

ASSESSMENT OF KEFIR AND SOURDOUGH ON THE
FLAVOR PROFILE, QUALITY OF WHITE BREAD AND
RHEOLOGY OF WHEAT DOUGH

By

SABITRI SHARMA GAUTAM

Bachelor of Science in Food Science and Technology

National College of Food Science and Technology

Tribhuvan University

Kathmandu, Nepal

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Thesis Approved:

Dr. Patricia Rayas-Duarte

Thesis Adviser

Dr. Mark E. Payton

Dr. Ranjith Ramanathan

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Title of Study: ASSESSMENT OF KEFIR AND SOURDOUGH ON THE FLAVOR PROFILE, QUALITY OF WHITE BREAD AND RHEOLOGY OF WHEAT DOUGH

Major Field: FOOD SCIENCE

Abstract: Kefir sourdough bread is a new development on product design strategy and is alternative starter for sourdough bread. Na reduction is desirable due to health effects associated with excess sodium consumption. The objective of the study was to investigate the effect of kefir, sourdough (SD) and NaCl on the flavor characteristics, rheological property and shelf life of white bread. Breads were prepared with NaCl (0.1, 0.4, 0.8, 1.2% flour based), kefir (30, 40, 50, 60% flour based) and sourdough (20, 40, 70% flour based) in a factorial design. Crumb firmness and color were measured over 7 days of storage. Elastic recovery index of dough was evaluated using a compression-recovery test (Gluten CORE). Sensory evaluation was done with a consumer acceptance test with 64 untrained panelists in three independent replicates.

NaCl did not affect texture and color of white bread while high sourdough and kefir made softer breads. Increase in crumb firmness from the combination of treatments ranged from 32 to 62% at day 4 and 45 to 78% at day 7 while bread with 0.8% NaCl without kefir and sourdough showed highest increase by 116% at day 7 compared to day 1. Dough with kefir at 50% had significantly higher recovery than 30% kefir. Significantly higher height of bread was obtained at 70% sourdough than 40%. In the breads without kefir or sourdough, 1.2% NaCl had higher scores of all sensory attributes compared to 0.8%. Sourdough had more influence on the sensory perception of breads than kefir. In the presence of fermented products, difference in NaCl levels were not identified by the panelists and reduction of NaCl up to 47% could be achieved without affecting sensory quality and shelf life of the bread.

This study suggested that sourdough and kefir are potential ingredients for the improvement of dough rheology, texture, and flavor attributes of white bread.

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CHAPTER I

INTRODUCTION

Statement of problem

The ingestion of sodium chloride is important for human health to maintain the sodium balance in the body (Girgis et al., 2003). Sodium chloride is a stimulus for salty taste in food which increases the sensory properties by increasing saltiness, sweetness, decreasing bitterness and increasing other flavors of food. However, excess sodium intake is associated with an increase in blood pressure, which is a major cause of cardiovascular diseases (Liem et al., 2011). In a 2003, WHO (World Health Organization) survey reported that one third of total death is caused by cardiovascular diseases (CVD) which includes heart attack, stroke, high blood pressure, renal failure and other related diseases (He and MacGregor, 2007; Lynch et al., 2009). It has been found that 62% of stroke and 49% of coronary heart disease is caused by high blood pressure (He and MacGregor, 2010). Other negative effects of salt include gastric cancer, decreased bone mineral density and possibly obesity (He and MacGregor, 2009; Tsugane et al., 2004). Humans consume well above the recommended level of 3-4 g salt per day per adult making sodium reduction a priority for public health (Neal et al., 2006) . However, taking out sodium from food is not easy due to sodium specific functionality like influence in product flavor and overall palatability (Keast et al., 2008). Bread is said to be a major contributor of sodium in the diet because it is consumed as staple food in most of the countries (30-50%) (Liem et al., 2011; Lynch et al., 2009; Noort et al., 2012).

Sourdough bread provides consumer safe and high quality products by the use of natural fermentation. Increase in shelf life of sourdough is due to preservation of flavor, overall quality and prevention of mold spoilage in bread. Introduction of new starter cultures during fermentation vs spontaneous fermentation is another technique to extend the shelf life of bread (Plessas et al., 2011). Spontaneous sourdough fermentation is obtained by natural flora present in flour or water (Catzeddu et al., 2011). Another interesting application of making sourdough with improved shelf life, aroma and taste of bread is by using kefir culture. The symbiotic relationship of many types of yeast and lactic acid bacteria in kefir made it more special to enhance aroma, taste, texture, and shelf life via in-situ production of antimicrobial compounds (Simova et al., 2002). Sourdough improves bread volume, texture, flavor, nutritional and sensorial features, as well as their shelf-life by slowing down the staling process and inhibiting mold growth (Mariotti et al., 2014). Only few studies have explored the use of sourdough for studying salt reduction and improvement of sensory properties of bread (Mariotti et al., 2014).

One of the methods of salt reduction in baking products like bread is adding one or more flavor compounds which give sense of saltiness to the product (Doyle and Glass, 2010). Kefir grains, a mixed culture of various microorganisms was suggested as alternative in sourdough fermentations (Gobbetti et al., 1995). Study have proved the positive impact of kefir grains on microbiological safety, overall palatability and quality assurance of the produced breads by delaying mold and rope spoilage up to 6 days and producing more flavors due to increase concentration of lactic acid and acetic acid bacteria (Simova et al., 2002). Other reported effect of kefir included improving texture, less moisture loss and long term freshness of the bread leading to less economic loss. Due to the perishable nature of bread, the use of kefir can be an alternative as a starter culture for sourdough (Plessas et al., 2011).

Making sourdough bread specialty bread is a recent development on product design strategy. Researchers have used different proportion of sourdough in bread and have evaluated

the change of gluten rheology and other quality parameters. However, there is limited research on the use fermented dairy ingredients in making sourdough bread. This research is intended to evaluate the effect of reducing the salt content of bread by natural fermentation that modulates the perception of saltiness and determine the effect of fermented dairy ingredients on rheological properties of dough, shelf life, flavor and consumer acceptability of bread.

Purpose of the study

The objectives of the study were:

1. To investigate the effect of different levels of sourdough, kefir and sodium chloride in flavor perception of white pan bread.
2. To analyze the effect of sourdough, kefir and sodium chloride combination on the rheological property of the wheat dough.
3. To study the effect of different levels of sourdough, kefir and salt on the shelf life in terms of texture and color of white pan bread.
4. To identify predominant aroma and flavor tones via descriptive analysis in kefir sourdough bread using trained panelists.

Hypotheses

Null hypothesis of the study is as follows:

1. There is no significant difference on flavor profile of white wheat bread with addition of different levels of sourdough, kefir and sodium chloride in comparison to the control treatments.
2. There is no significant effect of sourdough, kefir and salt on elastic recovery index of dough.

3. There is no significant difference on texture and color of the breads made with different levels of sourdough, kefir and salt in comparison to the control treatments.

Alternate hypotheses

If the null hypothesis is rejected, then the effect of sourdough, kefir and sodium chloride will be explained in terms of the interaction of different compounds formed during fermentation of kefir and sourdough that has change the flavor profile, texture, and color of the bread and on change in protein and carbohydrate structure to explain rheology of the dough.

Assumptions

The alternate hypothesis will use these assumptions to explain the effects observed. Sourdough has partially hydrolyzed gluten which releases amino acids responsible of distinct aroma and flavor. Kefir produces a number of lactic acid bacteria and acetic acid bacteria and produces volatile and non-volatile flavor compounds. The interaction of the fermented products can lead to a complex flavor profile stimuli that is sent to the brain, the interaction of so many flavor compounds lead to perception of saltiness even if amount of salt in the product is less as compared to regular bread. Addition of fermented products dilutes the gluten content of flour which affects gluten network formation and rheology of dough will change. Change in the amount of sodium chloride will change the gluten network formation and change the elasticity of the dough.

CHAPTER II

REVIEW OF LITERATURE

2.1 Wheat grain

Wheat grain consist of three different structural sections; bran, germ and endosperm. Bran accounts for 13-14%, germ 2-3% and endosperm 80-85% of total dry matter of the grain (Dewettinck et al., 2008). The interior layer is made up of carbohydrate (70-75%), proteins (10-12%), moisture (13-14%) and very small amounts of lipid (1.5-2%), fiber (1.5%) and minerals (0.5%). Proteins of endosperm are made up of albumins, globulins, prolamins and glutenins (gliadins and glutenins) and prolamins and glutenins are vital to form gluten in dough making (Panahandeh, 2012).

Wheat proteins are of two types on the basis of its functionality; non gluten protein (15-20%) and gluten protein (80-85%) (Goesaert et al., 2005). Gluten is essential for the dough network formation in bread making. The glutenins are responsible for the viscoelastic behavior of dough and the extensibility of wheat dough is mostly provided by the gliadins (Panahandeh, 2012; Song et al., 2009).

2.2 Bread making

The purpose of bread making is to present cereal flours to the consumer in an attractive, palatable and digestible form. Bread is one of the most popular staple foods consumed by humans (Clarke and Arendt, 2005). By the intervention of fermentation, use of sourdough has aided in

leavening the dough. Sourdough during fermentation is safe due to inhibition of spoilage organism by reducing pH (3.5-4.3) and ultimately giving mold-free shelf life of bread (Arendt et al., 2007). However, pH of straight and sponge dough is less acidic than sourdough which is recorded to be 5.5 (Gamel et al., 2015). During baking of bread, dough passes through major physical changes due to high temperature heating which lead to transformation of raw dough into crust and crumb. Crust and crumb account for several significant properties like flavor, texture and characteristic color of bread (Mohd Jusoh et al., 2009). After baking, bread undergoes several physical, physiochemical, sensory and microbial changes during storage. The time dependent loss in quality of flavor and texture is known as bread staling. Staling is an important quality determining factor of bread (Gellynck et al., 2009; Torrieri et al., 2014). With the increase in storage time of bread, crumb firmness increase, bread loses its aroma; crust become softer and flavor become stale. Studies have proven that the changes occur due to retro-gradation of starch, exchange of moisture between starch and protein molecules, interaction between starch and protein and removal of aromatic molecules (Torrieri et al., 2014).

Due to the long fermentation time of sourdough, the flavor of sourdough breads is richer than yeast leavened bread (Clarke and Arendt, 2005). Lactic acid bacteria and high level of amino acids (ornithine) have enhancing effect on aroma of bread crumb (Pico et al., 2015). The biochemical changes in carbohydrate, protein components during fermentation produce many flavorful compounds due to the microbial and indigenous enzymatic action on carbohydrates and protein present. Also extended shelf life of sourdough is due to the bread low pH which ranges from 3.5 to 4.3 (Arendt et al., 2007; Corsetti et al., 1998). High loaf specific volume is related to the long fermentation time (Clarke et al., 2005).

2.3 Importance of flavor in bread

Flavor in bread is the most important attribute regarding consumer acceptability and product recognition. Volatile and non-volatile components are responsible for basic taste characteristics of bread (Pico et al., 2015). Non volatiles contribute to the basic taste such as saltiness, sweetness, bitterness and sourness whereas volatiles components contribute to the overall palatability of the bread (Plessas et al., 2011). Bread aroma is increasingly receiving attention from consumers and producers. The odors and flavors which are produced in bread result from complex interactions between several factors including amount and type of ingredients used, yeast activity, fermentation temperatures and times and the bread baking process. Wheat flour is the basic ingredient in the bread; therefore variations in the odor and flavor of different varieties and species of wheat vary the odor and flavor of bread crumb (Starr et al., 2015). During the complex system of reactions of non-enzymatic browning, the availability of reagents largely determines the quality of the volatile compounds formed, though the kind of sugar and the occurrence of free amino acids depend mostly on the raw materials used. The key aroma compound of bread is considered to be 2-acetyl-1-pyrroline (2ACP) and its main precursors are ornithine, citrulline, and proline (Pacynski et al., 2015).

Lynch et al.(2009) study indicated that the production of bread containing lower salt levels is technologically feasible, but that the taste of the bread needs to be improved. The NaCl interaction with other components indicates that the sensory contrast depends not only on the size of the local regions of high salt concentration but also on the overall salt level. While it is expected to observe decline of liking with decreasing salt content, Noort et al.(2012) found no significant difference in liking score between 1.0%, 1.5% and 2.0% NaCl in breads. Sodium reduction tool as the overall flavor profile is balanced and saltiness perception itself may also be increased through umami-salt interactions (Busch et al., 2013).

2.4 Effect of salt in gluten network and dough rheology

Wheat dough is a complex material of gluten proteins and starch granules network. Dough development involves the hydration followed by the interaction of glutenins and gliadins of gluten protein which is responsible for viscoelastic properties of dough (Beck et al., 2012; Ding and Yang, 2013; Tuhumury et al., 2014). The increase in sodium chloride increases the mixing tolerance, extends the dough development time (gluten network formation time), extensibility, resistance and elasticity of dough (Song and Zheng, 2008). Study conducted by McCann and Day (2013) suggested that sodium chloride also reduces the gluten hydration rate. So, it is very important to know the effect of sodium chloride on major protein of the dough. It is possible to nullify the effect of reduced NaCl on dough rheology by selecting flour with suitable gluten quality and quantity which would allow formation of gluten network with a positive impact on processing of reduced sodium chloride cereal products. They further emphasize that NaCl had a greater effect on enhancing the strength of dough prepared from the low protein flour compared to those from the high protein flour.

Gluten has the greatest influence on the viscoelasticity of wheat flour dough compared to starch and other components. Due to this contribution of gluten, the usage of wheat flour is quite common to make breads and related products. The rheology of dough impacts the handling properties of dough during processing and quality of the final product (Miller and Hoskeney, 2008). The rheological properties depend on quality of gluten protein and their structures at the molecular level. Salt influences the hydration of protein and starch in the presence of water during initial hydration of gluten proteins when flour is mixed with water and later affects rheological properties of dough (Tuhumury et al., 2014). Gluten protein of wheat flour is also responsible for the extensibility of the bread dough (Salvador et al., 2006).

Studies have proven that reduction of salt reduced the resistance of dough to extension and extensibility while there were not major structural changes, final bread quality like specific volume and moisture loss (Beck et al., 2012; Lynch et al., 2009; McCann and Day, 2013). Lynch et al., (2009) reported a negligible effect of salt on both dough rheology and quality of bread when using salt in the range from 0.3 to 1.2%. The same author suggested a secondary factor that affects dough rheology is starch but the effect of salt on starch is not well documented yet.

2.5 Elastic recovery of dough

Wheat flour dough is viscoelastic in nature; its characteristics depend on the properties of the flour, the quantity of water added, the air incorporated into it and the mixing conditions (Salvador et al., 2006). The texture and rheology of bread are determined by the quality of dough like extensibility, cohesiveness, springiness and water and oil holding capacity (Panahandeh, 2012). The network formed by wheat protein, salt and water help in holding gas during fermentation. So, the factors responsible for dough structure are protein, starch granules and entrapped air (Ding and Yang, 2013).

Different rheological methods have been used to study the viscoelastic nature of dough including extensional techniques (Bollain and Collar, 2004), shear oscillation (Baltsavias et al., 1997), stress relaxation and creep recovery (Campos et al., 1997). Even though there are many physiological and rheological tests available for wheat dough, better understanding of cultivars can also be obtained from the tensile strength and stress relaxation behavior of dough by measuring degree of elastic recovery (Chapman et al., 2012). A novel rheology instrument, the CORE, was introduced as a result of continuous effort to find effective way to measure quality of wheat. The instrument applies a biaxial compression force followed by a free recovery and can provide valuable data using dough or gluten as test material. Halabi (2012) optimized the CORE

for dough and compressed at 1 Newton (N) for 5 seconds, followed by a 55-second free recovery and the team confirmed improved elasticity of dough from weak flour upon blending strong flour.

2.6 Sourdough

Sourdough is traditionally one of the key methods for enhancement of flavor and texture of bread. The chemical and microbial changes in sourdough depend on the flour type, amount of water, temperature, time, and type and amount of starter (Flander et al., 2011). The metabolic activity of microorganisms developed in sourdough affect the technological performance of dough and nutritional properties, aroma profile, shelf life and overall quality of the bread (Preedy et al., 2011). Microorganisms naturally present in the flour are numerous species of lactic acid bacteria including members of the genera *Lactobacillus*, *Pediococcus*, *Enterococcus*, *Lactococcus*, and *Leuconostoc* and the vast majority of yeasts like *Candida milleri*, *Candida holmii*, *Saccharomyces exiguus*, and *Saccharomyces cerevisiae* and they can also be activated in the course of sourdough fermentation (Clarke and Arendt, 2005). In good bakery practices, a sponge should contain 10^8 - 10^9 cfu/g and yeasts at 10^6 - 10^7 cfu/g of lactic acid bacteria and yeasts respectively (Paterson and Piggott, 2006).

As mentioned before, volatile compounds formed during fermentation are responsible for complex blend of overall flavor and palatability of the bread. Sourdough can reduce the loss of volatiles during storage of bread maintaining bread's freshness for an extended time in comparison to no sourdough bread (Plessas et al., 2011). Kefir is a mixed culture starter containing diverse spectrum of yeast and bacteria mostly lactic acid bacteria in symbiotic relationship (Witthuhn et al., 2005). It has been considered as a new, interesting, superior and simpler combination of yeast and bacteria starter which have been evaluated for sourdough production (Blandino et al., 2003; Plessas et al., 2011). Milk product has also been found to

improve the nutritional characteristics, sensory properties, shelf life, texture, taste and aroma of the cereal product (Blandino et al., 2003).

