.26	d				
F1	C	2	45.5	±	1.76	abc	9.11%			
F1	S1	1	46.2	±	1.01	ab		10.53%		
F1	S1	2	43.3	±	0.81	bcd				
F1	S2	1	47.2	±	1.34	a		13.01%		
F1	S2	2	45.9	±	0.96	abc				
F1	S3	1	43.0	±	1.70	cd				
F1	S3	2	46.1	±	0.98	abc				
F1	S4	1	45.1	±	0.61	abc		7.98%		
F1	S4	2	43.5	±	0.59	bcd				
F1	S5	1	45.0	±	0.29	abc		7.82%		
F1	S5	2	45.7	±	0.80	abc				

[a]Mean (n=3) ± standard error. Means followed by different letter 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 Hm of hard red winter wheat (F2) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Hm (mm)				I	II	III	Pvalue
F2	C	0	44.3	±	0.45	f				<.0001
F2	C	1	51.2	±	0.73	cd	15.41%			
F2	C	2	48.2	±	1.33	e	-5.73%			
F2	S1	1	54.3	±	1.48	a		6.19%		
F2	S1	2	51.4	±	0.54	bcd	-5.34%		6.63%	
F2	S2	1	54.0	±	0.90	ab		5.47%		
F2	S2	2	50.3	±	0.64	de	-6.86%			
F2	S3	1	51.3	±	1.19	cd				
F2	S3	2	50.4	±	0.45	de				
F2	S4	1	53.7	±	1.08	abc				
F2	S4	2	51.5	±	0.32	bcd			6.84%	
F2	S5	1	55.0	±	0.46	a		7.43%		
F2	S5	2	53.4	±	1.06	abc			10.71%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 Hm of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Hm (mm)				I	II	III	Pvalue
F3	C	0	46.2	±	1.05	fg				<.0001
F3	C	1	47.9	±	0.67	def				
F3	C	2	52.5	±	1.04	ab	9.61%			
F3	S1	1	52.5	±	0.90	ab		9.75%		
F3	S1	2	50.3	±	0.81	bcd				
F3	S2	1	51.6	±	0.23	abc		7.80%		
F3	S2	2	54.1	±	2.35	a				
F3	S3	1	49.9	±	0.97	cde				
F3	S3	2	51.4	±	0.45	bc				
F3	S4	1	47.6	±	0.17	ef				
F3	S4	2	50.3	±	0.85	bcd	5.74%			
F3	S5	1	44.9	±	0.55	g		-6.27%		
F3	S5	2	49.8	±	0.72	cde	11.00%		-5.08%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 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 height of dough of soft red winter wheat (F1) [abcde]

Flour	Salt	Level (%)	Height if dough (mm)				Percentage change I	Percentage change II	Percentage change III	Pvalue
										<.0001
F1	C	0	14.4	±	0.74	e				
F1	C	1	17.3	±	0.55	d	20.09%			
F1	C	2	30.1	±	0.26	b	73.65%			
F1	S1	1	14.2	±	0.64	e		-17.88%		
F1	S1	2	23.9	±	0.98	c	67.68%		-20.71%	
F1	S2	1	24.7	±	1.37	c		42.69%		
F1	S2	2	32.6	±	1.45	a	31.81%		8.31%	
F1	S3	1	16.1	±	0.21	de				
F1	S3	2	26.1	±	0.72	c	61.90%		-13.40%	
F1	S4	1	15.5	±	0.67	de				
F1	S4	2	23.8	±	1.07	c	53.76%		-20.82%	
F1	S5	1	17.8	±	0.64	d				
F1	S5	2	26.0	±	0.69	c	46.07%		-13.62%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 height of dough of hard red winter wheat (F2) [abcde]

Flour	Salt	Level (%)	Height of dough (mm)				Percentage change I	Percentage change II	Percentage change III	Pvalue
F2	C	0	40.3	±	1.31	e				0.0003
F2	C	1	49.6	±	1.65	abcd	23.08%			
F2	C	2	47.9	±	1.13	abcd				
F2	S1	1	50.4	±	1.42	ab				
F2	S1	2	51.0	±	0.83	ab				
F2	S2	1	49.4	±	1.69	abcd				
F2	S2	2	49.7	±	0.58	abcd				
F2	S3	1	46.1	±	0.95	cd				
F2	S3	2	49.8	±	0.46	abc				
F2	S4	1	45.9	±	2.71	d				
F2	S4	2	49.6	±	0.57	abcd				
F2	S5	1	47.5	±	1.26	bcd				
F2	S5	2	51.4	±	0.62	a	8.14%			

[a]Mean (n=3) ± standard error. Means followed by different letter 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 height of dough of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Height of dough (mm)				I	II	III	Pvalue
F3	C	0	45.0	±	1.67	fg				<.0001
F3	C	1	47.7	±	0.74	def				
F3	C	2	52.4	±	1.00	ab	9.85%			
F3	S1	1	52.3	±	1.02	abc		9.50%		
F3	S1	2	50.1	±	0.83	bcde				
F3	S2	1	51.2	±	0.15	bc		7.26%		
F3	S2	2	54.1	±	2.35	a	5.66%			
F3	S3	1	49.6	±	1.07	cde				
F3	S3	2	51.4	±	0.45	abc				
F3	S4	1	47.4	±	0.12	efg				
F3	S4	2	50.3	±	0.90	bcd	6.05%			
F3	S5	1	44.8	±	0.52	g		-6.08%		
F3	S5	2	49.7	±	0.77	bcde	10.93%			