Bread staling is a result of changes in the starch and protein microstructures and moisture migration and redistribution. To achieve bread with extended preservation time, improved organoleptic and nutritional quality, and satisfy the recent demand of consumers for natural technologies production of sourdough bread is recommended (Arendt et al., 2007; Corsetti et al., 2000). Mixed culture of yeast and lactic acid bacteria give improved flavor (taste and aroma), nutritional quality, texture as well as extension of preservation time through the in situ production of antimicrobial compounds (Blandino et al., 2003; Simova et al., 2002). In such mixed-cultures, yeasts act mainly as leavening agents, while LAB contributes mainly to the sensory quality and longer shelf life of bread. Many microorganisms have been isolated from kefir microflora, sharing symbiotic relationships, including yeasts (*Kluyveromyces*, *Candida*, *Torulopsis* and *Sacharomyces sp*), lactobacilli (*L. brevis*, *L. acidophilus*, *L. casei*, *L. helveticus*, *L. delbruecki*), streptococci (*Streptococcus salivarius*), lactococci (*Lc. Lactis ssp. thermophilus*, *Leuconostoc mesenteroides* and *L. cremoris*) and occasionally acetic acid bacteria (Plessas et al., 2005).

In sourdough, flavor compounds; volatiles and non-volatiles are produced by LAB and yeasts individually and/or through their interactions (Salim ur et al., 2006). Organic acids, alcohols, aldehyde, ketones and carbonyl compounds are formed during cereal fermentation which is regarded as a major flavor contributing compounds in sourdough (Blandino et al., 2003).

2.6.1 Effect of dough fermentation on protein

Major changes during fermentation that affect nutritional quality of sourdough are acidification, proteolysis, and activation of enzymes. The extensive degradation of proteins during fermentation causes bread flattening which is related to gluten network during the expansion of CO₂ in leavening and baking. It may also degrade wheat allergens, so the fermented

baked goods can be tolerated by consumers suffering from gluten sensitivity. Fungal proteases and sourdough lactobacilli play a part in digesting wheat flour (Di Cagno et al., 2014; Torrieri et al., 2014). Torrieri et al. (2014) reported that lactic acid bacteria produce a number of metabolites like organic acids, exopolysaccharides (EPS) and enzymes which have positive effect on texture and staling of bread when sourdough was used in the amount of 30 g/100 g dough which is in the range used in this study. The same author further illustrated that exopolysaccharides improve the viscoelastic properties of dough, increase loaf volume, reduce crumb hardness and extended shelf life of bread. Moreover, during fermentation, breaking down of protein into amino acids and peptides and transformation of amino acids and peptides into volatiles (aromatic components) contribute to the flavor in bread.

2.6.2 Research on sourdough

Poutanen et al.,(2009) reported the development of specific culture and controlled fermentation of sourdough and its impact on bread texture, flavor and nutritional quality. The effect of nutritional quality is observed by increasing or decreasing levels of compounds, enhancing or retarding the bioavailability of nutrients. The same author suggested that EPS such as glucan, fructans and gluco- and fructo-oligosaccharides can improve the gut health, and gluten degradation. Improvement of sensory quality, stability of vitamins and bioactive compounds are another positive effect obtained by fermentation of sourdough. In addition, Torrieri et al.,(2014) emphasize that in situ production of EPS can avoid the addition of bread improvers in bread making but production of exopolysaccharides can be hindered by acidification developed during fermentation which can diminish positive technological impact of EPS.

Fermentation of cereal products increase the bioavailability of β -glucan by reducing the molecular weight and increase the proportion of low molecular weight β -glucan without affecting the total β -glucan content in bread (Flander et al., 2011). Similar observation on the effect of

fermentation (sourdough) was seen in gluten free fermented product which included positive effects on metabolic activities, improved quality, slowing down the staling process, inhibiting mold growth and improve acceptability of regular and gluten free bread (Mariotti et al., 2014; Moroni et al., 2009).

Moroni et al.,(2011) recognized that addition of sourdough induced substantial inhibition of the CO₂ production by the baker's yeasts (479.7 ml in the control batter and 181.0 ml in the 50% sourdough batter) during proofing, resulting in lower volume and harder crumb of the sourdough bread. They speculated that acidification might have induced the hardening of starch gel upon cooking resulting in low bread volume. The same authors theorized that acidification also causes reduction in elasticity and strengthening of dough leading to increased water holding capacity of protein and starch granules complexes. Ganzle et al.,(2008) stated that the increase in sensory and nutritional quality of sourdough bread is also due to degradation of anti-nutritional factors present in the flours.

2.7 Importance of texture in bread

One of the major changes occurs during storage of bread is the loss of desirable texture and flavor characteristics associated with its freshness. This causes the loss of sensory perception and mechanical properties including elasticity which subsequently affect the consumer purchase behavior (Arendt et al., 2007). Instrumental and sensory analysis of bread staling is performed by measuring crumb firmness (Angioloni and Collar, 2009; Arendt et al., 2007). Studies have measured crumb firmness using a texture analyzer in static compression mode using a cylindrical compression probe of 36mm which is applied to bread slices (25mm) (Al-Saleh and Brennan, 2012; Angioloni and Collar, 2009).

Addition of lactic acid bacteria (LAB) in the form of sourdough has been reported to positively affect bread by increasing loaf specific volume leading to a reduction in crumb

firmness for sourdough breads during storage. Slower staling is due to retrogradation properties of starch and hydrolysis proteins by the production of enzymes by LAB (Arendt et al., 2007). LAB produce metabolites such as acetic acid, ethanol, aroma compounds, bacteriocins, exopolysaccharides, and several enzymes that decrease bread firmness and lead to improved sensory profile of the food product (Plessas et al., 2011). A decrease in the staling rate as measured by differential scanning calorimetry has been reported for breads containing sourdough showing that during the first 144 h storage, sourdough bread gave lowest percentage increase in enthalpy (<40%) compared to that of yeast bread (Corsetti et al., 1998).

2.8 Sensory perception of food in humans

The sense of smell is dependent on the sensory receptor protein in the olfactory epithelium that responds to the airborne chemical trigger (Berger, 2015). The ability to taste is based on the function of receptors that exist in on taste buds found on the tongue, roof of the mouth, and back of the throat (Hadhazy, 2013). In fermented products carbonyl and esters of simple structures play an important role in providing flavor. Esters, such as 2-phenylethyl acetate, impart fruity notes to yeast cultures (Berger, 2015). Five taste qualities distinguished by the taste buds are sweet, sour, salty, bitter and umami. Taste stimuli are detected by taste receptors located on the tongue, mouth and pharynx. Taste includes the olfactory, tactile and thermal attributes of food in addition to flavor (Daly et al., 2012; Jackson, 2009). There are between 2000 to 5000 taste buds in human oral cavity distributed on the tongue (Roper, 2013).

Aroma giving compounds are volatile molecules which have to be released from food during the eating process and must reach the olfactory receptors. A stimulated receptor generates an impulse along the membrane of nerve cells in a nearby sensory neuron leading sense to the brain. The receptor of salt (NaCl) is an ion channel that allows Na⁺ to enter directly into the cell depolarizing it and prompting action potentials in a nearby sensory neuron. Sour receptors detect

the protons (H⁺) liberated by sour substances like acids. Interaction of volatiles with non-volatile compounds present in food is of importance in order to release volatile compounds from the food matrix (Guichard, 2015). Perception of taste depends on many factors like gender, ethnicity, age, salivary composition of individuals and tasting environments (Bajec and Pickering, 2008).

Taste buds also contribute to our quality of life by analyzing food chemicals into the gustatory qualities of sweet, salty, sour, bitter and umami. Signals generated by taste buds are transmitted to higher centers in the brain possibly via two or more parallel streams of information (Roper, 2009). Taste is influenced by other chemical present at the level of receptor and centrally in the brain. These levels of receptor can be reported to increase saltiness perception by using other flavor on the basis of which we can lower the sodium of food (Keast et al., 2008).

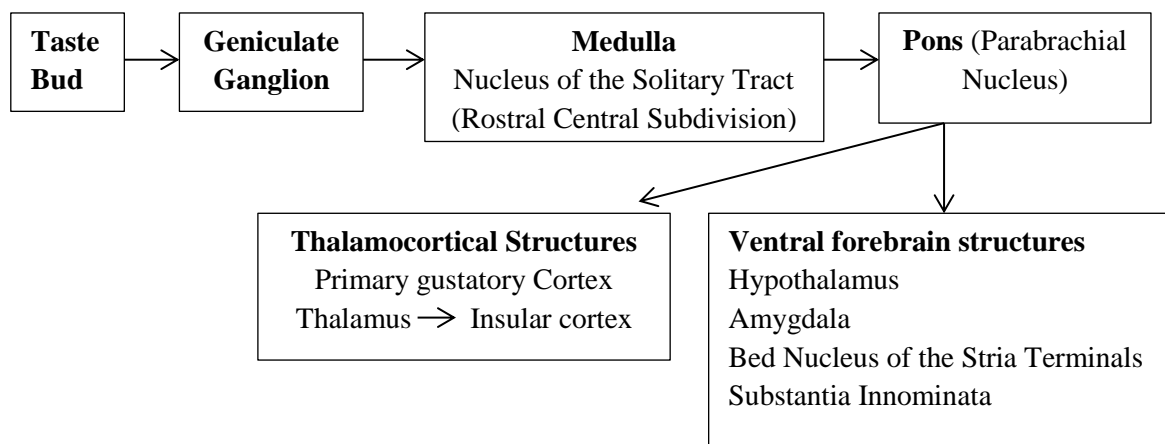


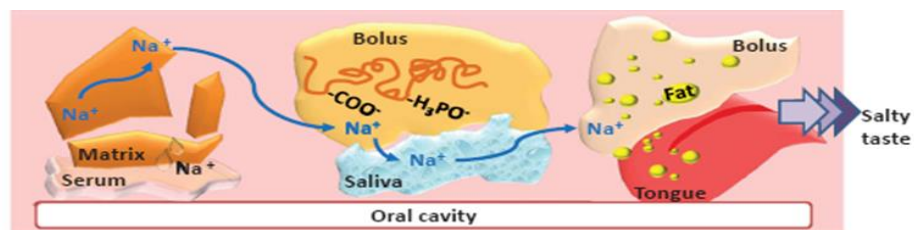
Figure 1. Parallel neuronal pathways for information from taste buds to higher brain center (Roper, 2009).

There are multiple cell types in the taste buds. Neurons from taste buds pass through ganglions and then to nucleus of solitary tract. Perception of the basic taste qualities is believed to take place in the primary gustatory cortex. Neurons in the parabrachial nucleus target to thalamocortical and ventral forebrain structures. Discrimination of the basic taste qualities is

believed to be take place in the primary gustatory cortex at the inferior frontal gyrus of the frontal lobe (Roper, 2009).

2.9 Saltiness perception in humans

In a study conducted to investigate the influence of crumb texture on the intensity of saltiness/release of sodium ion during chewing revealed that the coarse pore bread released significantly more sodium and faster compared to fine-pored bread in the mouth and in a mastication simulator (Pflaum et al., 2013). The results indicated that enhanced salty taste is obtained with an increase in proofing time and influenced by the velocity of sodium release and crumb texture. Pflaum et al., (2013) further suggested that appropriate modification of texture can possibly provide salt reduction strategies in bread. Another study by Kuo and Lee (2014) theorized that enhancing sodium release rate from a food matrix will increase perception of saltiness. Saltiness perception is divided into 3 stages; 1) release of sodium from food matrix into oral cavity 2) delivery of sodium in oral cavity and 3) detection of sodium by taste receptor cells. In the first stage, the type of food affects the availability of sodium that's released and affects spontaneous migration of sodium from matrix to oral cavity. In second and third stage, the food matrix affects the availability of sodium, mixing with saliva and physical availability of sodium for taste receptor cells.



Release from food matrix---Delivery in oral cavity--- Saltiness generation

Figure 2. Schematic illustration of the matrix effects during the three stages of saltiness perception (Kuo and Lee, 2014).

Taste receptor cells are located throughout the oral cavity. Most receptor cells are components of taste buds. When food enters the mouth, chemicals from those foods activate taste receptors. Chemical signal from food is converted to an electrical signal and sent to gustatory processing region of brain where taste is characterized in terms of quality, intensity, temporal and spatial patterns. Taste quality is the most important feature of taste sensation. It is a descriptive noun and elicits: sweet, sour, salty, bitter (Roper, 2013). So, the primary effect of reducing sodium chloride will be decrease of saltiness perception. There will also be increase in bitterness and decrease in sweetness (Liem et al., 2011). Sodium chloride gives salty taste but at different concentration it gives perception of sweetness and sourness. At lower level of sodium chloride, the stimulus gives sweet taste. However, mid-range concentration of sodium chloride somewhat tastes sour (Smith and van der Klaauw, 1995).

2.10 Consumer perception of bread quality

The freshness of bread according to consumer's perception depends on flavor, appearance, crispness of crust, firmness of crumb and bread volume. Several microorganisms have been proposed to use in bread making (Plessas et al., 2011). Consumer choice of food and flavor perception depends on their beliefs, choice and attitudes. Another perception determining factors are interior characteristic of product like color, texture, shape, overall appearance. Based on these quality attributes, believes are formed about the quality attributes of the product. Besides that, freshness (softness), color, biting properties radically influence the overall perception of bread (Gellynck et al., 2009).

Fermented products are produced by the action of microorganisms or enzymes causing desirable biochemical changes on food (Blandino et al., 2003). Fermented dough bread is emerging interest of the consumer (Dewettinck et al., 2008). The formation of sourdough by

natural occurring bacteria is characterized by acid taste, aroma and increased volume due to gas formation (Clarke and Arendt, 2005).

2.11 Color of bread

Color is one of the important sensory qualities of bread. The color in the crust and crumb is due to the Maillard reaction between reducing sugars and proteins (Mohamed et al., 2010). Final quality including color of the bread depends on the quality of raw materials like flour, ingredients, additives, production process and bread staling. An objective instrumental technique to measure crumb color of bread complements well with the subjective measurement of color in a sensory evaluation. The crumb color of aged bread is reported lighter than fresh bread crumb. (Angioloni and Collar, 2009; Popov-Raljac et al., 2009). The result obtained by Popov-Raljac et al., (2009) showed that the process of staling follows a linear change as a function of time.

HunterLab LabScan XE Spectrophotometer is a commonly used instrument for the analysis of bread and meat samples. The color is measured in three dimensions L^* a^* b^* . The L^* value gives a measure of the lightness of the product whose value ranges from 100 for white to 0 for black. The redness/greenness and the yellowness/blueness are denoted by a^* and b^* value, respectively and range from -120 to 120 (Al-Saleh and Brennan, 2012; Mohd Jusoh et al., 2009).

Other study suggested the storage of bread in double zip-lock bag and using D65 as a light source for measuring crumb color of bread. The presence of compound responsible for high water binding capacity negatively affects color of the bread (Mohamed et al., 2010). L^* a^* b^* system gives uniformity in color distribution and closeness to human perception as Euclidean distance between two different colors in L^* a^* b^* corresponds approximately to the color difference perceived by the human eye, so it is widely used system of color analysis (Leon et al., 2006; Mohd Jusoh et al., 2009).

2.12 Kefir sourdough bread

Kefir addition in straight bread and sourdough bread making is a new perspective to improve bread sensorial characteristics, shelf life and flavor (Plessas et al., 2011). Mantzourani et al., (2014) reported that the bread made with kefir has rope spoilage occurrence shown only after 15th day of bread storage in comparison to 7th day on spontaneously fermented bread. The content of lactic acid in such bread was approximately 41–82% higher than the control samples. Shelf life of bread can be increased by two fold by using kefir instead of regular sourdough. The reason behind this may be due to high amount of organic acids in kefir sourdough which inhibit *Bacillus* spp., which are responsible for rope spoilage in bread (Mantzourani et al., 2014).

Mantzourani et. al.,(2014) proved that in the kefir sourdough bread organic acids like lactic acid, acetic acid, pentanoic acids and hexanoic acids are present in double amount than those present in sourdough made with wild cultures while using similar amount of cultures in both cases. Kefir also maintain dough water absorption, dough mixing stability, bread specific volume and help to increase bread firmness after 1 and 7 days of bread storage (Gelinas et al., 1995).

2.12.1 Advantages of kefir in bread

Adding kefir to replace yeast to make sourdough bread probably increase the shelf life due to higher acidity and formation of natural antimicrobial like bacteriocins by kefir microflora and can improve the aroma and taste of bread. Extension of shelf life can be obtained with the reduction of staling rate and microbial stability on bread (Plessas et al., 2005).

The microflora of kefir grains is held together in a matrix of protein and exopolysaccharide (Hsieh et al., 2012). The microorganisms isolated from kefir includes yeasts (*Kluyveromyces*, *Candida*, *Torulopsis* and *Saccharomyces* sp.), lactobacilli (*L. brevis*, *L. acidophilus*, *L. casei*, *L. helveticus*, *L. delbruecki*), leuconostoc, streptococci (*Streptococcus*

salivarius), lactococci (*Lactococcus lactis* ssp. *thermophilus*, *Leuconostoc mesenteroides* and *L. cremoris*) and sometimes acetic acid bacteria (Kok-Tas et al., 2013).

In the preparation of milk kefir culture, kefir grains (2–3% w/v) are fermented in reconstituted milk at 20 to 25°C for about 24 h. The fermented kefir product gives unique sensory properties by forming mixture of lactic acid, acetaldehyde, ethanol and other fermented byproducts where lactic acid bacteria (LAB) convert lactose to lactic acid and other flavor compounds while yeast produces CO₂ and ethanol (Guzel-Seydim et al., 2011). The biomass of kefir grains increases after successive fermentations. The lactobacilli and lactococci were present in a kefir beverage at levels of 10⁸ CFU/mL, and yeasts and acetic acid bacteria were present at levels of 10⁵ and 10⁶ CFU/mL, respectively (Urdaneta et al., 2007).

The rise in interest in applying new starter cultures has developed in recent years in the food industry. The main purpose of using starter cultures is the production of food products which have high bacteriocins production, probiotic properties, improved sensory characteristics and higher nutritional value (Plessas et al., 2011). Kefir is regarded as a probiotic which have positive effect on intestinal tract of the host directly or indirectly through the variation of the endogenous microflora or the intestinal immune system. Several studies have proven kefir to have lactose digestive effect by preventing lactose intolerance due to the synergistic effect of several microorganisms (Urdaneta et al., 2007).

2.13 Sodium chloride

Sodium is an essential micronutrient for human beings. Appropriate sodium balance is critical for health in the body (Dotsch et al., 2009). An improper sodium balance in human causes malfunction of muscle, nerve and renal cells. Higher sodium ingestion is associated with different types of diseases like hypertension and cardiovascular disease (Panahandeh, 2012). The major source of sodium in our food is the common salt or sodium chloride (He and MacGregor, 2010).

2.13.1 Salt in bread making

Addition of sodium chloride has various functions in bread making. It is commonly used to provide saltiness, improve flavor, provide some of the technological functions like contributing to structuring of bread, preservation by preventing spoilage, modification of enzyme activity in bread making (Busch et al., 2013). Moreover, sodium chloride limits the growth of yeast and assists the development of gluten structure in bread. So, the reduction of sodium chloride in bread may result in an increase in the growth of yeast and an under developed gluten structure, which has adverse effects on the texture of bread (Liem et al., 2011).

Sodium chloride (NaCl) also impacts the viscoelastic properties of dough. It increases sensory characteristics, bread loaf volume, stabilizes the gluten networks thereby improving gas holding time and reduces yeast fermentation in bread making (Panahandeh, 2012). The presence of NaCl in dough formation creates smooth crumb structure and improves air cell of the viscoelastic matrix (Belz et al., 2012).

In general, salt is added around 2% to bread based on flour weight. The consumer's perception reveals that the presence of salt in bread is essential for taste. Salt has the ability to enhance sweetness and it can cover off-flavors such as bitter and metallic taste (Miller and Hoskeney, 2008).

2.13.2 Need for salt substitutes

There is need of salt substitutes such as natural flavors or other chemicals that increase the perception of saltiness in food products with minimum alteration of taste and textural properties. Study has shown that it is possible to decrease NaCl in bread up to 50% without any significant change in sensory attributes and technological properties (Belz et al., 2012). Three main principles are identified towards sodium reduction; chemical stimulation to increase the saltiness perception peripherally at the level of receptor by chemical stimulation, cognitive

mechanisms towards increasing awareness or shifting the saltiness preference, and designed product structure in such a way that it delivers salt to the taste buds. Stimulation of saltiness by using ingredients that provide flavors with saltiness feel would be the best option to partially reduce some salt from processed foods (Busch et al., 2013).

CHAPTER III

MATERIALS AND METHODS

3.1. Raw Materials and source of microorganism

Commercial bread flour was obtained from Shawnee Milling Co., Shawnee, OK and Kefir culture from Wilderness Family Naturals, Silver Bay, MN. Other materials including whole wheat flour, salt, sugar and shortening were purchased from local food retailer. Yeast and yeast food were purchased from Lesaffre Yeast Corporation (Milwaukee, WI). Reverse osmosis water was used to make dough during baking.

3.2 Experimental

3.2.1 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 triplicate.

3.2.2 Kefir preparation

Kefir was prepared as described by manufacturer's instruction. A 3-g pack kefir culture was mixed with 4 cups skimmed milk at 25°C and fermented for 24 h at room temperature (23°C) and was considered a first or mother batch. Consequent batches were made using 4-5 spoons of

previous kefir batch mixed with 3 cups of skimmed milk at 25°C and fermented for 24 h at room temperature. This culture was maintained active by continued feeding with skimmed milk.

3.2.3 Levain (sourdough) preparation

Sourdough culture was prepared following the procedure of Suas (2008) with slight modification to include kefir in the culture. Development of mature sourdough (levain) takes 5 days of feeding schedule. Two levels of kefir (30, 50%) were determined on the basis of result obtained from a preliminary study. Two batches of sourdough were made using two levels of kefir in the dough. On day 1, 500 g of whole wheat flour and 500 g of bread flour were mixed with 1 kg of water and kefir 300 g (30%) or 500 g (50%) for each treatment was added and incubated at 23°C for 24 h. On second day, 500 g of bread flour was mixed with 500 g of starter from day 1 and 500 g of tap water and kefir 150 g (30%) or 250 g (50%) and incubated for 8 h. Similar formula of day 2 was applied from day 3 to day 5 following alternate schedule of 16 h and 8 h of fermentation while feeding the new batch with previous day culture. Flour, kefir and water were fed in given proportions on every given hours to get mature sourdough (Levain) at the end of 5 days. The mature levain was then used to make bread by adding it in different proportions.

3.2.4 Bread making and storage of bread

A preliminary bread baking study was conducted using a 3x2x2 design of sourdough (20, 40 and 70%), NaCl (0.1 and 0.4%) and kefir (40 and 60%). Baking was conducted using an Optimized Straight-Dough Bread-Making Method 10-10.03 (AACCI, 1999). The dough was mixed for 2 minutes in speed 1 and 7 min in speed 2 in a 5 quarts Kitchen Aid Mixer (Benton Harbor, MI).

From the results of the preliminary study, a 2x2x2 experimental design with two controls was made. Two controls were made using 0.8% and 1.2% of NaCl without adding fermented

products to them. Bread was made with combination of sourdough (40 and 70%), NaCl (0.8 and 1.2%), kefir (30 and 50%) using a Sponge-Dough, Pound-Loaf Method 10-11.01 (AACCI, 1999). The dough was mixed in a Hobart mixer (12 qt capacity, Troy, OH) and the optimum mixing times were obtained from various trials (2 min at speed setting 1 and 7min at 2). After baking, breads were allowed to cool at room temperature, packed in double zip lock bags and stored overnight at room temperature. Next day, breads were sliced (12.5mm thick) and stored again in double zip lock bags until analysis.

3.2.5 Sensory evaluation

On day 1, sliced breads were cut into quarters for sensory analysis. A preliminary consumer acceptance test was carried out with 22 untrained panelists of age 18-60 years including students, staff and faculty member from Food and Agricultural Product Center (FAPC), Oklahoma State University. For the second experiment, consumer acceptance test was conducted with 64 untrained panelists. The panelists were evaluated breads separately for saltiness, sweetness, sourness, aroma, bitterness, pasteboardiness and overall palatability. Consumer acceptance test used a 9-point hedonic scale (pleasantness dimension) with 1= dislike extremely and 9=like extremely. The sensory evaluation study was approved by Institutional Review Board (IRB) at Oklahoma State University (Appendix 1a). A sample of consumer test ballot for bread is given in Appendix 1b.

3.2.6 Descriptive sensory analysis

A descriptive sensory analysis was conducted with five panelists of age 24-65 (lab members) who are able to detect the bread flavor and participated in at least 9 sensory sessions. The five panelists were trained about the perception of different aroma and flavors. They also verbally expressed the type of flavor pronounced in white yeast leavened and sourdough leavened bread. The objective was to identify predominant aroma and flavor tones in breads with and

without sourdough and kefir. The panelist suggested, discussed and finally identified six major flavor tones in the bread as sour, acidity, sweetness, fruitiness, overall perception and different volatiles. They performed odor profiling of the samples by sniffing the surface of the slices and assigning the intensity of each odor and flavor descriptor using a 10-cm graphic scale anchored at 0 to “none” and at 10 to “extremely strong”. All bread treatments (n=10) were evaluated by generic descriptive analysis in accordance to (Hansen and Hansen, 1996; Heenan et al., 2008; Pacynski et al., 2015). For evaluation, 1/4th of bread slice of each sample, including crust and crumb were given to panelist. During the evaluations the panelists were provided with tap water to cleanse and refresh the mouth between each sample evaluation.

3.3 Instrumental analysis

3.3.1 Bread crumb firmness

To access the crumb quality and shelf life of bread, pan white breads were measured by means of a Texture Analyzer TA-XT2i (Texture Technologies Corp, Scarsdale, NY) using the AACCI (74-09) Standard Method for Measurement of Bread Firmness (AACCI, 1999). Crumb firmness (force g) readings were taken over the storage period of 7 days on 1, 4 and 7 days of storage. The breads were packed in polythene double zip locked during the storage period. For the measurements, the center of the bread slice of 25 mm thick (two 12.5 mm slices) was compressed with a plunger (36 mm cylindrical probe) at 30% strain using a 5 kg load cell. The test speed and holding time under strain were 1.7 mm/s and 32 s, respectively. Five slices of the bread per treatment were analyzed at day 1, 4 and 7. Analysis was conducted in triplicate.

3.3.2 Color analysis

The L* (lightness), a* (redness) and b* (yellowness) values of bread crumbs were measured utilizing a HunterLab LabScan XE Spectrophotometer with a D65 light source (Hunter Associates Laboratory, Inc., Reston, VA). The colorimeter was calibrated before each analysis

with white and black standard tiles. Crumb color measurement was determined on five points on the central slices of bread loaf. Five bread slices of each treatment were analyzed per storage day (Angioloni and Collar, 2009). The L^* value represents lightness component and the value ranges from 0 to 100 while a^* and b^* values are chromatic components of redness to greenness and blueness to yellowness that range from -120 to 120 (Mohd Jusoh et al., 2009).

3.3.3 Dough recovery index

The recovery of dough was analyzed with a compression-recovery test to determine the elastic recovery. Five gram of dough for each treatment was allowed to rest for 1-2 min. Round shape dough was manually prepared and placed at the center lower plate of pre-calibrated Gluten CORE analyzer (Perten Instrument Ab, Huddinge, Sweden). The dough samples were then subsequently compressed for 5 s with a force of 2 N and allowed to recover freely for 55 s. The force applied for dough was optimized using an experiment based on standard for gluten (8N) (Chapman et al., 2012) and dough (1N) according to Halabi (2012). The experiment was conducted at room temperature. The Gluten CORE recorded the height of the dough as a function of time and calculated the elastic recovery as the ratio of the recovered height. At least three independent replicates with five sub samples in each replicate were analyzed for all 10 treatments of the experiment. Oil was applied on the lower and upper plates to avoid stickiness inherent in sourdough.

3.4 Statistical analysis

SAS Version 9.4 (SAS Institute, Cary, NC) was used for all statistical analyses. Analysis of variance methods were used to assess effects of factors in the studies. For the preliminary data, a completely randomized design with a 3x2x2 factorial arrangement was used. For the second study, a completely randomized design with a 2x2x2 factorial arrangement plus two controls was used. For both studies, simple effects of a factor given fixed levels of the other factors were

assessed with planned contrasts and protected pairwise t-tests (LSD). In addition to the ANOVAs, correlations of the response variables were calculated. The coefficients of variability of all the tests were lower than 10%. All experiments were conducted in triplicate. Significance was determined for $P < 0.05$. All results were reported as mean value \pm standard error.

CHAPTER IV

RESULTS AND DISCUSSION

Results

4.1 Partial proximate analysis of flour

Partial proximate analysis of flour was evaluated for protein, moisture and ash content using NIR system. The percentage mean protein content of flour was 11.7. Similarly, average percent moisture content of the flour was 12.6 and ash content 0.47.

4.2 Preliminary sensory evaluation of bread

A preliminary experiment was conducted to select the levels of ingredients and analyze their effect on the bread sensory profile. Twelve treatments were selected using 3x2x2 factorial design consisting of NaCl 0.1 and 0.4%, kefir 40 and 60% and sourdough 20, 40 and 70%. The sensory evaluation of bread consisted in a consumer acceptance test evaluating saltiness, sweetness, sourness, pasteboardiness, bitterness, aroma and overall palatability and was evaluated by 22 untrained panelists.

4.2.1 Saltiness

4.2.1.1 Effect of NaCl

One of the important parameters in the sensory analysis of bread is saltiness perception. Two levels of sodium chloride were compared for its effect on saltiness at different levels of sourdough and kefir (Appendix Table 1). Significant different saltiness perception was perceived ($P<0.05$) with the treatments containing 40% kefir, 20% sourdough among two levels of sodium chloride (0.1, 0.4%), and overall means of 4.9 (Dislike slightly) and 5.9 (Neither like nor dislike), respectively. The score for the treatment combination with 0.4% sodium chloride was 20.4% higher than that of 0.1% (Appendix Table 1). Score for saltiness perception were not affected in the treatment combination kefir%-sourdough% 40-40, 40-70, 60-20 and 60-40 among two levels of sodium chloride. NaCl at 0.4% had significantly higher saltiness perception score ($P<0.05$) in the presence of 60% kefir and 70% sourdough than 0.1% sodium chloride with mean scores of 6.8 (Like slightly) and 5.3 (Neither like nor dislike), respectively (Appendix Table 1). Mean score of 0.4% NaCl was 28.3% higher than mean score of 0.1% NaCl. The effect of sodium chloride (0.1, 0.4%) was noticed only at higher and lower end of kefir and sourdough of the design. Thus, with the combinations of kefir %-sourdough % 40-40, 40-70, 60-20 and 60-40, the saltiness perception is similar for 0.1 and 0.4% NaCl in bread.

4.2.1.2 Effect of sourdough

The effect of sourdough levels on saltiness perception of bread in the presence of given levels of kefir and sodium chloride were compared (Appendix Table 2). Three levels of sourdough (20, 40 and 70%) in the presence of 40% kefir and 0.1% sodium chloride affected significantly ($P<0.05$) the saltiness perception. Significantly higher perception of saltiness was recorded at 40% (by 20.4%) and 70% (by 26.5%) sourdough when compared to 20%. Overall means of 4.9, 5.9 and 6.2 were recorded for 20, 40 and 70% sourdough levels, respectively for

this combination. In the presence of 0.4% sodium chloride, sourdough levels (20, 40 and 70%) did not result in a significantly different saltiness perception at 40 and 60% kefir levels. In the presence of 60% kefir and 0.1% sodium chloride, three levels of sourdough resulted in significant different ($P < 0.05$) saltiness perception with mean scores of 5.4 (Neither like nor dislike), 6.2 (Like slightly) and 5.3 (Neither like nor dislike) for 20, 40 and 70% sourdough levels, respectively (Appendix Table 2). The effect on saltiness perception was not linear with increase in sourdough percentage as 40% sourdough perceived significantly higher saltiness perception than 70% sourdough in the presence of 60% kefir and 0.1% NaCl. In this combination, perception of saltiness was decreased by 14.5% when sourdough increased from 40% to 70%.

4.2.1.3 Effect of kefir

The effect of kefir levels on saltiness perception of breads was compared at given levels of sourdough and sodium chloride (Appendix Table 3). The two levels of kefir (40, 60%) at treatment combination tested having three levels of sourdough (20, 40 and 70%) and NaCl (0.1 and 0.4%) had no effect on saltiness perception of the bread. The saltiness score in those observations were from 4.9 (Neither like nor dislike) to 6.8 (Like moderately). The results suggested that when kefir is used in the range of 40 to 60%, consumers could not differentiate in saltiness perception for 0.1% and 0.4% NaCl and reduction of NaCl is easily achieved without adverse effects on saltiness perception of sourdough bread.

4.2.2 Sweetness

4.2.2.1 Effect of NaCl

Sodium chloride among two levels (0.1 and 0.4%) at a given levels of sourdough and kefir were considered (Appendix Table 4). Treatment containing kefir at 40%, sourdough at 20% among two levels of sodium chloride (0.1 and 0.4%) resulted in sweetness perception significantly different with overall means of 5.0 and 6.0, representing “Neither like nor dislike”

and “Like slightly”, respectively (Appendix Table 4). Mean score of sweetness for 0.4% sodium chloride was 20% higher than mean of 0.1% sodium chloride. Similarly, in treatments containing 40% kefir and 40% sourdough, two levels of sodium chloride (0.1, 0.4%) affected sweetness perception with average score of 5.6 (Neither like nor dislike) and 6.5 (Like slightly), respectively. Sodium chloride at 0.4% increased by 16.1% the saltiness score compared to that of 0.1% sodium chloride (Appendix Table 4). In the treatment containing 40% kefir and 70% sourdough, sodium chloride did not affect sweetness perception ($P>0.05$). In the presence of 60% kefir with 20% and 40% sourdough, two levels of sodium chloride (0.1 and 0.4%) did not affect sweetness perception (Appendix Table 4). In the treatment containing 60% kefir and 70% sourdough, two levels of sodium chloride (0.1 and 0.4%) resulted in significantly different ($P<0.05$) sweetness perception with mean score of 5.1 (Neither like nor dislike) and 6.7 (Like moderately), respectively (Appendix Table 4). Sweetness score of 0.4% sodium chloride was 31.4% higher than mean score of 0.1% sodium chloride. The effect of sodium chloride was significant when used at higher and lower end of kefir and sourdough.

4.2.2.2 Effect of sourdough

Sourdough among three levels (20, 40 and 70%) in the presence of 40% kefir and 0.1% sodium chloride significantly affected ($P<0.05$) sweetness perception with an overall mean of 5, 5.6 and 6.2 representing “Neither like nor dislike” and “Like slightly”, respectively (Appendix Table 5). Sourdough at 70% level showed significantly higher sweetness perception with 24% increase in comparison to 20% sourdough. At 40% kefir, sourdough among three levels did not result in significantly different sweetness perception when 0.4% sodium chloride was studied. At 20% sourdough, sweetness perception had an overall mean of 5.9, 40% had mean score of 6.2 and 70% had mean score of 5.1 which were statistically different ($P<0.05$) when treatments were studied with 60% kefir and 0.1% sodium chloride (Appendix Table 5). In this combination, a decrease of 17.7% sweetness score was obtained at 70% sourdough in comparison to 40%

sourdough. At 60% kefir level, sweetness perception in the presence of 0.4% sodium chloride among three levels of sourdough was significantly different ($P < 0.05$) with mean score of 6.2 (Like slightly), 5.5 (Neither like nor dislike) and 6.7 (Like slightly) for 20, 40 and 70% sourdough, respectively. The increase in sweetness score by about 22% was obtained when sourdough level was increased from 40% to 70% in the presence of 60% kefir and 0.4% NaCl. The effect of sourdough in perception of sweetness did not follow the same pattern as one out of three significantly different results showed decrease in sweetness perception at 70% sourdough while two out of three significant results showed an increase in sweetness perception at 70% sourdough.