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 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 T1 of soft red winter wheat (F1) [abcde]

Flour	Salt	Level (%)	T1 (min)				Percentage change I	Percentage change II	Percentage change III	Pvalue
										<.0001
F1	C	0	72	±	2.2913	h				
F1	C	1	92	±	1.8028	e	27.78%			
F1	C	2	115	±	6.5	ab	25.00%			
F1	S1	1	87.5	±	1.8028	ef				
F1	S1	2	108	±	0.866	bc	23.43%			
F1	S2	1	94	±	2	de				
F1	S2	2	117.5	±	2.1794	a	25.00%			
F1	S3	1	78.5	±	2.7839	gh		-14.67%		
F1	S3	2	101	±	2	cd	28.66%		-12.17%	
F1	S4	1	83	±	1.8028	fg		-9.78%		
F1	S4	2	107.5	±	3.0414	bc	29.52%		-6.52%	
F1	S5	1	78.5	±	3.6056	gh		-14.67%		
F1	S5	2	100.5	±	2.5981	cd	28.03%		-12.61%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 T1 of hard red winter wheat (F2) [abcde]

							Percentage change			
Flour	Salt	Level (%)	T1 (min)				I	II	III	Pvalue
F2	C	0	123.5	±	13.26	cdef				<.0001
F2	C	1	142.5	±	18.74	bcd				
F2	C	2	178.5	±	0.87	a	25.26%			
F2	S1	1	123.5	±	4.92	cdef				
F2	S1	2	160.5	±	10.85	ab	29.96%			
F2	S2	1	120.5	±	2.00	def				
F2	S2	2	177.5	±	1.32	a	47.30%			
F2	S3	1	114.0	±	7.55	f		-20.00%		
F2	S3	2	157.5	±	10.21	ab	38.16%			
F2	S4	1	118.0	±	3.61	ef		-17.19%		
F2	S4	2	140.0	±	3.91	bcde	18.64%		-21.57%	
F2	S5	1	117.5	±	4.27	ef		-17.54%		
F2	S5	2	145.0	±	10.04	bc	23.40%		-18.77%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 T1 of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	T1 (min)				I	II	III	Pvalue
F3	C	0	174.5	±	3.50	a				0.2147
F3	C	1	179.5	±	0.50	a				
F3	C	2	179.5	±	0.50	a				
F3	S1	1	178.5	±	1.50	a				
F3	S1	2	178.0	±	1.32	a				
F3	S2	1	176.0	±	1.00	a				
F3	S2	2	180.0	±	0.00	a				
F3	S3	1	171.0	±	6.87	a				
F3	S3	2	180.0	±	0.00	a				
F3	S4	1	177.5	±	0.50	a				
F3	S4	2	179.0	±	1.00	a				
F3	S5	1	179.5	±	0.50	a				
F3	S5	2	179.5	±	0.50	a				

[a]Mean (n=3) ± standard error. Means followed by different letter 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 10.9%, 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 H'm of soft red winter wheat (F1) [abcde].

Flour	Salt	Level (%)	H'm (mm)				Percentage change I	Percentage change II	Percentage change III	Pvalue
										<.0001
F1	C	0	89.3	±	2.67	a				
F1	C	1	78.6	±	2.97	de	-12.01%			
F1	C	2	67.7	±	2.47	g	-13.91%			
F1	S1	1	84.3	±	0.90	abc		7.25%		
F1	S1	2	75.3	±	0.48	ef	-10.72%		11.23%	
F1	S2	1	81.1	±	1.99	cd				
F1	S2	2	73.4	±	1.71	f	-9.57%		8.42%	
F1	S3	1	82.4	±	0.87	bcd				
F1	S3	2	79.3	±	0.67	cde			17.19%	
F1	S4	1	89.1	±	1.64	a		13.32%		
F1	S4	2	75.9	±	1.92	ef	-14.75%		12.22%	
F1	S5	1	87.4	±	0.47	ab		11.20%		
F1	S5	2	80.0	±	1.23	cde	-8.47%		18.23%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 H'm of hard red winter wheat (F2) [abcde].

							Percentage change			
Flour	Salt	Level (%)	H'm (mm)				I	II	III	Pvalue
F2	C	0	103.2	±	1.11	a				<.0001
F2	C	1	88.0	±	0.68	cd	-14.79%			
F2	C	2	62.9	±	1.75	g	-28.50%			
F2	S1	1	98.7	±	3.07	b		12.20%		
F2	S1	2	84.7	±	1.29	de	-14.22%		34.61%	
F2	S2	1	96.3	±	1.03	b		9.44%		
F2	S2	2	79.0	±	1.61	f	-17.90%		25.65%	
F2	S3	1	97.9	±	0.72	b		11.33%		
F2	S3	2	89.9	±	0.61	c	-8.24%		42.87%	
F2	S4	1	96.8	±	1.88	b		10.04%		
F2	S4	2	84.1	±	1.39	e	-13.09%		33.76%	
F2	S5	1	98.4	±	1.12	b		11.90%		
F2	S5	2	89.7	±	0.88	c	-8.91%		42.55%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 H'm of hard red winter wheat (F3) [abcde]
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Flour	Salt	Level (%)	H'm (mm)				Percentage change I	Percentage change II	Percentage change III	Pvalue
F3	C	0	107.6	±	0.99	a				<.0001
F3	C	1	89.4	±	0.17	e	-16.89%			
F3	C	2	59.0	±	2.21	h	-34.00%			
F3	S1	1	102.2	±	0.61	b		14.35%		
F3	S1	2	88.2	±	1.19	e	-13.69%		49.55%	
F3	S2	1	96.5	±	2.06	cd		7.94%		
F3	S2	2	79.1	±	3.04	g	-18.00%		34.12%	
F3	S3	1	99.8	±	1.08	bc		11.63%		
F3	S3	2	93.6	±	0.91	d	-6.18%		58.70%	
F3	S4	1	94.0	±	0.94	d		5.18%		
F3	S4	2	84.0	±	1.68	f	-10.63%		42.43%	
F3	S5	1	96.0	±	1.56	cd		7.42%		
F3	S5	2	88.1	±	0.75	ef	-8.23%		49.38%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 14% moisture basis.

Table 29. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on T'1 of soft red winter wheat (F1) [abcde]

							Percentage change			
Flour	Salt	Level (%)	T'1 (min)				I	II	III	Pvalue
F1	C	0	59.0	±	2.65	e				<.0001
F1	C	1	69.5	±	4.09	cde				
F1	C	2	80.8	±	4.80	b	16.31%			
F1	S1	1	69.0	±	3.12	cde				
F1	S1	2	100.0	±	3.50	a	44.93%		23.71%	
F1	S2	1	67.5	±	3.77	cde				
F1	S2	2	98.7	±	5.51	a	46.17%		22.06%	
F1	S3	1	69.5	±	3.61	cde				
F1	S3	2	70.0	±	1.32	cd			-13.40%	
F1	S4	1	61.0	±	1.80	de				
F1	S4	2	72.0	±	6.25	bc	18.03%			
F1	S5	1	66.5	±	1.80	cde				
F1	S5	2	73.5	±	2.29	bc				

[a]Mean (n=3) ± standard error. Means followed by different letter 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 30. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on T'1 of hard red winter wheat (F2) [abcde]

							Percentage change			
Flour	Salt	Level (%)	T'1 (min)				I	II	III	Pvalue
F2	C	0	144.5	±	3.28	c				0.0072
F2	C	1	162.0	±	2.60	b	12.11%			
F2	C	2	180.0	±	0.00	a	11.11%			
F2	S1	1	172.5	±	3.77	ab				
F2	S1	2	172.5	±	3.77	ab				
F2	S2	1	174.0	±	3.97	ab				
F2	S2	2	173.5	±	6.50	ab				
F2	S3	1	168.5	±	3.50	ab				
F2	S3	2	166.0	±	8.23	ab				
F2	S4	1	172.5	±	6.06	ab				
F2	S4	2	167.5	±	6.95	ab				
F2	S5	1	167.0	±	5.07	ab				
F2	S5	2	175.5	±	4.50	ab				

[a]Mean (n=3) ± standard error. Means followed by different letter 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]F protein content 10.9%, 14% moisture basis.

Table 31. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on T'1 of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	T'1 (min)				I	II	III	Pvalue
F3	C	0	131.0	±	4.00	e				<.0001
F3	C	1	162.5	±	4.09	bc	24.05%			
F3	C	2	180.0	±	0.00	a	10.77%			
F3	S1	1	151.5	±	3.00	d		-6.77%		
F3	S1	2	175.5	±	2.29	a	15.84%			
F3	S2	1	155.5	±	5.00	cd				
F3	S2	2	180.0	±	0.00	a	15.76%			
F3	S3	1	152.0	±	3.61	cd				
F3	S3	2	171.5	±	2.78	ab	12.83%			
F3	S4	1	154.5	±	3.12	cd				
F3	S4	2	177.5	±	1.32	a	14.89%			
F3	S5	1	148.0	±	8.67	d		-8.92%		
F3	S5	2	178.0	±	1.00	a	20.27%			

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 14% moisture basis.