4.2.2.3 Effect of kefir

Effect of kefir level on sweetness perception of sourdough bread was compared at given levels of sourdough and sodium chloride (Appendix Table 6). Half of the treatment comparisons showed significantly different perception of sweetness in the presence of kefir. Treatment containing sourdough at 20% level in the presence of 0.1% NaCl resulted in significantly different sweetness perception for two levels of kefir (40 and 60%). At 40% kefir level, average score of 5 (Neither like nor dislike) and at 60% kefir average score of 5.9 (Like slightly) were recorded. The mean score for 60% kefir was 18% higher than mean score for 40% kefir (Appendix Table 6). For sweetness, in the presence of 20% sourdough and 0.4% sodium chloride, two levels of kefir obtained similar perception of sweetness. Two levels of kefir when present with 40% sourdough and 0.4% sodium chloride gave significantly different ($P < 0.05$) sweetness perception with higher score (6.5) for 40% kefir and lower score (5.5) for 60% kefir (Appendix Table 6). The mean score for 60% kefir was 15.4% lower mean score for 40% kefir. Similarly, significantly different ($P < 0.05$) sweetness perception was observed in the treatment with 70% sourdough and 0.1% sodium chloride while comparing the two levels of kefir; 40 and 60%. Panelists gave average score of 6.2 and 5.1, respectively. The score for 60% kefir in this

combination was 17.7% lower than 40% kefir. In those two combinations, there was negative effect of higher kefir in sweetness perception.

4.2.3 Sourness

4.2.3.1 Effect of NaCl

Sodium chloride levels were compared at given levels of kefir and sourdough (Appendix Table 7). Treatment containing kefir at 40% with 20% sourdough resulted in significantly different sourness perception when two levels of sodium chloride were compared. The mean values for 0.1 and 0.4% sodium chloride were 4.8 (Dislike slightly) and 5.9 (Like slightly), respectively. Sourness score for 0.4% sodium chloride was 23% higher than score for 0.1% sodium chloride. When kefir and sourdough level reached the higher end of the treatment design, significantly different perception of sourness was recorded. Significantly higher ($P<0.05$) sourness score (6.6) was observed for 0.4% sodium chloride in comparison to 0.1% sodium chloride (5.2) in the presence of 60% kefir and 70% sourdough (Appendix Table 7). The mean of sourness score at 0.4% NaCl was 27% higher than mean at 0.1%. Again, effect of sodium chloride on sourness perception was pronounced at higher and lower end of kefir and sourdough while in intermediate levels, the effects were not significant.

4.2.3.2 Effect of sourdough

Sourdough levels were compared at given levels of kefir and sodium chloride (Appendix Table 8). Kefir at 40% level and 0.1% sodium chloride, three levels of sourdough (20, 40 and 70%) significantly affected the sourness perception with the overall means of 4.8, 6.1 and 5.9 for 20, 40 and 70% sourdough, respectively. Sourdough at 40 and 70% obtained significantly higher sourness perception scores in comparison to 20% sourdough. Sourdough at 40% level obtained 27.1% higher sourness perception than 20% and 70% sourdough obtained 23% higher sourness score in comparison to 20% level (Appendix Table 8). Kefir at 40% level in the presence of 0.4%

sodium chloride affected ($P<0.05$) sourness perception when three levels of sourdough (20, 40 and 70%) were compared among themselves with average means of 5.9 (Like slightly), 5.3 (Neither like nor dislike) and 6.3 (Like slightly), respectively. In this combination, 70% sourdough gave 18.9% higher sourness perception than 40% sourdough. Significantly different ($P<0.05$) sourness was perceived with overall means of 5.4, 6.1 and 5.2 in the presence of 60% kefir, 0.1% sodium chloride for three levels of sourdough; 20, 40 and 70%, respectively (Appendix Table 8). Sourdough at 70% level scored 14.7% lower sourness score than 40% sourdough. Similarly, three levels of sourdough were compared for 60% kefir and 0.4% sodium chloride level which gave significantly different ($P<0.05$) perception of sourness with overall means of 4.9 (Neither like nor dislike), 5.9 (Like slightly) and 6.6 (Like slightly) for 20, 40 and 70% sourdough, respectively (Appendix Table 8). Score of sourness at 40% sourdough was 20.4% higher and 70% sourdough was 35% higher than 20% sourdough containing treatment. Significant increase in sourness perception score was observed at 40 and 70% in comparison to 20% sourdough in half of the comparisons.

4.2.3.3 Effect of kefir

The effect of kefir levels was compared at given levels of sourdough and sodium chloride (Appendix Table 9). Effects of kefir were not significant on sourness perception of sourdough bread in most of combination treatments except for one treatment comparison of 20% sourdough and 0.4% sodium chloride. In this comparison, a decrease of sourness perception by 17% was found at 60% kefir in comparison to 40% kefir. Average mean sourness score of 5.9 (Like slightly) and 4.9 (Neither like nor dislike) was obtained at 40 and 60% kefir, respectively. Overall, the results indicated that two levels of kefir (40 and 60%) at treatment combination tested having three levels of sourdough (20, 40 and 70%) and NaCl (0.1 and 0.4%) had no effect on sourness perception of sourdough bread. The result signified that when kefir is used in the range of 40 to 60%, consumer could not distinguish difference in sourness perception.

4.2.4 Pasteboardiness

4.2.4.1 Effect of NaCl

This parameter determines the perception of a dry mouth sensation and an increase in the score means the bread was liked more and less dry mouth sensation was detected. Treatment containing sourdough at 20% and kefir 40% gave significantly different ($P<0.05$) pasteboardy perception in the presence of 0.1 and 0.4% sodium chloride with average values of 5.1 and 6.2, respectively (Appendix Table 10). Sodium chloride at 0.4% gave 21.6% higher pasteboardy perception score than 0.1% sodium chloride. Treatment containing sourdough 40% did not affect pasteboardy perception, in the presence of 40 and 60% kefir when sodium chloride was compared among two levels (0.1 and 0.4%). Sourdough at 70% when 60% level of kefir was present, NaCl significantly affected ($P<0.05$) the pasteboardiness of bread with average score of 5.4 (Neither like nor dislike) and 6.6 (Like moderately) for 0.1 and 0.2% sodium chloride, respectively. NaCl at 0.4% in this combination obtained 22% higher pasteboardy score than 0.1% NaCl (Appendix Table 10). Effect of sodium chloride only detected at the higher and lower level end of kefir and sourdough in the treatment design while in intermediate levels, the effect of NaCl in pasteboardy perception was not significant.

4.2.4.2 Effect of sourdough

Another comparison was done to study the effect of sourdough on pasteboardy of the bread (Appendix Table 11). Sourdough among three levels (20, 40 and 70%) did not affect significantly the pasteboardy perception in the presence of 40 and 60% kefir and two levels of sodium chloride (0.1 and 0.4%). Although, all the treatment combinations were liked by the consumers as the pasteboardy scores were in the range of 5.1 to 6.6, no significant effect of sourdough was obtained in the study. The result suggested that, bread can be prepared with

sourdough (20, 40, and 70%) and combination with kefir (40, 60%) and NaCl (0.1, 0.4%) without affecting the pasteboardy perception.

4.2.4.3 Effect of kefir

Effect of two levels of kefir (40 and 60%) at given levels of sourdough and sodium chloride was studied (Appendix Table 12). None of the treatment combinations in the presence of sourdough (20, 40 and 70%), NaCl (0.1 and 0.4%) and kefir (40 and 60%) significantly affected the pasteboardy perception of the bread. The pasteboardy scores were in the range of 5.1 (Neither like nor dislike) to 6.6 (Like moderately). The result suggested that when kefir is used in the range of 40 to 60%, consumer could not distinguish adverse effect on pasteboardy perception of the white bread.

4.2.5 Aroma

4.2.5.1 Effect of NaCl

The bread samples were presented in zip-lock bags and the panelists were asked to score the aroma. The mean values of the results are presented in Appendix Table 13. The NaCl levels (0.1 and 0.4%) at the treatment combination with sourdough (20, 40 and 70%) and kefir (40 and 60%) tested had no effect on aroma perception of bread. The score of aroma ranged from 5 (Neither like nor dislike) to 6.9 (Like moderately). The result indicated that when NaCl was used in any proportion between 0.1 and 0.4%, there is no adverse effect in terms of aroma and NaCl can be reduced to 0.1% without any effect on aroma of sourdough bread.

4.2.5.2 Effect of sourdough

Sourdough was compared among three levels (20, 40 and 70%) for its effect on the aroma perception of bread (Appendix Table 14). There was no significantly different aroma perception among three levels of sourdough (20, 40 and 70%) in the presence of 40% kefir and 0.1%

sourdough. In the presence of 40% kefir and 0.4% sodium chloride, three levels of sourdough affected significantly ($P < 0.0001$) the aroma perception with average score of 5.1 (Neither like nor dislike), 5 (Neither like nor dislike) and 6.9 (Moderately like) for 20, 40 and 70% sourdough, respectively (Appendix Table 14). In this combination, aroma scores between 20% and 70% sourdough and 40% and 70% sourdough were significantly different. Sourdough at 70% level scored 35.3% higher aroma perception than 20% and 38% higher aroma score than 40% sourdough treatment when kefir was present at 40% level and NaCl at 0.4% level. The effect of sourdough in aroma perception was significantly decreased when sourdough increased from 40% to 70% by 15.4% in the presence of 60% kefir and 0.1% sodium chloride. The aroma perception scores were 6.3, 6.5 and 5.5 for 20, 40 and 70% sourdough, respectively. At 0.4% sodium chloride in the presence of 60% kefir, no significant effect on aroma perception was observed among three levels of sourdough.

4.2.5.3 Effect of kefir

Effect of different levels of kefir (40 and 60%) on aroma scores was compared with sourdough and sodium chloride (Appendix Table 15). Sourdough at 20, 40 and 70% and NaCl at 0.1 and 0.4% had no effect on aroma scores except for one treatment comparison; sourdough at 40%, 0.4% NaCl. In this comparison, 60% kefir scored 22% higher aroma perception score than 40% kefir with an average score of 5.0 (Neither like nor dislike) and 6.1 (Like slightly) for 40 and 60% kefir, respectively. Result suggested that kefir can be used in the range of 40 to 60% in the presence of sourdough and NaCl without any effect on aroma perception of bread.

4.2.6 Bitterness

4.2.6.1 Effect of NaCl

This parameter determines the likeliness of perception bitterness of bread and increase in the score means bitterness was liked more or no bitterness was detected in the bread. Two levels

of sodium chloride (0.1 and 0.4%) were studied with given levels of sourdough and kefir (Appendix Table 16). Kefir level at 40% in the presence of 20% sourdough, NaCl significantly affected ($P<0.0001$) bitterness perception. The overall mean of 3.9 (Dislike slightly) was recorded in the presence of 0.1% sodium chloride while average of 6.1 (Like slightly) was obtained with 0.4% sodium chloride. NaCl at 0.4% resulted in 56% higher likeliness of bitterness perception than that of 0.1% NaCl at 40% kefir and 20% sourdough. For the treatment containing kefir at 40% level in the presence of 40% sourdough, sodium chloride among two levels (0.1 and 0.4%) did not affect likeliness of bitterness perception ($P>0.05$). At 40% kefir level, 70% sourdough gave significantly different ($P<0.05$) bitterness perception with 5.8 (Like slightly) and 6.7 (Like moderately) overall means for 0.1 and 0.4% sodium chloride, respectively. Breads were liked by 15.5% more with 0.4% NaCl than 0.1%. Kefir at 60% level in the presence of 20 and 40% sourdough resulted in significantly different bitterness perception score for two levels of sodium chloride (Appendix Table 16). Overall means of 5.8 (Like slightly) and 4.6 (Neither like nor dislike) was obtained at 0.1 and 0.4% sodium chloride, respectively. Breads were less liked by 21% and 30.5% at 0.4% NaCl in comparison to 0.1% NaCl in the presence of 20 and 40% sourdough, respectively when kefir was present at 60% level. At 60% kefir with 70% sourdough, sodium chloride did not affect the likeliness of bitterness perception. The effect of sodium chloride on likeliness of bitterness was not similar as 50% of significant result showed positive effect while other 50% showed negative effect.

4.2.6.2 Effect of sourdough

Sourdough among three levels (20, 40 and 70%) in the presence of 0.1% sodium chloride and 40% kefir resulted in significantly different bitterness perception with overall means of 3.9 (Dislike slightly), 5.6 (Like slightly) and 5.8 (Like slightly), respectively (Appendix Table 17). Mean score of 70% sourdough was 48.7% higher than score for 20% sourdough and 40% sourdough obtained 43.6% higher score in comparison to 20% sourdough. This means that the

breads were liked about 48.7% and 43.6% more when bread had 70 and 40% sourdough, respectively in comparison to 20% sourdough. In the presence of 0.4% sodium chloride with 40% kefir, three levels of sourdough resulted in significantly different ($P<0.05$) bitterness perception with high score for 20% and 70% sourdough. Mean scores of 6.1, 5.8 and 6.7 were recorded for 20, 40 and 70% sourdough, respectively. Mean for 70% sourdough was 15.5% higher than 40% sourdough. Kefir at 60% level in the presence of 0.4% sodium chloride, affected significantly ($P<0.05$) the bitterness perception at three levels of sourdough; 20, 40 and 70% with overall means of 4.6 (Neither like nor dislike), 4.1 (Dislike slightly) and 5.6 (Like slightly), respectively (Appendix Table 17). The mean score for 70% sourdough was 36.6% higher than mean score for 40% sourdough and 21.7% higher than 20% sourdough score. However, 0.1% sodium chloride at same 60% level of kefir did not affect significantly the different bitterness perception at three levels of sourdough.

4.2.6.3 Effect of kefir

Sourdough level at 20% between two levels of kefir (40, 60%) in the presence of 0.1% sodium chloride resulted in significantly different ($P<0.0001$) likeliness of bitterness perception and average score of 3.9 (Dislike slightly) for 40% kefir and 5.8 (Like slightly) for 60% kefir were obtained (Appendix Table 18). Bread with 60% kefir was 48.7% more liked than 40% kefir treatment. Sodium chloride at 0.4% for the same level of sourdough level gave a significantly different ($P<0.05$) bitterness perception and average score of 6.1 (Like slightly) and 4.6 (Dislike slightly) were recorded for 40 and 60% kefir, respectively. The mean score of 60% kefir was 24.6% lower than 40% kefir. That means breads with 60% kefir were less liked than 40% kefir bread. Kefir between two levels (40, 60%) in the presence of 40% sourdough and 0.1% sodium chloride resulted in a similar likeliness of bitterness perception (Appendix Table 18). At 0.4% sodium chloride with same 40% sourdough level, two levels of kefir significantly affect the bitterness perception of bread. Average score for 60% kefir was 4.1 (Dislike slightly) which were

29.3% lower than score for 40% kefir (5.8-Like slightly). With higher sourdough level (70%) in the presence 0.4% sodium chloride, two levels of kefir; 40 and 60% gave a significantly different ($P<0.05$) bitterness perception with average score of 6.7 and 5.6 representing “Like moderately” and “Like slightly”, respectively. In this comparison, 60% kefir perceived 16.4% lower likeliness of bitterness perception than 40% kefir. At 0.1% sodium chloride, the effect of kefir was not significant when higher level (70%) sourdough was present.

4.2.7 Overall Palatability

4.2.7.1 Effect of NaCl

Effect of NaCl on overall palatability score was significantly different in half of the treatment combinations (Appendix Table 19). Sodium chloride among two levels (0.1 and 0.4%) with 40% kefir gave significantly different ($P<0.05$) palatability perception for 20% sourdough, with overall means of 4.6 (Neither like nor dislike) and 6.1 (Like slightly), respectively. The mean for 0.4% sodium chloride was 32.6% higher than mean for 0.1%. Kefir at 40% level in the presence of 40 and 70% sourdough, two levels of sodium chloride resulted in similar palatability perception representing “Neither like nor dislike” and “Like slightly” (Appendix Table 19). Sourdough at 40% and 60% kefir level, two level of sodium chloride gave significantly different ($P<0.05$) palatability perception. Mean score of 6.1 for 0.1% sodium chloride and 5.2 for 0.4% sodium chloride was recorded. The palatability score for 0.4% sodium chloride was 14.7% lower than mean for 0.1% sodium chloride. Sourdough at 70% in the presence of 60% kefir gave significantly different ($P<0.05$) palatability perception at two levels of sodium chloride. The mean values of 5.4 representing “Neither like nor dislike” and 6.6 representing “Like moderately” for 0.1 and 0.4% sodium chloride, respectively were recorded. NaCl at 0.4% obtained 22.2% higher palatability perception in comparison to 0.1% NaCl.

4.2.7.2 Effect of Sourdough

Effect of sourdough on overall palatability score was significant except for the one treatment combination group (60% kefir, 0.1% NaCl) (Appendix Table 20). Sodium chloride at 0.1% in the presence of 40% kefir resulted in significantly different ($P<0.05$) palatability among three levels of sourdough (20, 40 and 70%) with overall means of 4.6 (Neither like nor dislike), 5.3 (Neither like nor dislike) and 6 (Like slightly), respectively (Appendix Table 20). Mean score for 70% sourdough was 30.4% higher than mean of 20% sourdough. At 0.4% sodium chloride in the presence 40% kefir, three levels of sourdough gave significantly different palatability perception. Significantly different ($P<0.05$) palatability perception was recorded with mean values of 6.1, 5.6 and 6.5 for 20, 40 and 70% sourdough, respectively (Appendix Table 20). Mean of 70% sourdough was 16.1 % higher than mean score of 40% sourdough. At 0.4% sodium chloride and 60% kefir, sourdough among three levels (20, 40 and 70%) resulted in significantly different ($P<0.05$) palatability perception with overall means of 5.6 (Like slightly), 5.2 (Neither like nor dislike) and 6.6 (Like moderately), respectively. Mean value for 70% SD was 18% higher than mean value of 20% SD and 27% higher than mean value of 40% sourdough.