Table 32. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on Tx of soft red winter wheat (F1) [abcde]

Flour	Salt	Level (%)	Tx (min)				Percentage change I	Percentage change II	Percentage change III	Pvalue
F1	C	0	24.5	±	3.04	c				<.0001
F1	C	1	43.0	±	2.65	a	75.51%			
F1	C	2	33.3	±	2.09	b	-22.48%			
F1	S1	1	20.8	±	0.73	cd		-51.55%		
F1	S1	2	22.0	±	1.32	cd			-34.00%	
F1	S2	1	21.2	±	0.83	cd		-50.78%		
F1	S2	2	20.7	±	1.17	cd			-38.00%	
F1	S3	1	40.7	±	2.19	a				
F1	S3	2	19.5	±	0.00	d	-52.05%		-41.50%	
F1	S4	1	31.5	±	0.87	b		-26.74%		
F1	S4	2	30.5	±	1.76	b				
F1	S5	1	19.5	±	0.00	d		-54.65%		
F1	S5	2	19.5	±	0.00	d			-41.50%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 33. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on Tx of hard red winter wheat (F2) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Tx (min)				I	II	III	Pvalue
F2	C	0	24.5	±	5.00	ef				0.0135
F2	C	1	34.5	±	7.70	bcdef				
F2	C	2	54.0	±	9.64	a	56.52%			
F2	S1	1	25.5	±	5.27	def				
F2	S1	2	35.0	±	8.05	bcdef			-35.19%	
F2	S2	1	28.0	±	7.05	cdef				
F2	S2	2	42.5	±	2.18	abcd				
F2	S3	1	19.5	±	0.00	f				
F2	S3	2	43.5	±	4.58	abc	123.08%			
F2	S4	1	37.5	±	7.50	abcde				
F2	S4	2	30.0	±	5.27	bcdef			-44.44%	
F2	S5	1	25.5	±	3.12	def				
F2	S5	2	45.8	±	5.42	ab	79.74%			

[a]Mean (n=3) ± standard error. Means followed by different letter 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 34. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on Tx of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Tx (min)				I	II	III	Pvalue
F3	C	0	20.3	±	0.83	d				<.0001
F3	C	1	48.2	±	2.77	b	136.89%			
F3	C	2	66.0	±	10.50	a	37.02%			
F3	S1	1	22.0	±	1.32	d		-54.33%		
F3	S1	2	64.0	±	2.00	a	190.91%			
F3	S2	1	29.7	±	1.45	c		-38.41%		
F3	S2	2	47.0	±	4.36	b	58.43%		-28.79%	
F3	S3	1	22.2	±	1.36	d		-53.98%		
F3	S3	2	44.8	±	2.74	b	102.26%		-32.07%	
F3	S4	1	48.0	±	3.00	b				
F3	S4	2	46.0	±	2.65	b			-30.30%	
F3	S5	1	21.5	±	1.32	d		-55.36%		
F3	S5	2	20.3	±	0.83	d			-69.19%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 14% moisture basis

Table 35. 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 volume of soft red winter wheat (F1) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Total volume (ml)				I	II	III	Pvalue
F1	C	0	1260.67	±	26.735	cd				<.0001
F1	C	1	1257	±	25.658	cd				
F1	C	2	1223.33	±	4.177	d				
F1	S1	1	1336.33	±	17.266	a		6.31%		
F1	S1	2	1362.33	±	8.667	a			11.36%	
F1	S2	1	1277	±	14.933	c				
F1	S2	2	1328	±	18.028	ab	3.99%		8.56%	
F1	S3	1	1345.33	±	6.741	a		7.03%		
F1	S3	2	1321	±	10.408	ab			7.98%	
F1	S4	1	1336.67	±	17.072	a		6.34%		
F1	S4	2	1286.67	±	1.202	bc	-3.74%		5.18%	
F1	S5	1	1361	±	13.65	a		8.27%		
F1	S5	2	1340.33	±	2.404	a			9.56%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 36. 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 volume of hard red winter wheat (F2) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Total volume (ml)				I	II	III	Pvalue
F2	C	0	2331.3	±	48.79	a				<.0001
F2	C	1	2037.3	±	31.23	cd	-12.61%			
F2	C	2	1361.0	±	28.59	g	-33.20%			
F2	S1	1	2197.7	±	112.15	ab		7.87%		
F2	S1	2	1846.0	±	62.98	ef	-16.00%		35.64%	
F2	S2	1	2197.3	±	45.48	b		7.85%		
F2	S2	2	1756.0	±	77.53	f	-20.08%		29.02%	
F2	S3	1	2197.0	±	14.50	b		7.84%		
F2	S3	2	1977.3	±	27.39	de	-10.00%		45.29%	
F2	S4	1	2156.3	±	48.83	bc				
F2	S4	2	1854.3	±	42.22	ef	-14.01%		36.25%	
F2	S5	1	2210.0	±	42.03	ab		8.48%		
F2	S5	2	1909.3	±	17.13	de	-13.60%		40.29%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 37. 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 volume of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Total volume (ml)				I	II	III	Pvalue
F3	C	0	2482	±	41.016	a				<.0001
F3	C	1	1925	±	13.013	de	-22.44%			
F3	C	2	1272.33	±	49.451	i	-33.90%			
F3	S1	1	2263.33	±	36.789	b		17.58%		
F3	S1	2	1784.67	±	51.089	efg	-21.15%		40.27%	
F3	S2	1	2104.33	±	77.744	bc		9.32%		
F3	S2	2	1597.67	±	96.844	h	-24.08%		25.57%	
F3	S3	1	2098.33	±	109.406	c		9.00%		
F3	S3	2	1889	±	29.206	def	-9.98%		48.47%	
F3	S4	1	2031.33	±	20.667	cd				
F3	S4	2	1686.33	±	45.732	gh	-16.98%		32.54%	
F3	S5	1	2130.67	±	79.646	bc		10.68%		
F3	S5	2	1757.67	±	29.801	fgh	-17.51%		38.15%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 14% moisture basis.

Table 38. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on volume lost of soft red winter wheat (F1) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Volume lost (ml)				I	II	III	Pvalue
F1	C	0	79.3	±	3.84	a				0.0657
F1	C	1	70.3	±	1.20	a				
F1	C	2	71.3	±	2.33	a				
F1	S1	1	76.7	±	3.84	a				
F1	S1	2	83.0	±	3.06	a				
F1	S2	1	75.0	±	1.15	a				
F1	S2	2	77.7	±	3.28	a				
F1	S3	1	77.3	±	1.86	a				
F1	S3	2	75.0	±	2.08	a				
F1	S4	1	75.0	±	1.53	a				
F1	S4	2	72.0	±	3.51	a				
F1	S5	1	79.3	±	3.18	a				
F1	S5	2	74.7	±	1.86	a				

[a]Mean (n=3) ± standard error. Means followed by different letter 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 39. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on volume lost of hard red winter wheat (F2) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Volume lost (ml)				I	II	III	Pvalue
F2	C	0	135.7	±	5.36	a				<.0001
F2	C	1	112.3	±	2.33	bcd	-17.20%			
F2	C	2	74.3	±	3.84	g	-33.83%			
F2	S1	1	118.0	±	5.03	b				
F2	S1	2	95.7	±	3.38	ef	-18.93%		28.70%	
F2	S2	1	118.0	±	4.51	b				
F2	S2	2	91.0	±	6.56	f	-22.88%		22.42%	
F2	S3	1	115.0	±	3.61	bc				
F2	S3	2	106.7	±	2.60	cde			43.50%	
F2	S4	1	113.3	±	2.19	bc				
F2	S4	2	95.7	±	1.76	ef	-15.59%		28.70%	
F2	S5	1	119.7	±	4.10	b				
F2	S5	2	102.0	±	3.21	def	-14.76%		37.22%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 9.8%, 14% moisture basis.

Table 40. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on volume lost of hard red winter wheat (F3) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Volume lost (ml)				I	II	III	Pvalue
F3	C	0	140.3	±	3.48	a				<.0001
F3	C	1	104.0	±	2.52	de	-25.89%			
F3	C	2	63.0	±	3.79	h	-39.42%			
F3	S1	1	125.3	±	2.73	b		20.51%		
F3	S1	2	98.3	±	2.73	ef	-21.54%		56.08%	
F3	S2	1	111.7	±	4.67	cd				
F3	S2	2	84.3	±	5.24	g	-24.48%		33.86%	
F3	S3	1	124.3	±	2.33	b		19.55%		
F3	S3	2	98.7	±	1.86	ef	-20.64%		56.61%	
F3	S4	1	112.0	±	2.08	cd				
F3	S4	2	92.7	±	3.18	fg	-17.26%		47.09%	
F3	S5	1	118.0	±	5.29	bc		13.46%		
F3	S5	2	98.3	±	4.98	ef	-16.67%		56.08%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 14% moisture basis.

Table 41. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on volume retained of soft red winter wheat (F1) [abcde]

							Percentage change			
Flour	Salt	Level (%)	volume retained (ml)				I	II	III	Pvalue
F1	C	0	1185.0	±	28.79	cd				<.0001
F1	C	1	1187.0	±	24.69	cd				
F1	C	2	1152.3	±	3.53	d				
F1	S1	1	1259.3	±	15.39	a		6.09%		
F1	S1	2	1279.3	±	7.62	a			11.02%	
F1	S2	1	1202.0	±	13.80	c				
F1	S2	2	1250.3	±	15.30	ab	4.02%		8.50%	
F1	S3	1	1268.3	±	7.80	a		6.85%		
F1	S3	2	1246.3	±	8.01	ab			8.16%	
F1	S4	1	1261.3	±	17.03	a		6.26%		
F1	S4	2	1215.0	±	2.65	bc	-3.67%		5.44%	
F1	S5	1	1281.7	±	11.47	a		7.98%		
F1	S5	2	1265.7	±	2.33	a			9.84%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 42. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on volume retained of hard red winter wheat (F2) [abcde]

Flour	Salt	Level (%)	volume retained (ml)				Percentage change I	Percentage change II	Percentage change III	Pvalue
F2	C	0	2195.3	±	53.74	a				<.0001
F2	C	1	1924.7	±	31.84	cd	-0.12329			
F2	C	2	1286.7	±	24.77	g	-0.33149			
F2	S1	1	2079.7	±	107.45	ab		8.05%		
F2	S1	2	1750.7	±	59.98	ef	-0.1582		36.06%	
F2	S2	1	2079.0	±	42.36	ab		8.02%		
F2	S2	2	1665.3	±	71.18	f	-0.19898		29.43%	
F2	S3	1	2082.0	±	15.95	ab		8.17%		
F2	S3	2	1870.7	±	25.17	de	-0.1015		45.39%	
F2	S4	1	2043.0	±	48.50	bc				
F2	S4	2	1759.0	±	42.00	ef	-0.13901		36.71%	
F2	S5	1	2091.0	±	38.63	ab		8.64%		
F2	S5	2	1807.3	±	16.33	de	-13.57%		40.47%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 43. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on volume retained of hard red winter wheat (F3) [abcde]