4.2.7.3 Effect of kefir

The effect of kefir on overall palatability score was not significant except for one treatment combination group (20% sourdough, 0.1% NaCl) (Appendix Table 21). Sourdough levels at 20% also resulted in significantly different palatability for 0.1% sodium chloride in the presence of 40 and 60% kefir with average score of 4.6 (Neither like nor dislike) and 5.9 (Like slightly) respectively (Appendix Table 21). Mean score of 60% kefir was 28.3% higher than 40% kefir. In the other treatment combination, two level of kefir tested did not have effect on overall palatability of the bread although all the treatment combinations were liked by consumer as the palatability scores were ranged from 5.2 (Neither like nor dislike) to 6.6 (Like moderately) in

these combinations. The result indicated that the level of kefir can be used in any level between 40 to 60% without any adverse effect on overall palatability of the bread.

4.2.8 Graphical comparison of sensory analysis

The purpose of this comparison was to visually find trends and summarize the sensory attributes of white bread containing kefir and sourdough by radar graphs.

4.2.8.1 Effect of NaCl

Two levels of NaCl (0.1 and 0.4%) were compared for sensory scores in the presence of sourdough (20, 40 and 70%) and kefir (40 and 60%). The effect of NaCl on all sensory attributes from Table I was described in Figure 3. Radar graphical presentation (3a) suggested trend of low level of kefir (40%), sourdough (20%) and NaCl (0.1%) with lower scores for all the attributes and curve shrink at the center in comparison to other treatments as described earlier. For the same treatment bitterness trends projected towards the center with low scores and aroma trending to higher score longer curve away from center. Other treatments gave evenly distributed means in the figure except projected graph of bitterness towards center with 60% kefir, 40% sourdough and 0.4% NaCl (Fig. 3b) but the score of other parameters for same treatment was evenly distributed in the radar.

Table I was divided into 2 Figures (3a and 3b) for better visual observation. Figure 3a showed that 40% kefir, 70% sourdough and 0.4% NaCl was evenly distributed and had distinctly higher scores for all parameter than other treatment. Similarly, Figure 3b showed than 60% kefir, 70% sourdough and 0.4% NaCl scored significantly higher sensory score than other treatments in Figure 3b. This confirms the result discussed in sections 4.2.1.1, 4.2.2.1, 4.2.3.1, 4.2.4.1, 4.2.5.1, 4.2.6.1 and 4.2.7.1 and summarized Table I that higher NaCl at higher levels of kefir and sourdough trend to higher perception of sensory attributes.

Table I. Summary of effect of NaCl (0.1 and 0.4%) in sensory scores of white bread at different levels of kefir (40 and 60%) and sourdough (20, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Saltiness	Sweetness	Sourness	Pasteboardy	Aroma	Bitterness	Overall Palatability
40	20	0.1	4.9±0.34 b	5±0.22 b	4.8 ±0.26 b	5.1±0.33 b	5.7±0.39 a	3.9±0.37 b	4.6±0.21 b
40	20	0.4	5.9±0.41 a	6±0.36 a	5.9±0.36 a	6.2±0.31 a	5.1±0.42 a	6.1±0.36 a	6.1±0.34 a
40	40	0.1	5.9±0.36 a	5.6±0.34 b	6.1±0.34 a	5.4±0.44 a	5.6±0.41 a	5.6±0.26 a	5.3±0.34 a
40	40	0.4	6.4±0.17 a	6.5±0.22 a	5.3±0.25 a	5.9±0.34 a	5±0.44 a	5.8±0.26 a	5.6±0.26 a
40	70	0.1	6.2±0.34 a	6.2±0.36 a	5.9±0.38 a	5.2±0.33 a	6.1±0.36 a	5.8±0.33 b	6±0.32 a
40	70	0.4	6.7±0.26 a	6.7±0.29 a	6.3±0.31 a	6±0.28 a	6.9±0.22 a	6.7±0.28 a	6.5±0.26 a
60	20	0.1	5.4±0.35 a	5.9±0.31 a	5.4±0.27 a	5.9±0.39 a	6.3±0.35 a	5.8±0.33 a	5.9±0.34 a
60	20	0.4	6±0.35 a	6.2±0.35 a	4.9±0.37 a	5.8±0.31 a	6.1±0.38 a	4.6±0.39 b	5.6±0.36 a
60	40	0.1	6.2±0.35 a	6.2±0.38 a	6.1±0.42 a	6±0.41 a	6.5±0.36 a	5.9±0.38 a	6.1±0.38 a
60	40	0.4	6±0.45 a	5.5±0.39 a	5.9±0.41 a	6±0.34 a	6.5±0.32 a	4.1±0.39 b	5.2±0.33 b
60	70	0.1	5.3±0.39 b	5.1±0.35 b	5.2±0.38 b	5.4±0.31 b	5.5±0.36 a	5.4±0.39 a	5.4±0.33 b
60	70	0.4	6.8±0.28 a	6.7±0.24 a	6.6±0.29 a	6.6±0.3 a	6.4±0.27 a	5.6±0.31 a	6.6±0.31 a

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are significantly different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

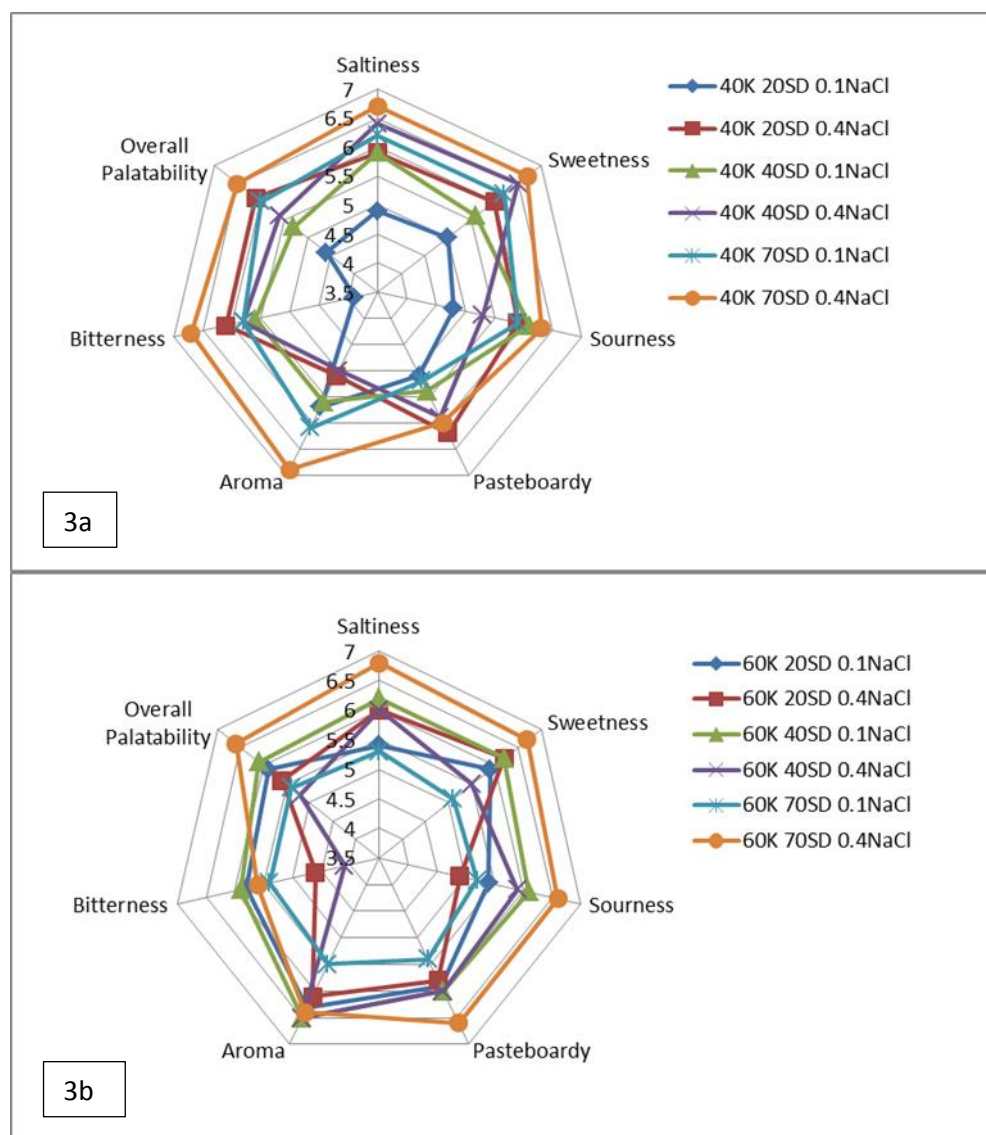


Figure3. Radar graphical representation of effect of NaCl in sensory attributes of white bread.

3a. Effect of NaCl (0.1 and 0.4%) when kefir was present in 40% and sourdough at 20, 40, 70%.

3b. Effect of NaCl (0.1 and 0.4%) when kefir was present in 60% and sourdough at 20, 40, 70%.

4.2.8.2 Effect of sourdough

Three levels of sourdough (20, 40 and 70%) were compared for sensory scores in the presence of kefir (40 and 60%) and NaCl (0.1 and 0.4%). An effect of sourdough on all sensory attributes from Table II was presented in radar (Figure 4).

Table II. Summary of effect of sourdough (20, 40 and 70%) in sensory scores of white bread at different levels of kefir (40 and 60%) and NaCl (0.1 and 0.4%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Saltiness	Sweetness	Sourness	Pasteboardy	Aroma	Bitterness	Overall Palatability
40	0.1	20	4.9±0.34 b	5±0.22 b	4.8±0.26 b	5.1±0.33 a	5.7±0.39 a	3.9±0.37 b	4.6±0.21 b
40	0.1	40	5.9±0.36 a	5.6±0.34 ab	6.1±0.34 a	5.4±0.44 a	5.6±0.41 a	5.6±0.26 a	5.3±0.34 ab
40	0.1	70	6.2±0.34 a	6.2±0.36 a	5.9±0.38 a	5.2±0.33 a	6.1±0.36 a	5.8±0.33 a	6±0.32 a
40	0.4	20	5.9±0.41 a	6±0.36 a	5.9±0.36 ab	6.2±0.31 a	5.1±0.42 b	6.1±0.36 ab	6.1±0.34 ab
40	0.4	40	6.4±0.17 a	6.5±0.22 a	5.3±0.25 b	5.9±0.34 a	5±0.44 b	5.8±0.26 b	5.6±0.26 b
40	0.4	70	6.7±0.26 a	6.7±0.29 a	6.3±0.31 a	6±0.28 a	6.9±0.22 a	6.7±0.28 a	6.5±0.26 a
60	0.1	20	5.4±0.35 ab	5.9±0.31 ab	5.4±0.27 ab	5.9±0.39 a	6.3±0.35 ab	5.8±0.33 a	5.9±0.34 a
60	0.1	40	6.2±0.35 a	6.2±0.38 a	6.1±0.42 a	6±0.41 a	6.5±0.36 a	5.9±0.38 a	6.1±0.38 a
60	0.1	70	5.3±0.39 b	5.1±0.35 b	5.2±0.38 b	5.4±0.30 a	5.5±0.36 b	5.4±0.39 a	5.4±0.33 a
60	0.4	20	6±0.35 a	6.2±0.35 ab	4.9±0.37 b	5.8±0.31 a	6.1±0.38 a	4.6±0.39 b	5.6±0.36 b
60	0.4	40	6±0.45 a	5.5±0.39 b	5.9±0.41 a	6±0.34 a	6.5±0.32 a	4.1±0.39 b	5.2±0.33 b
60	0.4	70	6.8±0.28 a	6.7±0.24 a	6.6±0.29 a	6.6±0.30 a	6.4±0.27 a	5.6±0.31 a	6.6±0.31 a

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table II was divided in 2 Graphs 4a and 4b. At lower level (40%) of kefir, 0.1% NaCl and 20% sourdough, scores for all parameter concentrated at the center signifying lowest scores in comparison to other treatments (Fig. 4a). However, higher level of sourdough (70%) and NaCl (0.4%) gave evenly distributed means in Figure 4a and 4b at 40 and 60% kefir. This shows a trend of increasing consumer acceptability with increase in kefir, sourdough and NaCl and confirmed the results described in sections; 4.2.1.2, 4.2.2.2, 4.2.3.2, 4.2.4.2, 4.2.5.2, 4.2.6.2 and 4.2.7.2.

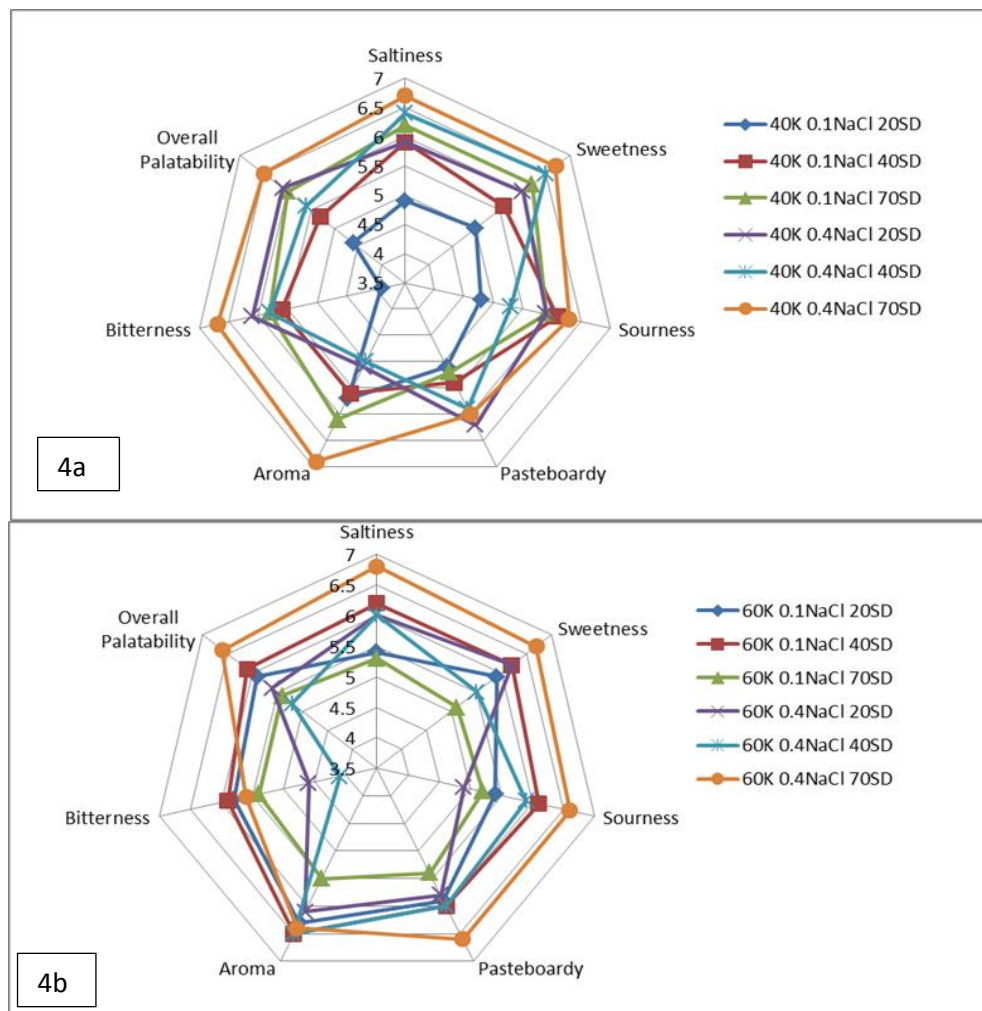


Figure 4. Radar graphical representation of effect of sourdough in sensory attributes of white bread. 4a. Effect of sourdough (20, 40 and 70%) when kefir was present in 40% and NaCl at 0.1, 0.4%. 4b. Effect of sourdough (20, 40 and 70%) when kefir was present in 60% and NaCl at 0.1, 0.4%.

4.2.8.3 Effect of Kefir

Two levels of kefir (40 and 60%) were compared for sensory scores in the presence of sourdough (20, 40 and 70%) and NaCl (0.1 and 0.4%). Effect of kefir on all sensory attributes from Table III is represented in Figure 5. Effect of kefir on sensory attributes of the bread is presented in radar graph (Fig. 5). Treatment containing 20% sourdough, 0.1% NaCl and 40% kefir has means projected towards center indicating trends to lower means than other treatments (Fig. 5a). In figure 5b, 40% SD, 0.4% NaCl and 60% kefir has bitterness score projected towards center and other parameters are low compare to other treatments but evenly distributed in the graph. Again, kefir at 60% level, the means was evenly distributed indicating higher acceptance of bread at higher level of kefir. This confirmed the result described in sections; 4.2.1.3, 4.2.2.3, 4.2.3.3, 4.2.4.3, 4.2.5.3, 4.2.6.3 and 4.2.7.3.

Table III. Summary of effect of kefir (40 and 60%) in sensory scores of white bread at different levels of sourdough (20, 40 and 70%) and sodium chloride (0.1 and 0.4%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Saltiness	Sweetness	Sourness	Pasteboardy	Aroma	Bitterness	Overall Palatability
20	0.1	40	4.9±0.34 a	5±0.22 b	4.8±0.26 a	5.1±0.33 a	5.7±0.39 a	3.9±0.37 b	4.6±0.21 a
20	0.1	60	5.4±0.35 a	5.9±0.31 a	5.4±0.27 a	5.9±0.39 a	6.3±0.35 a	5.8±0.33 a	5.9±0.34 b
20	0.4	40	5.9±0.41 a	6±0.36 a	5.9±0.36 a	6.2±0.31 a	5.1±0.42 a	6.1±0.36 a	6.1±0.34 a
20	0.4	60	6±0.35 a	6.2±0.35 a	4.9±0.37 b	5.8±0.31 a	6.1±0.38 a	4.6±0.39 b	5.6±0.36 a
40	0.1	40	5.9±0.36 a	5.6±0.34 a	6.1±0.34 a	5.4±0.44 a	5.6±0.41 a	5.6±0.26 a	5.3±0.34 a
40	0.1	60	6.2±0.35 a	6.2±0.38 a	6.1±0.42 a	6±0.41 a	6.5±0.36 a	5.9±0.38 a	6.1±0.38 a
40	0.4	40	6.4±0.17 a	6.5±0.22 a	5.3±0.25 a	5.9±0.34 a	5±0.44 b	5.8±0.26 a	5.6±0.26 a
40	0.4	60	6±0.45 a	5.5±0.39 b	5.9±0.41 a	6±0.34 a	6.1±0.32 a	4.1±0.39 b	5.2±0.33 a
70	0.1	40	6.2±0.34 a	6.2±0.36 a	5.9±0.38 a	5.2±0.33 a	6.1±0.36 a	5.8±0.33 a	6±0.32 a
70	0.1	60	5.3±0.39 a	5.1±0.35 b	5.2±0.38 a	5.4±0.30 a	5.5±0.36 a	5.4±0.39 a	5.4±0.33 a
70	0.4	40	6.7±0.26 a	6.7±0.29 a	6.3±0.31 a	6±0.28 a	6.9±0.22 a	6.7±0.28 a	6.5±0.26 a
70	0.4	60	6.8±0.28 a	6.7±0.24 a	6.6±0.29 a	6.6±0.30 a	6.4±0.27 a	5.6±0.31 b	6.6±0.31 a

^aMean (n=22) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are significantly different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

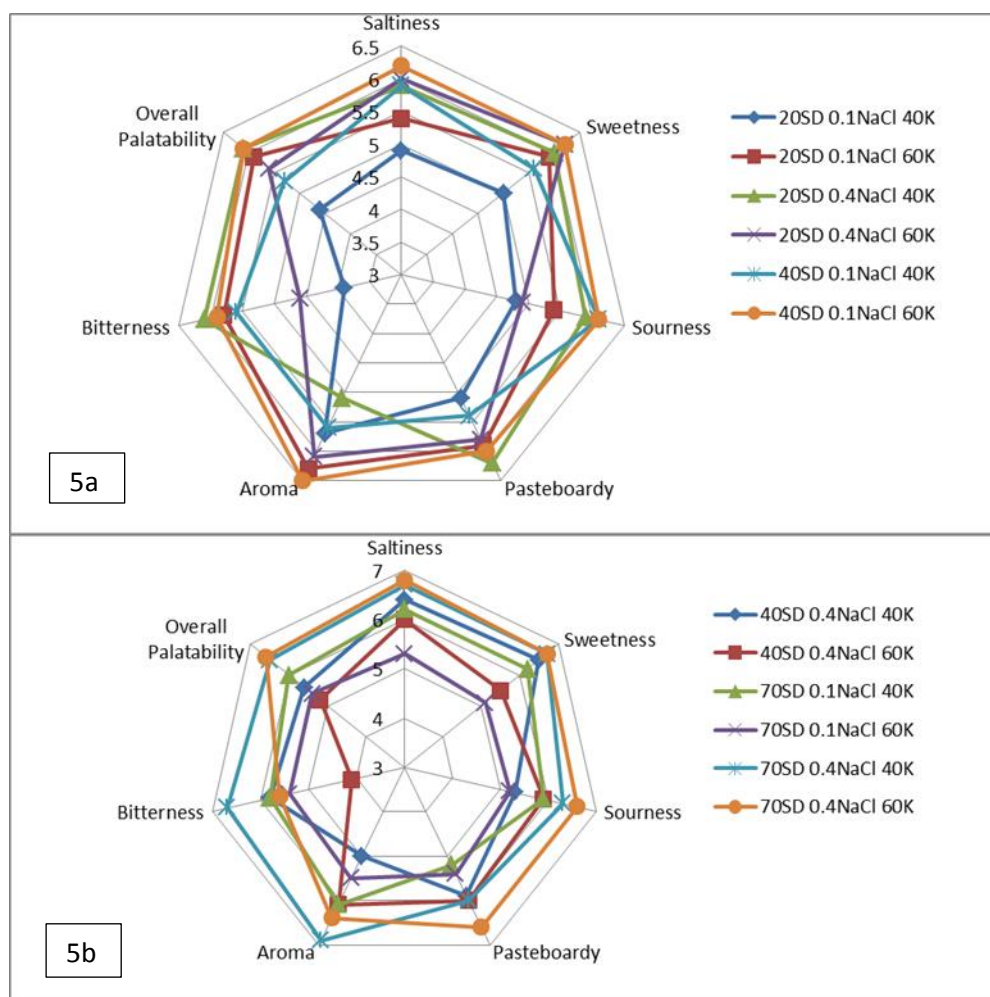


Figure 5. Radar graphical representation of effect of kefir in sensory attributes of white bread.
 5a. Effect of kefir (40 and 60%) when sourdough was present in 20, 40% and NaCl at 0.1, 0.4%.
 5b. Effect of kefir (40 and 60%) when sourdough was present in 40, 70% and NaCl at 0.1, 0.4%.

4.3 Second sensory analysis

Two levels of salt 0.8% and 1.2%, two levels of sourdough 40% and 70% and two combinations of kefir 30% and 50% were selected for the second sensory analysis of breads. These treatment combinations were based on statistical analyses and conclusions from the preliminary sensory analysis. In second sensory analysis, there were 10 treatments combinations and the breads were analyzed by 64 untrained panelists.

4.3.1 Saltiness

4.3.1.1 Effect of NaCl

Sodium chloride among two levels (0.8 and 1.2%) in the presence of 0% sourdough and kefir resulted in significantly different saltiness perceptions with higher score for high NaCl level of 1.2% (Appendix Table 22). Panelist scored significantly higher saltiness score of 5.6 representing “Like slightly” at 1.2% NaCl in comparison to 0.8% NaCl which was 5.2 (Neither like nor dislike). Saltiness score at 1.2% NaCl was 8% higher than 0.8% NaCl. In the presence of 30% kefir and 40% sourdough, significant effect of two levels of NaCl was observed with mean score of 5.9 and 6.2 for 0.8 and 1.2% respectively. Mean score for 1.2% NaCl was 8.5% higher than 0.8% NaCl. Sodium chloride gave significantly similar saltiness perception at 30% kefir and 70% sourdough. In the presence of 50% kefir and 40% sourdough, 1.2% NaCl gave significantly higher perception of salt with overall mean of 6.4 representing “Like slightly” while 0.8% NaCl scored overall mean of 6.1 representing “Like slightly”. NaCl at 1.2% scored 5.1% higher saltiness perception than 0.8% NaCl in this comparison. The effect of NaCl in saltiness score followed a linear pattern, higher NaCl gave higher saltiness perception.

4.3.1.2 Effect of sourdough

At all levels of kefir (30 and 50%), saltiness perception was not significantly different among two levels of sourdough (40 and 70%) in the presence of 0.8 and 1.2% of NaCl (Appendix Table 23). The score for saltiness was relatively higher in the range of 5.9 (Like slightly) to 6.4 (Like slightly) in these treatment combinations but the level of sourdough we tested did not affect significantly on perception of saltiness of white bread. The result indicated that sourdough can be used in any amount between 40 to 70% without any effect on saltiness perception of white bread.

4.3.1.3 Effect of kefir

Kefir among two levels (30 and 50%) with 0.8 and 1.2% sodium chloride did not affect the saltiness perception significantly when present with 40 and 70% of sourdough (Appendix Table 24). The score of saltiness was in the range of 5.8 to 6.4 representing “Like slightly” response by the consumer. Similar perception of saltiness was indicated that kefir can be used at any level between 30 to 50% without adverse effect on saltiness perception of the bread.

4.3.2 Sweetness

4.3.2.1 Effect of NaCl

Sodium chloride among two levels significantly affects sweetness perception in 40% of the treatment combination group (Appendix Table 25). Sodium chloride among two levels (0.8 and 1.2%) in the presence of 0% kefir and sourdough resulted in significantly different sweetness perceptions of sourdough bread with a higher score of mean 5.6 (Liked slightly) at higher sodium chloride level than mean of 5.1 (Neither like, nor dislike) for lower NaCl. 1.2% sodium chloride scored 9.8% higher score than 0.8% level (Appendix Table 25). Similarly, 1.2% sodium chloride showed significantly higher sweetness perception when present with 30% kefir and 70% sourdough than 0.8% NaCl with mean sweetness score of 6.1 (Like slightly) and 6.5 (Like moderately) for 0.8 and 1.2% NaCl respectively. In this comparison, 1.2% NaCl scored 6.6% higher sweetness perception than 0.8% NaCl. The effect of NaCl on sweetness perception follows the linear pattern; increase in sodium chloride increases the sweetness perception.

4.3.2.2 Effect of sourdough

Sourdough among two levels (40 and 70%) with 30% kefir and 0.8% sodium chloride did not affect the sweetness perception of sourdough bread significantly in any of the treatment combination group. The sweetness scores obtained were relatively higher and was in the range of

6.1 (Like slightly) to 6.6 (Like moderately). The result indicated that sourdough can be used in any level between 40 to 70% without any effect in sweetness perception of white bread.

4.3.2.3 Effect of kefir

Kefir among two levels (30 and 50%) in the presence of 40 and 70% sourdough and 0.8 and 1.2% sodium chloride did not affect significantly the sweetness perception of sourdough bread in any of the treatment combination group (Appendix Table 27). The average scores of sweetness were in the range of 6.1 (Like slightly) to 6.6 (Like moderately). The results indicated that kefir can be used in any level between 30 to 50% without adverse effect on sweetness of the white bread.

4.3.3 Sourness

4.3.3.1 Effect of NaCl

Overall effect of NaCl on sourness score was not significant except for the one treatment combination group (0% kefir and 0% SD) (Appendix Table 28). In other four treatments combination there was no effect of NaCl in sourness perception of bread. Sodium chloride among two levels (0.8 and 1.2%) in the presence of 0% kefir and 0% sourdough resulted in significantly different sourness perceptions. Sodium chloride at 0.8% and 1.2% gave significantly different sourness perceptions with average score of 5 and 5.5 respectively, representing “Neither like nor Dislike” and “Like slightly”, respectively (Appendix Table 28). The sourness score for 1.2% sodium chloride was 10% higher than score of 0.8% NaCl. In rest of the treatment comparison, mean sourness scores were in the range of 5.9 (Like slightly) to 6.2 (Like slightly). The result indicated that when NaCl is used in the range of 0.8 and 1.2% there is no adverse effect on sourness perception at given levels of kefir (30, 50%) and sourdough (40, 70%).

4.3.3.2 Effect of sourdough

At two levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%), sourness perception was not significantly different among 40 and 70% sourdough. The average sourness scores were obtained in the range of 5.9 representing “Like slightly” to 6.2 representing “Like slightly” (Appendix Table 29). The result indicated that sourdough can be used at any level between 40 to 70% without any effect on sourness perception at given level of kefir (30, 50%) and NaCl (0.8, 1.2%).

4.3.3.3 Effect of kefir

The effect of kefir levels on sourness perception of breads was compared at given levels of sourdough and sodium chloride (Appendix Table 30). Kefir among two levels (30 and 50%) with 40 and 70% sourdough and 0.8 and 1.2% sodium chloride did not affect the sourness perception significantly. The overall means were obtained in the range of 5.9 (Like slightly) and 6.2 (Like slightly) (Appendix Table 30). The result indicated that kefir can be used in any amount between 30 to 50% in the presence of sourdough (40 or 70%) and NaCl (0.8 or 1.2%) without any adverse effect on sourness perception of the white bread.

4.3.4 Pasteboardiness

4.3.4.1 Effect of NaCl

Effect of NaCl on pasteboardy perception of breads was compared at given levels of kefir and sourdough (Appendix Table 31). Pasteboardy is defined as a dry mouth feel which measure the dry mouth after taste of the sourdough. 40% of the treatment combinations were significantly affected by the levels of NaCl on pasteboardy perception. Sodium chloride among two levels (0.8 and 1.2%) in the presence of 0% kefir and 0% sourdough significantly affect the pasteboardy perception. Sodium chloride at 0.8 and 1.2% gave significantly different pasteboardy perception

with the average of 5.3 and 5.8 respectively representing “Neither like nor dislike” and “Like slightly”, respectively (Appendix Table 31). Sodium chloride at 1.2% scored 9.4% higher pasteboard score than 0.8% sodium chloride treatment. In the presence of 30% kefir and 40% sourdough, two levels of sodium chloride significantly affect pasteboard perception with 5.8 and 6.2 means for 0.8 and 1.2% sodium chloride. Mean for 1.2% sodium chloride was 7% higher than mean for 0.8%.

4.3.4.2 Effect of sourdough

Effect of sourdough on pasteboard perception of bread was compared at given levels of kefir and NaCl (Appendix Table 32). The effect of two levels of sourdough (40 and 70%) on pasteboard scores was not significant in all of the treatment combinations. The overall means in these comparisons were in the range of 5.8 (Like slightly) to 6.3 (Like slightly) (Appendix Table 32). The result indicated that sourdough can be used at any level between 40 to 70% without adverse effect on pasteboard perception of bread at given levels of kefir (30 and 50%) and NaCl (0.8 and 1.2%).

4.3.4.3 Effect of kefir

For the most part, effect of kefir on pasteboard score was not significant except for one treatment combination group (70% sourdough, 0.8% NaCl) (Appendix Table 33). Sourdough at 70% level and 0.8 % sodium chloride gave a significantly higher ($P < 0.05$) pasteboard perception at 50% kefir with mean of 6.3 (Like slightly) in comparison to 30% kefir having 5.9 (Like slightly) mean. Kefir at 50% level obtained 7.0% higher mean value than 30% kefir.

4.3.5 Aroma

4.3.5.1 Effect of NaCl

The effect of NaCl on aroma perception of bread was compared at given levels of kefir and sourdough (Appendix Table 34). Three levels of kefir (0, 30 and 50%), sourdough (0, 40 and 70%) among two levels of NaCl (0.8 and 1.2%) did not affect significantly on aroma perception of the bread. The aroma scores for treatment combinations were obtained in the range of 5.1 (Neither like nor dislike) to 6.4 (Like slightly) (Appendix Table 34). The result indicated that the NaCl can be used at any level between 0.8 to 1.2% without any effect on aroma perception of the bread in the presence of 0, 30 and 50% kefir and sourdough (0, 40 and 70%).

4.3.5.2 Effect of sourdough

The effect of sourdough on aroma perception of bread was studied at given levels of kefir and NaCl (Appendix Table 35). Two level of sourdough (40 and 70%) in the presence of kefir (30 and 50%) and NaCl (0.8 and 1.2%) did not affect significantly on aroma score of white bread in all of the treatment combinations. The aroma scores for the treatment combinations were in the range of 6.1 (Like slightly) to 6.4 (Like slightly). The result indicated that the sourdough can be used in any level between 40 to 70% without any effect on aroma perception of the white bread.

4.3.5.3 Effect of kefir

The effect of kefir on aroma perception of bread was studied at given levels of sourdough and NaCl (Appendix Table 36). At 40 and 70% sourdough, 0.8 and 1.2% sodium chloride, kefir between two levels (30, 50%) did not make a significant difference in aroma in all of the treatment combinations. The overall means for this comparisons were in the range of 6.1 (Like slightly) to 6.5 (Like moderately) (Appendix Table 36). The result indicated that kefir can be used

in any levels between 30 to 50% in the presence of sourdough (40 and 70%) and NaCl (0.8 and 1.2%) without any adverse effect on aroma perception of the white bread.

4.3.6 Bitterness

4.3.6.1 Effect of NaCl

The effect of NaCl on bitterness perception of bread was studied at given levels of kefir and sourdough (Appendix Table 37). The effect of NaCl (0.8, 1.2%) in the presence of kefir (0, 30 and 50%) and sourdough (0, 40 and 50%) on bitterness score was not significant on any of the treatment comparisons. The overall means of this comparison were in the range of 4.9 (Neither like nor dislike) to 6.3 (Like slightly) (Appendix Table 37). The result indicated that the amount of NaCl can be used at any level between 0.8 to 1.2% in the presence of kefir (0, 30 and 50%), sourdough (0, 40 and 70%) without adverse effect on bitterness of the white bread.

4.3.6.2 Effect of sourdough

The effect of sourdough on bitterness scores was compared at given levels of kefir and NaCl (Appendix Table 38). Two levels of sourdough (40, 70%) in the presence of kefir (30, 50%) and NaCl (0.8, 1.2%) did not affect significantly the bitterness perception of bread at all of the treatment combinations. The mean bitterness scores of 5.7 to 6.3 (Like slightly) were recorded in this treatment comparisons. The results indicated that sourdough can be used in any of the levels between 40 to 70% without adverse effect on bitterness perception of the bread in the presence of kefir (30, 50%) and NaCl (0.8, 1.2%).

4.3.6.3 Effect of kefir

The effect of two levels of kefir on bitterness perception was compared at the given level of sourdough and NaCl (Appendix Table 39). In the presence of 40, 70% sourdough and 0.8, 1.2% sodium chloride, kefir between two levels (30, 50%) did not affect significantly the

bitterness score of the white bread. The bitterness score in this comparisons were in the range of 5.7 to 6.3 (Like slightly). The result from these observations signified that kefir can be used in any levels between 30 to 50% without any effect on bitterness perception of white bread in the presence of sourdough (40, 70%) and NaCl (0.8, 1.2%).

4.3.7 Overall palatability

4.3.7.1 Effect of NaCl

The effect of two levels of NaCl (0.8 and 1.2%) in the presence of kefir and sourdough was significant in 60% of the treatment combinations group (Appendix Table 40). Kefir at 0% and sourdough at 0% level, sodium chloride between two levels affect significantly ($P < 0.05$) the overall palatability of sourdough bread. The overall mean of 4.9 (Dislike slightly) and 5.6 (Neither like nor dislike) were recorded for 0.8 and 1.2%, respectively (Appendix Table 40). The mean for 1.2% sodium chloride is 14.3% higher than 0.8% sodium chloride. At 30% kefir and 40% sourdough, two levels of sodium chloride (0.8 and 1.2%) affect significantly in overall palatability of bread with overall mean of 6.1 (Like slightly) and 6.5 (Like moderately) respectively. Sodium chloride at 1.2% gave 6.6% higher overall palatability score in comparison to 0.8% sodium chloride. In the presence of 50% kefir and 40% sourdough, sodium chloride among two levels gave significantly different overall palatability perception. Different palatability was perceived at 0.8 and 1.2% NaCl and overall means of 6.2 (Like slightly) and 6.6 (Like moderately) respectively were recorded. The palatability score at 1.2% NaCl was 6.5% higher than that of 0.8% NaCl. This concludes that with 1.2% sodium chloride level, palatability was much more accepted when compared with lower level (0.8%) of sodium chloride at different levels of sourdough and kefir.