Flour	Salt	Level (%)	volume retained (ml)				Percentage change I	Percentage change II	Percentage change III	Pvalue
F3	C	0	2342.0	±	37.24	a				<.0001
F3	C	1	1821.0	±	14.73	de	-22.25%			
F3	C	2	1209.0	±	45.37	i	-33.61%			
F3	S1	1	2137.7	±	34.11	b		17.39%		
F3	S1	2	1686.7	±	48.04	efg	-21.10%		39.51%	
F3	S2	1	1992.3	±	73.54	bc		9.41%		
F3	S2	2	1513.3	±	91.63	h	-24.04%		25.17%	
F3	S3	1	1983.0	±	98.22	c		8.90%		
F3	S3	2	1790.3	±	27.35	def	-9.72%		48.08%	
F3	S4	1	1919.0	±	18.72	cd				
F3	S4	2	1593.3	±	42.53	gh	-16.97%		31.79%	
F3	S5	1	2013.0	±	74.57	bc		10.54%		
F3	S5	2	1659.7	±	24.90	fgh	-17.55%		37.28%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 14% moisture basis.

Table 44. Effect of 1 and 2% commercial sodium chloride substitutes (S1, S2, S3, S4 and S5) and 0, 1 and 2% NaCl (Control, C) on coefficient retentionof soft red winter wheat (F1) [abcde]

							Percentage change			
Flour	Salt	Level (%)	Coefficient retention				I	II	III	Pvalue
F1	C	0	94.0	±	0.55	a				0.6488
F1	C	1	94.4	±	0.03	a				
F1	C	2	94.2	±	0.19	a				
F1	S1	1	94.3	±	0.23	a				
F1	S1	2	93.9	±	0.21	a				
F1	S2	1	94.1	±	0.03	a				
F1	S2	2	94.2	±	0.19	a				
F1	S3	1	94.3	±	0.13	a				
F1	S3	2	94.4	±	0.12	a				
F1	S4	1	94.4	±	0.12	a				
F1	S4	2	94.4	±	0.27	a				
F1	S5	1	94.2	±	0.18	a				
F1	S5	2	94.4	±	0.13	a				

[a]Mean (n=3) ± standard error.

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

							Percentage change			
Flour	Salt	Level (%)	Coefficient retention				I	II	III	Pvalue
F2	C	0	94.2	±	0.35	a				0.1891
F2	C	1	94.5	±	0.15	a				
F2	C	2	94.4	±	0.07	a				
F2	S1	1	94.6	±	0.09	a				
F2	S1	2	94.8	±	0.06	a				
F2	S2	1	94.6	±	0.15	a				
F2	S2	2	94.8	±	0.20	a				
F2	S3	1	94.8	±	0.17	a				
F2	S3	2	94.6	±	0.07	a				
F2	S4	1	94.7	±	0.12	a				
F2	S4	2	94.8	±	0.15	a				
F2	S5	1	94.6	±	0.10	a				
F2	S5	2	94.7	±	0.15	a				

[a]Mean (n=3) ± standard error.

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

							Percentage change			
Flour	Salt	Level (%)	Coefficient retention				I	II	III	Pvalue
F3	C	0	94.4	±	0.03	e				0.0075
F3	C	1	94.6	±	0.15	bcde	0.25%			
F3	C	2	95.0	±	0.15	a	0.42%			
F3	S1	1	94.5	±	0.06	cde				
F3	S1	2	94.5	±	0.00	cde			-0.53%	
F3	S2	1	94.7	±	0.12	bcd				
F3	S2	2	94.7	±	0.03	abc				
F3	S3	1	94.5	±	0.17	cde				
F3	S3	2	94.8	±	0.00	ab	0.35%			
F3	S4	1	94.5	±	0.09	cde				
F3	S4	2	94.5	±	0.06	cde			-0.53%	
F3	S5	1	94.5	±	0.09	cde				
F3	S5	2	94.4	±	0.2	de			-0.60%	

[a]Mean (n=3) ± standard error. Means followed by different letter 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 13.3%, 14% moisture basis

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CHAPTER VII

CONCLUSION

Study I aimed at analyzing 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 analysis 0% tempe had higher scores in all flavor parameters significantly compared to 5% tempe level. The possible explanation is that tempe contains soy bean which in baking liberates aldehydes and ketones. These aldehydes and ketones are a results of auto or enzymatic oxidation of linoleic and linolenic fatty acids which results in strong beany flavor and make end product undesirable. Sourdough (11, 17 and 33%) and NaCl (0.5, 1 and 1.5%) did not affect flavor profile of white bread significantly. In second sensory session NaCl at 0.75 and 1.5% level gave same saltiness perception in the presence of 2% tempe. Tempe at 2% had lower scores in other flavor parameters. Tempe at 2% gave complex flavor profile which gave similar saltiness perception at 0.75 and 1.5% NaCl levels. In third sensory evaluation session 3.5% tempe had significantly higher scores in flavor profile compared to 0% tempe in few treatment combinations. Sourdough at 17% in the presence of 3.5% tempe gave significantly higher saltiness perception at 0.75% NaCl compared to 1.5% NaCl. Fermented products gave complex flavor profile also known as umami flavor which enhanced saltiness perception at lower levels of salt. Better solubility due to viscous dough helped in better and effective disposal of ions responsible for saltiness on tongue receptors. This study concluded that saltiness perception can be enhanced even at lower levels of NaCl with the addition of fermented products.

Study II aimed at analyzing the effect of fermented products (sourdough and tempe) and reduced NaCl levels on rheological properties of wheat flour. With the addition of sourdough and tempe increased viscosity and decreased elasticity of gluten was observed. Sourdough addition dilutes the gluten content of flour and creates an acidic environment. Acidity unravels gluten structure and make it more vulnerable to hydrolysis. The possible explanation is that with the addition of sourdough Polymeric proteins (high molecular weight glutenin subunits) breakdown to monomeric proteins (low molecular weight glutenin subunits) which results in thicker and coarser fibrils of gluten instead of longer, elastic fibrils. This phenomenon imparts viscosity in gluten and reduced elasticity. Addition of tempe (Wheat/soy fermented product) interferes with gluten network formation by increasing thiole group concentration. This results in increased soy and gluten protein interaction which weakens the gluten network. Fermentation properties of wheat flour were also affected with addition of fermented products and educed NaCl levels. Lower maximum height of dough, height of the dough at the end of the test and volume lost was observed. Weak gluten network resulted in viscous dough which ended up producing more gas and also retaining more gas within the dough structure. Addition of fermented products interfere with gluten network formation and results in viscous dough interpreted as soft dough. These changes can affect rheological properties drastically.

Study III aimed at analyzing the effect of salt substitutes on rheological properties of wheat flour. A significant increase in viscosity was observed in F1 (9.8%) with the increase in salt level. In F2 (10.9%) significant increase in elasticity and decrease in viscosity was observed with increase in salt level, whereas, no significant effect on viscoelastic properties of gluten were observed in F3 (13.4%). In comparison to respective controls C1 and C2 most of salt substitute levels (1 and 2%) gave significant increase in viscosity and decrease in elasticity in F2. Opposite trend was observed in F1. With increase in salt level lower maximum dough development height, maximum gaseous release curve, total volume and volume lost were observed, whereas, higher dough height, time to reach maximum height and volume retained were observed. Higher levels of salt retards yeast activity which resulted in lower total volume produced. Higher levels of salt strengthen the gluten network significantly which resulted in higher dough height at the end of the test. This study concluded that effect of salt on flour depends on its type and protein content and also reduced sodium affects rheological properties significantly.

CHAPTER VIII

Future Studies

- According to study I treatment combination containing 17% sourdough in the presence of 3.5% tempe gave significantly higher saltiness perception compared to 1.5% NaCl, but in other flavor parameters this combination had significantly lower scores. I suggest adding a bitterness blocker (L-arginine or lysine) or a flavor improver to this treatment combination so it will have better flavor profile.
- Study II aimed at analyzing the effect of fermented products (sourdough and tempe) and reduced sodium chloride levels on rheological properties of wheat flour. The results were interpreted as confounding effect of gluten dilution and the effect of fermented products with reduced NaCl on viscoelastic properties of gluten as well as on fermentation properties of wheat dough. A significant increase in viscosity and a decrease in elasticity of gluten was observed. I suggest adding transglutaminase to improve viscoelastic properties of flour and also developing an experimental design which will only address the rheological changes of wheat flour with gluten dilution so we can quantify the effect of rheological changes with dilution of gluten.
- Study III aimed at analyzing the effect of salt substitutes on rheological properties of wheat flour which significantly affect viscoelastic properties of gluten by increasing viscosity and deformation. I suggest partial replacement of NaCl with salt substitutes and quantifying its effect on rheological and baking properties.

APPENDIX

List of abbreviations

AACCI	AACC international
Hm	Maximum height of dough development curve in fermentation test
h	Height of the dough at the end of fermentation test
T1	Time required to reach maximum height of dough development curve
H’m	Maximum height of gaseous release curve in fermentation test
T’1	Time of maximum rise of gaseous release curve
Tx	Time to release CO_2 from dough in fermentation test
RCY	Gluten recovery in creep recovery test
J-Jr	Difference in creep and recovery compliance at 100 seconds

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							

Table 1. 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 2. 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 3. 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 4. 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 5. 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 6. 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 7. 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 8. 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 9. 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 10. 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. Means followed by different letter are statistically different (P= 0.05).

Table 11. 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 12. 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 13. 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 14. 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 are statistically different (P= 0.05).

Table 15. 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 16. 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 17**.** 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 are statistically different (P= 0.05).

Table 18. 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 19. 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 20. 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 are statistically different (P= 0.05).