4.3.7.2 Effect of sourdough

Two levels of sourdough were compared to study its effect on overall palatability (Appendix Table 41). The effect of sourdough on overall palatability score was not significant except for one treatment combination group (50% kefir, 1.2% NaCl). For 40 and 70% sourdough, significantly different palatability perception was obtained in the presence of 50% kefir and 1.2% sodium chloride. Significantly different palatability was observed with overall mean of 6.6 and 6.3 (Like slightly) for 40 and 70% sourdough, respectively. In this case, the mean for 70% sourdough was 5% lower than mean for 40% sourdough. In other treatment combinations, mean palatability were obtained in the range of 6.0 (Like slightly) to 6.5 (Like moderately).

4.3.7.3 Effect of kefir

Two levels of kefir were compared to study overall palatability of sourdough bread (Appendix Table 42). One out of four treatment combination groups was significantly affected by two levels of kefir (30, 50%). Sourdough at 70% results in significant different palatability perception in the presence of 0.8% sodium chloride while comparing two levels of kefir. With 30% kefir, overall mean of 6.0 (Like slightly) was recorded while with 50% kefir, overall mean of 6.4 (Like slightly) was recorded. Mean for 50% kefir is 6.7% higher than mean for 30% kefir. Other treatment combination groups were not significantly affected by kefir and overall palatability means for these combinations were in the range of 6.1 (Like slightly) to 6.6 (Like moderately). The take home message is that, kefir do not have significant effect on overall palatability of bread.

4.3.8 Summary and graphical comparison of sensory analysis

The purpose of this comparison was to visually find trends and summarize the sensory attributes of white bread from the second sensory analysis containing kefir and sourdough by radar graphs.

4.3.8.1 Effect of NaCl

Two levels of NaCl (0.8 and 1.2%) were compared in the presence of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%). The effect of NaCl on all sensory attributes from Table IV is described in Figure 6. Radar graphs on the effect of NaCl on sensory scores indicated that in the absence of fermented products and while comparing two levels of NaCl, the sensory scores showed a trend to lower values in comparison to the treatment with sourdough. The radar graph of 0% kefir and 0% sourdough shrined at the center on both treatments at 0.8% and 1.2% NaCl. The scores were lower than 5.5 for both treatments. However, when kefir and sourdough level increased, the radar graph showed a trend to be evenly distributed and scores were well above 5.5 in all treatments (Figure 6a). In another Graph (6b), it was observed that 50% kefir, 40% sourdough and 1.2% NaCl gave distinctly high sensory scores with lower score for bitterness.

Table IV. Summary of effect of NaCl (0.8 and 1.2%) in sensory scores of white bread at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Saltiness	Sweetness	Sourness	Pasteboardy	Aroma	Bitterness	Overall Palatability
0	0	0.8	5.2±0.13 b	5.1±0.14 b	5±0.13 b	5.3±0.14 b	5.1±0.16 a	4.9±0.14 a	4.9±0.15 b
0	0	1.2	5.6±0.12 a	5.6±0.13 a	5.5±0.14 a	5.8±0.14 a	5.6±0.15 a	5.2±0.13 a	5.6±0.14 a
30	40	0.8	5.9±0.1 b	6.3±0.11 a	5.9±0.11 a	5.8±0.12 b	6.1±0.12 a	5.8±0.1 a	6.1±0.11 b
30	40	1.2	6.4±0.09 a	6.5±0.11 a	6.2±0.1 a	6.2±0.12 a	6.4±0.12 a	6.3±0.1 a	6.5±0.09 a
30	70	0.8	5.9±0.11 a	6.1±0.11 b	5.9±0.12 a	6±0.12 a	6.1±0.12 a	5.7±0.12 a	5.9±0.12 a
30	70	1.2	6.2±0.1 a	6.5±0.1 a	6.1±0.11 a	6.2±0.11 a	6.3±0.13 a	6.1±0.11 a	6.3±0.11 a
50	40	0.8	6.1±0.11 b	6.4±0.11 a	6.1±0.12 a	6.1±0.13 a	6.3±0.12 a	6.1±0.11 a	6.2±0.12 b
50	40	1.2	6.4±0.1 a	6.6±0.09 a	6.3±0.11 a	6.3±0.12 a	6.5±0.11 a	6.2±0.11 a	6.6±0.098 a
50	70	0.8	6.1±0.12 a	6.3±0.12 a	6.1±0.12 a	6.3±0.12 a	6.3±0.13 a	6.1±0.13 a	6.3±0.13 a
50	70	1.2	6.1±0.11 a	6.3±0.12 a	5.9±0.12 a	6.1±0.11 a	6.2±0.14 a	5.9±0.12 a	6.3±0.12 a

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are significantly different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

All parameters in treatments in this figure were more than 5.6 which indicated that the bread made with fermented products are liked by consumers although the scores were not significantly different. This graphical representation confirmed the result described in sections; 4.3.1.1, 4.3.2.1, 4.3.3.1, 4.3.4.1, 4.3.5.1, 4.3.6.1 and 4.3.7.1.

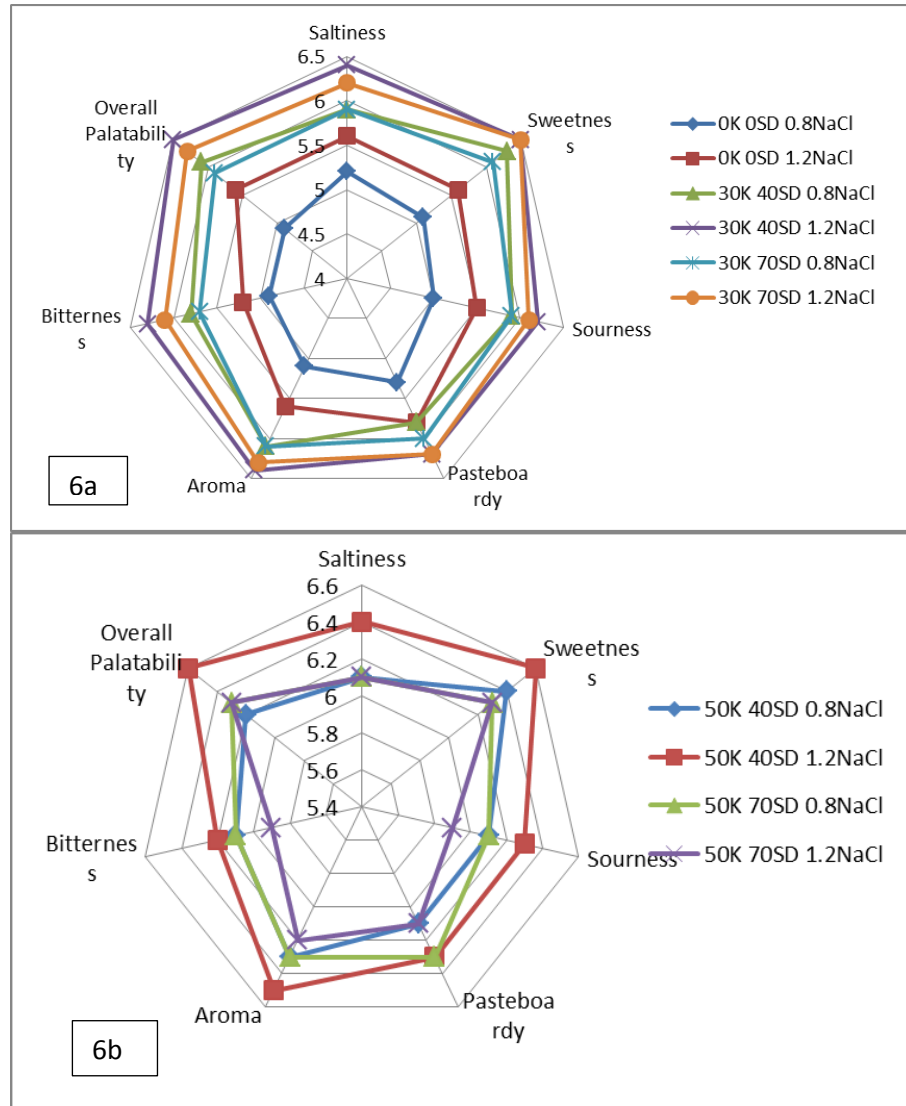


Figure 6. Radar graphical representation of effect of NaCl on sensory score of white bread.
 6a. Effect of NaCl (0.8 and 1.2%) when kefir was present in 0, 30% and sourdough at 40, 70%.
 6b. Effect of NaCl (0.8 and 1.2%) when kefir was present in 50% and sourdough at 40 and 70%.

4.3.8.2 Effect of sourdough

Two levels of sourdough (40 and 70%) were compared for sensory scores in the presence of kefir (30 and 50%) and NaCl (0.8 and 1.2%). The effect of sourdough in all sensory attributes given in Table V is presented in Figure 7. Radar graphs on the effect of sourdough on sensory scores showed a trend of treatments containing 30% kefir, 0.8% NaCl and 40 and 70% sourdough with lowest score while comparing between treatments. Both treatment graphs are towards center and sweetness and aroma scores are projected away from center which indicated the consumer preference on sweetness and aroma on those treatments (Figure 7a). Treatment having 30% kefir, 1.2% NaCl and 40% sourdough showed trend to uniformly distributed means in Figure 7a and similarly distributed means were seen in treatment having 50% kefir, 1.2% NaCl and 40% sourdough but bitterness score was shrunk towards center representing less likeliness of bitterness at that treatment combination. The graphical representation confirms the results described in sections 4.3.1.2, 4.3.2.2, 4.3.3.2, 4.3.4.2, 4.3.5.2, 4.3.6.2 and 4.3.7.2.

Table V. Summary of effect of sourdough (40 and 70%) in sensory scores of white bread at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Saltiness	Sweetness	Sourness	Pasteboardy	Aroma	Bitterness	Overall Palatability
30	0.8	40	6.0±0.10 a	6.3±0.11 a	5.9±0.11 a	5.8±0.12 a	6.1±0.12 a	5.8±0.10 a	6.1±0.11 a
30	0.8	70	5.9±0.11 a	6.1±0.12 a	5.9±0.12 a	6±0.12 a	6.1±0.12 a	5.7±0.12 a	5.9±0.12 a
30	1.2	40	6.4±0.09 a	6.5±0.11 a	6.2±0.1 a	6.2±0.12 a	6.4±0.12 a	6.3±0.10 a	6.5±0.09 a
30	1.2	70	6.2±0.10 a	6.4±0.1 a	6.1±0.11 a	6.2±0.11 a	6.3±0.13 a	6.1±0.11 a	6.31±0.11 a
50	0.8	40	6.1±0.11 a	6.4±0.11 a	6.1±0.12 a	6.1±0.13 a	6.2±0.12 a	6.1±0.11 a	6.2±0.12 a
50	0.8	70	6.1±0.12 a	6.3±0.12 a	6.1±0.12 a	6.3±0.12 a	6.3±0.13 a	6.1±0.13 a	6.3±0.12 a
50	1.2	40	6.4±0.10 a	6.6±0.09 a	6.3±0.11 a	6.3±0.12 a	6.5±0.11 a	6.2±0.11 a	6.6±0.10 a
50	1.2	70	6.1±0.11 a	6.3±0.12 a	6±0.12 a	6.1±0.11 a	6.2±0.14 a	5.9±0.12 a	6.3±0.12 b

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are significantly different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=extremely dislike and 9=extremely like.

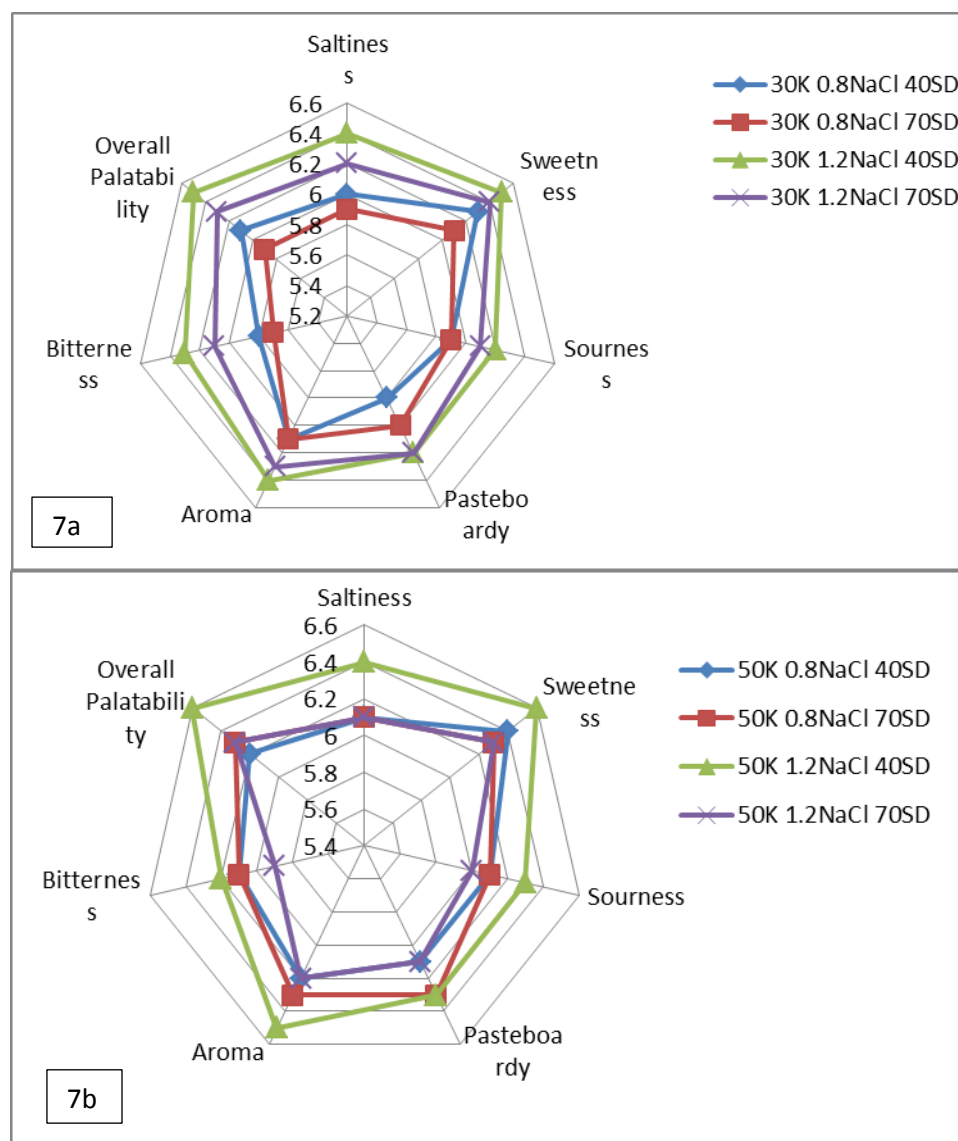


Figure 7. Radar graphical representation of effect of sourdough on sensory score of white bread
 7a. Effect of sourdough (40 and 70%) when kefir was present in 30% and NaCl at 0.8 and 1.2%.
 7b. Effect of sourdough (40 and 70%) when kefir was present in 50% and NaCl at 0.8 and 1.2%.

4.3.8.3 Effect of kefir

Two levels of kefir (30 and 50%) were compared for sensory scores in the presence of sourdough (40 and 70%) and NaCl (0.8 and 1.2%). The effect of kefir in all sensory attributes given in Table VI was presented in Figure 8.

Table VI. Summary of effect of kefir (30 and 50%) on sensory attributes of white bread at different levels of sourdough (40 and 70%) and Sodium Chloride (0.8 and 1.2%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Saltiness	Sweetness	Sourness	Pasteboardy	Aroma	Bitterness	Overall Palatability
40	0.8	30	6±0.11 a	6.3±0.11 a	5.9±0.11 a	5.8±0.12 a	6.1±0.12 a	5.8±0.10 a	6.1±0.10 a
40	0.8	50	6.1±0.12 a	6.4±0.12 a	6.1±0.12 a	6.1±0.13 a	6.2±0.12 a	6.1±0.11 a	6.2±0.12 a
40	1.2	30	6.3±0.09 a	6.5±0.11 a	6.2±0.1 a	6.2±0.12 a	6.4±0.12 a	6.3±0.10 a	6.5±0.09 a
40	1.2	50	6.4±0.1 a	6.6±0.09 a	6.3±0.11 a	6.3±0.12 a	6.5±0.11 a	6.2±0.11 a	6.6±0.09 a
70	0.8	30	5.8±0.11 a	6.1±0.11 a	5.9±0.12 a	5.9±0.12 b	6.1±0.12 a	5.7±0.12 a	5.9±0.12 b
70	0.8	50	6.1±0.12 a	6.3±0.12 a	6.1±0.12 a	6.3±0.12 a	6.3±0.13 a	6.1±0.13 a	6.3±0.12 a
70	1.2	30	6.2±0.1 a	6.4±0.1 a	6.1±0.11 a	6.2±0.11 a	6.3±0.13 a	6.1±0.11 a	6.3±0.11 a
70	1.2	50	6.1±0.11 a	6.3±0.12 a	6±0.12 a	6.2±0.11 a	6.2±0.14 a	5.9±0.12 a	6.3±0.12 a

^aMean (n=64) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are significantly different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1= dislike extremely and 9=like extremely.