Table 21. 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 22. 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 23. 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 24. 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 25. 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 26. 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 (%)	Sweetness				Pvalue
0.0	0.0	0.0	4.1	±	0.35	b	0.0011
0.0	0.0	0.75	5.3	±	0.25	a	
0.0	0.0	1.5	5.3	±	0.23	a	
0.0	3.5	0.0	4.2	±	0.25	b	0.0409
0.0	3.5	0.75	4.9	±	0.24	a	
0.0	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	<.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 are statistically different (P= 0.05).

Table 27. 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 (%)	sweetness	Pvalue
0.0	0.0	0.0	4.1 ± 0.35	0.6996
0.0	0.0	3.5	4.2 ± 0.25	
0.0	0.75	0.0	5.3 ± 0.25	0.3037
0.0	0.75	3.5	4.9 ± 0.24	
0.0	1.5	0.0	5.3 ± 0.23	0.0005
0.0	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	<.0001
17	1.5	3.5	3.5 ± 0.29	

[a]Mean (n=3) ± standard error.

Table 28. 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 (%)	Sweetness				Pvalue
0.0	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	0.0	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	0.0	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	0.0	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	0.0	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	0.0	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.

Table 29. 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 (%)	sourness				Pvalue
0.0	0.0	0.0	3.9	±	0.33	b	<.0001
0.0	0.0	0.75	5.5	±	0.27	a	
0.0	0.0	1.5	5.6	±	0.27	a	
0.0	3.5	0.0	4.4	±	0.27	a	0.4582
0.0	3.5	0.75	4.9	±	0.24	a	
0.0	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	<.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 are statistically different (P= 0.05).

Table 30. 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 (%)	Sourness	Pvalue
0.0	0.0	0.0	3.9 ± 0.33	0.2424
0.0	0.0	3.5	4.4 ± 0.27	
0.0	0.75	0.0	5.5 ± 0.27	0.1241
0.0	0.75	3.5	4.9 ± 0.24	
0.0	1.5	0.0	5.6 ± 0.27	0.023
0.0	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	<.0001
17	1.5	3.5	3.4 ± 0.23	

[a]Mean (n=3) ± standard error.

Table 31. 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 (%)	Sourness	Pvalue
0.0	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	0.0	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	0.0	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	0.0	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	0.0	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	0.0	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 are statistically different (P= 0.05).

Table 32. Effect of NaCl (0, 0.75 and 1.5%) on pasteboardy 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	0.0	4.0 ± 0.38 a	0.1436
0.0	0.0	0.75	4.8 ± 0.25 a	
0.0	0.0	1.5	4.5 ± 0.24 a	
0.0	3.5	0.0	3.7 ± 0.27 b	<0.0001
0.0	3.5	0.75	5.7 ± 0.23 a	
0.0	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 are statistically different (P= 0.05).

Table 33. Effect of tempe (0 and 3.5%) on Pasteboardyscores 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			Pvalue
0.0	0.0	0.0	4	±	0.38	0.3401
0.0	0.0	3.5	3.7	±	0.27	
0.0	0.75	0.0	4.8	±	0.25	0.026
0.0	0.75	3.5	5.7	±	0.23	
0.0	1.5	0.0	4.5	±	0.24	0.279
0.0	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	<.0001
17	1.5	3.5	3.8	±	0.24	

[a]Mean (n=3) ± standard error.

Table 34. 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 (%)	Pasteboardy				Pvalue
0.0	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	0.0	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	0.0	4.5	±	0.24	b	<.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	0.0	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	0.0	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	0.0	4.9	±	0.30	a	<0.0001
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 are statistically different (P= 0.05)

Table 35. 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				Pvalue
0.0	0.0	0.0	4.6	±	0.30	b	<.0001
0.0	0.0	0.75	5.4	±	0.25	b	
0.0	0.0	1.5	6.4	±	0.24	a	
0.0	3.5	0.0	4.8	±	0.26	a	0.6496
0.0	3.5	0.75	5.1	±	0.23	a	
0.0	3.5	1.5	5.1	±	0.28	a	
33	0.0	0.0	4.1	±	0.33	b	<.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	<.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	<.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 are statistically different (P= 0.05).

Table 36. 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	Pvalue
0.0	0.0	0.0	4.6 ± 0.30	0.6532
0.0	0.0	3.5	4.8 ± 0.26	
0.0	0.75	0.0	5.4 ± 0.25	0.5635
0.0	0.75	3.5	5.1 ± 0.23	
0.0	1.5	0.0	6.4 ± 0.24	0.0011
0.0	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	<.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	<.0001
17	1.5	3.5	3.9 ± 0.25	

[a]Mean (n=3) ± standard error.

Table 37. 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				Pvalue
0.0	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	0.0	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	0.0	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	0.0	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	0.0	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	0.0	5.1	±	0.28	a	<.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 are statistically different (P= 0.05).

VITA

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Master of Science/Arts

Thesis: ASSESMENT OF FERMENTED PRODUCTS AND SALT SUBSTITUTES ON FLAVOR PROFILE OF WHITE BREAD AND RHEOLOGICAL PROPERTIES

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