Radar graph on effect of kefir on sensory attributes indicated that treatments containing 40% sourdough, 0.8% NaCl and 30% and 50% kefir (Fig. 8a) and treatment containing 70% sourdough, 0.8% NaCl and 30% kefir (Fig. 8b) obtained low sensory score on all attributes and graphs are concentrated at center except for aroma which is projected away from center in comparison to other parameter. However, at higher NaCl, at 40% sourdough, two levels of kefir obtained higher means and distributed evenly around the corner of the graph (Fig. 8a). At 70% sourdough, 0.8 and 1.2% NaCl and 30 and 50% kefir containing treatment also obtained higher score and distributed evenly around the corner of the radar graph. Radar graph makes the visual observation of sensory scores of different treatments easier and easily see the difference in scores and any unusual values. In visual observation also, no distinct effect of kefir on sensory attributes were observed which confirms the result described in the sections 4.3.1.3, 4.3.2.3, 4.3.3.3, 4.3.4.3, 4.3.5.3, 4.3.6.3 and 4.3.7.3.

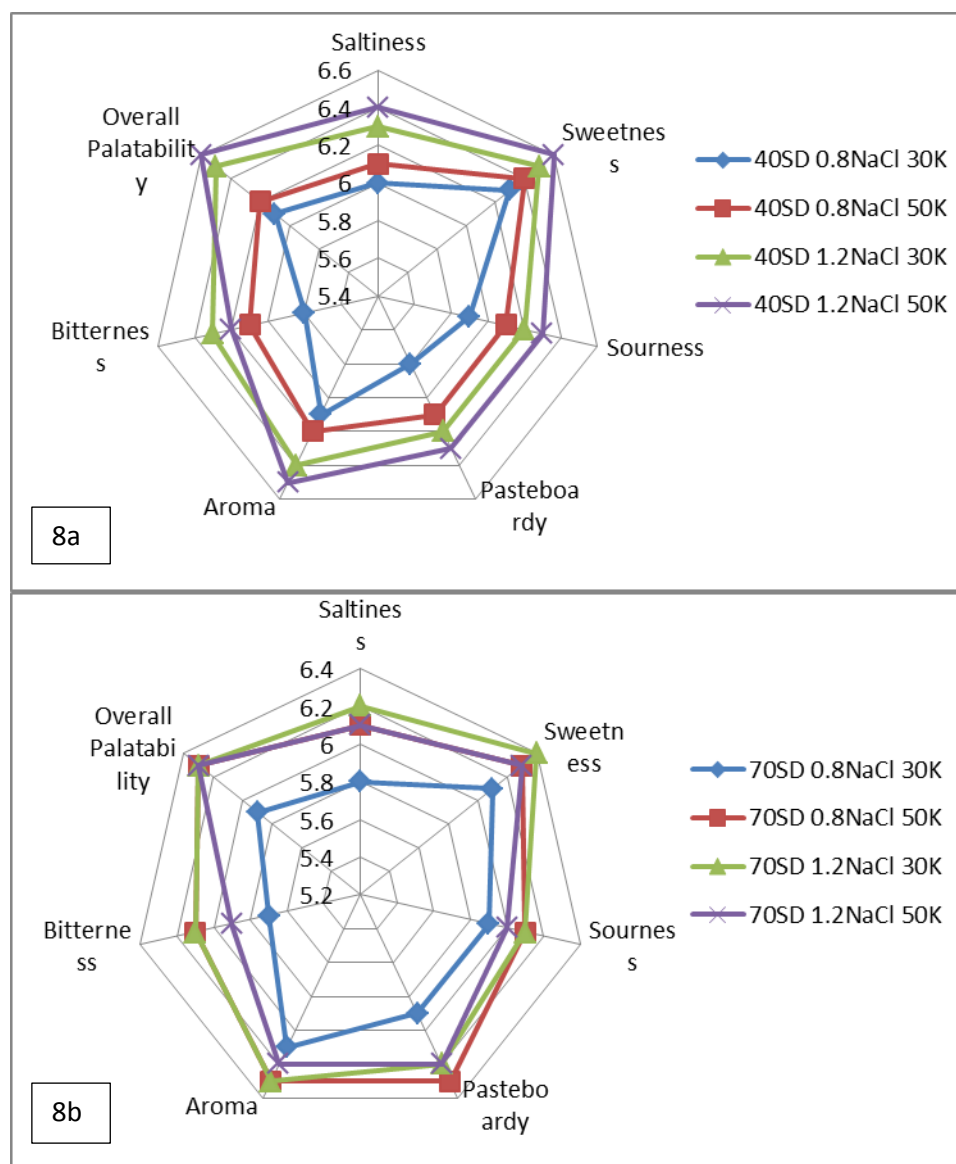


Figure 8. Radar graphical representation of effect of kefir on sensory score of white bread.
 8a. Effect of kefir (30 and 50%) when sourdough was present in 40% and NaCl at 0.8 and 1.2%.
 8b. Effect of kefir when sourdough was present in 70% and NaCl at 0.8 and 1.2%.

4.3.9 Descriptive sensory analysis of bread

Descriptive analysis of bread by five trained panelist described the aroma and flavor perception tones of by dilution analysis. The predominant aroma and flavor identified by the panelist were sour, acidic, sweet, fruit, overall perception and volatiles perception.

Table VII: Results of descriptive analysis of white bread at different levels of kefir (0, 30 and 50%), sourdough (0, 40 and 70%) and NaCl (0.8 and 1.2%).

Kefir (%)	SD (%)	NaCl (%)	Sourness	Acidic	Sweet	fruity	Overall Perception	Volatiles
0	0	0.8	5.4	5	3.8	4.2	6.8	Alcohol
0	0	1.2	4.6	4.8	4.2	3.6	6.6	Alcohol
30	40	0.8	5.2	5	5	5	7	Woody
30	40	1.2	5.2	5.8	5.2	5.4	6.6	Bleachy
30	70	0.8	5.6	5.2	4.6	4.4	6.2	Cheesy, grainy
30	70	1.2	5.6	5.4	5.2	5.4	7.4	Bleachy
50	40	0.8	4.6	5.6	4.8	5.4	6.8	Cheesy, woody
50	40	1.2	5.4	5.4	4.2	4.6	6.8	Cheesy
50	70	0.8	5.2	4.4	4	4.6	6.4	Sweet and sour
50	70	1.2	5.6	5.6	5	5.2	6.2	Sweet and sour

Results are expressed in overall mean with sensory score of 0=none to 10=extremely strong.

The result of descriptive analysis indicated that volatiles in the control treatments are predominated by alcohol smell volatiles. It was expected since yeast was used during fermentation of dough and ethanol is also produced during fermentation. At higher level of kefir (50%) and sourdough (70%), breads were perceived as a sweet and sour at both levels of NaCl (0.8 and 1.2%). In the treatment containing kefir at 50% in the presence of 40% sourdough and NaCl (0.8 and 1.2%), the predominant odor of cheesy flavor was identified. Similar perception of cheesy odor was perceived in treatment containing 30% kefir, 70% sourdough and 0.8% NaCl. Kefir at 30%, NaCl at 1.2%, two levels of sourdough (40 and 70%) gave perception of bleach in the descriptive analysis. Low kefir (30%), low sourdough (40%) and low NaCl (0.8%) gave bread perceiving woody odor. Fruitness was predominant (overall mean of 5.4) was reported in

treatments combination of kefir 30% kefir-40% sourdough-1.2% NaCl, 30% kefir-70% sourdough-1.2% NaCl and 50% kefir- 40% SD-0.8% NaCl. High kefir (50%) breads and control bread with 0.8% NaCl were able to score highest overall palatability of mean 6.8 in 0-10 rating scale with 0 no perception and 10 extremely strong perception. Sweetness level of 5.2 mean was recorded for treatment combinations 30% kefir-40% sourdough-1.2% NaCl and 30% kefir-70% sourdough-1.2% NaCl. So, high NaCl resulted in high perception of sweetness. High sourdough (70%) resulted in high sourness in the breads (Table VII).

4.4 Bread crumb firmness

4.4.1 Effect of storage days

After baking, breads were sliced and were stored in double zip-lock bags and analyzed on three day points (1, 4 and 7) (Appendix Table 43). Storage days have significant effect on firmness of the breads which increased with increase in storage days. Sodium chloride at 0.8% level in the absence of fermented products significantly affected ($P<0.05$) the firmness with overall means of 160.8, 263.4 and 347.7 for 1, 4 and 7 days, respectively (Appendix Table 43). Crumb firmness at day 7 was 116.3% higher than day 1 firmness. However, 1.2% sodium chloride did not show an effect on firmness at different days of storage. Kefir at 30%, sourdough at 40% in the presence of 0.8 and 1.2% NaCl, three storage days (1, 4 and 7) resulted in significantly different ($P<0.0001$) firmness of bread. Significantly different firmness was observed with average value of 682.9, 941.5 and 1092.6 for day 1, 4 and 7, respectively at 0.8% sodium chloride. Day 4 firmness was 37.8% higher than day 1 and day 7 crumb firmness was 60% higher than day 1 and 16% higher than day 4 crumb firmness. At 1.2% sodium chloride in the presence of 30% kefir and 40% sourdough, firmness (g) was 669.6, 959.4 and 1067.8 for day 1, 4 and 7 respectively (Appendix Table 43). Firmness at day 4 was 43.3% higher than day 1 firmness and firmness at day 7 was 59.5% higher than day 1. However, no significant difference

between day 4 and day 7 was observed in this combination. At 30% level of kefir, 70% sourdough in the presence of 0.8 and 1.2% sodium chloride resulted in significantly different firmness of the bread. At 0.8% sodium chloride, significantly different ($P<0.05$) firmness was recorded with mean values of 428.2, 692.9 and 725.2 at day 1, 4 and 7, respectively where firmness at day 4 was 62% higher than day 1 and firmness at day 7 was 69.4% than day 1 firmness. Likewise, mean firmness of 426.5, 651.5 and 757.9 were recorded at 1.2% sodium chloride for day 1, 4 and 7, respectively. Crumb firmness at day 4 was 53% higher and at day 7 crumb firmness was 78% higher than day 1 firmness (Appendix Table 43). When kefir was increased to 50%, 40% of sourdough in the presence of 0.8 and 1.2% of sodium chloride resulted in significantly different firmness of the bread. Sodium chloride at 0.8% resulted in significantly different ($P<0.05$) firmness with mean values of 535.4, 748.8 and 824.4 at day 1, 4 and 7, respectively. Crumb firmness at day 4 was 40% higher than day 1 and firmness at day 7 was 54% higher than day 1. However, no significant difference in firmness was recorded between day 4 and 7 (Appendix Table 43). Sodium chloride at 1.2% gave significantly different ($P<0.05$) firmness at 50% kefir and 40% sourdough with mean values of 668.5, 885.4 and 969.4 at day 1, 4 and 7 respectively. An increase of 32.4% firmness was recorded from day 1 to 4 while 45.1% increase was recorded at day 7 in comparison to day 1. At sourdough 70%, same kefir level resulted in significantly different ($P<0.05$) firmness with overall means of 336.4, 494.8 and 534.7 for day 1, 4 and 7, respectively. In this combination, increase of 47.1% crumb firmness was reported from day 1 to day 4 and 59% increase of firmness was observed from day 1 to day 7. At 50% kefir, 70% sourdough resulted in significantly different ($P<0.05$) firmness of bread among three days of storage with overall means of 458.8, 651.9 and 680.1 for 1, 4 and 7 days respectively. Crumb firmness at day 4 was 42.1% higher than firmness at day 1 and 48.2% higher firmness was reported at day 7 in comparison to day 1. However, no significant difference in firmness was observed between day 4 and 7.

4.4.2 Effect of NaCl in bread crumb firmness in different days of storage

Effect of NaCl on crumb firmness was compared at given levels of kefir and sourdough on a day 1 (Appendix Table 44). The effect of two levels of sodium chloride (0.8 and 1.2%) in the presence of sourdough (0, 40 and 70%) and kefir (0, 30 and 50%) on crumb firmness was not significant at day 1. The average scores in different treatment combinations were in the range of 159.1 to 669.6 (Appendix Table 44). The result indicated that NaCl level can be varied between 0.8 to 1.2% in bread making without any effect on crumb firmness of the bread.

Effect of NaCl on crumb firmness was compared at given level of kefir and sourdough on a day 4 (Appendix Table 45). The effect of two levels of sodium chloride (0.8 and 1.2%) in the presence of sourdough (0, 40 and 70%) and kefir (0, 30 and 50%) on crumb firmness was not significant at day 4 except for one treatment combination group (50% kefir, 70% sourdough). The average scores in different treatment combinations were in the range of 263.4 to 959.4 (Appendix Table 45). Sourdough at 70% level with 50% kefir resulted in significantly different ($P < 0.05$) firmness with means of 494.8 and 651.9 for 0.8 and 1.2% sodium chloride, respectively. NaCl at 1.2% level gave 32% lower firmness than 0.8% sodium chloride. Highest firmness was recorded for the treatments with low kefir and low sourdough levels. Lowest firmness was observed on controls but among treatments, high kefir and high sourdough resulted in significantly softer breads (Appendix Table 45).

Effect of sodium chloride on firmness of breads was studied on day 7 (Appendix Table 46). At day 7, no significant effect of sodium chloride on firmness of the breads was recorded in the presence of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%). The firmness was recorded in the range of 324.2 to 1092.6 in these treatment comparisons. Higher firmness values were obtained for the treatments with low kefir and low sourdough proportion. The mean values of 1092.6 and 1067.8 were recorded at 0.8 and 1.2% sodium chloride in the presence of 30% kefir

and 40% sourdough (Appendix Table 46). Similarly, among treatments lowest firmness was recorded when kefir and sourdough were in highest amounts but effect of sodium chloride was not significant. The significantly similar firmness at day 7 indicated that NaCl can be used in any amount between 0.8 to 1.2% in the presence of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) without any effect on firmness of the bread.

4.4.3 Effect of sourdough in bread crumb firmness in different days of storage

Effect of two levels of sourdough (40 and 70%) on firmness of bread was studied on day 1, 4 and 7. On day 1, kefir at 30% level in the presence of 0.8% sodium chloride resulted in significantly different ($P<0.05$) firmness among two levels of sourdough (40 and 70%) with average of 682.9 and 428.2 respectively (Appendix Table 47). Bread made of 70% sourdough had a reduction in firmness 37.3% than bread made of 40% sourdough. In the presence of 1.2% sodium chloride, significantly different ($P<0.05$) firmness was recorded with means of 669.6 and 426.5 for 40% and 70% sourdough, respectively. The mean firmness at 70% sourdough was 36.3% lower than 40% sourdough (Appendix Table 47). When kefir was increased to 50% in the presence of lower sodium chloride (0.8%), higher sourdough (70%) significantly lowered the firmness of bread in comparison to 40% sourdough. The significantly different ($P<0.05$) firmness was observed with overall means of 535.4 and 336.4 for 40 and 70% sourdough, respectively. Firmness of 70% sourdough was 37.2% lower than firmness of 40% sourdough. Similarly, at same kefir level, 1.2% sodium chloride resulted in significantly different ($P<0.05$) firmness among two levels of sourdough (40 and 70%) with overall means of 668.5 and 458.8, respectively. Sourdough at 70% level had 31.4% lower firmness than 40% sourdough on day 1 (Appendix Table 47).

Effect of sourdough on firmness of the breads was seen significantly different on a day 4 (Appendix Table 48). Kefir at 30% level, 0.8% sodium chloride resulted in significantly different

($P < 0.05$) firmness among 40 and 70% sourdough with average of 941.5 and 692.9, respectively. Increase in sourdough from 40% to 70% resulted in decrease of 26.4% firmness. At 1.2% sodium chloride, increase in sourdough from 40% to 70% resulted in 32.1% decrease in firmness with overall means of 959.4 and 651.5 for 40 and 70% sourdough, respectively (Appendix Table 48). Similarly, kefir at 50% in the presence of 0.8% sodium chloride resulted in significantly different ($P < 0.05$) firmness among two levels of sourdough. Significantly different firmness was recorded with overall means of 748.8 and 494.8 for 40 and 70%, respectively and the 70% sourdough resulted in 34% lower firmness than 40% sourdough. When sodium chloride was increased to 1.2%, significantly different ($P < 0.05$) firmness was recorded among two levels of sourdough with overall means of 885.4 and 651.9 for 40 and 70% respectively. Bread made with 70% sourdough was 26.4% softer than bread made with 40% sourdough (Appendix Table 48).

On day 7, kefir at 30% level in the presence of 0.8% sodium chloride resulted in significantly different ($P < 0.0001$) firmness among two levels (40 and 70%) of sourdough with the average of 1092.6 and 725.2, respectively (Appendix Table 49). At this level, 70% sourdough gave 33.6% less firm bread than 40% sourdough. When NaCl was increased to 1.2% significantly different ($P < 0.0001$) firmness was recorded among 40 and 70% sourdough with overall means of 1067.8 and 757.9, respectively. Sourdough at 70% level gave 29.1% less firm bread than 40% sourdough bread (Appendix Table 49). Kefir at 50% level in the presence of 0.8% sodium chloride gave significantly different ($P < 0.05$) firmness among two levels of sourdough. Overall means of 824.4 and 534.7 were recorded at 40 and 70% sourdough, respectively with 35.1% lower firmness in 70% sourdough than 40% sourdough. At same level of kefir, 1.2% sodium chloride gave significantly different firmness (g) means of 969.4 and 680.1 at 40% and 70% sourdough, respectively. The firmness of bread made with 70% sourdough was reduced by 30% compared to that made with 40% sourdough on a day 7 (Appendix Table 49).

4.4.4 Effect of kefir in bread crumb firmness in different days of storage

Effect of two levels of kefir on firmness of bread was studied throughout the storage days (1, 4 and 7). On a day 1, 30 and 50% levels of kefir did affect significantly ($P>0.05$) the crumb firmness when sourdough was present in 40% and NaCl in 0.8% level (Appendix Table 50). Overall means of 682.9 and 535.4 were recorded at 30 and 50% kefir, respectively. The result indicated that kefir can be used at any level between 30 to 50% in the presence of sourdough and NaCl without any effect on firmness compared to bread at day 1.

On day 4, the effect of kefir was significantly different among half of the treatment comparisons (Appendix Table 51). A sourdough at 40% level in the presence of 0.8% sodium chloride, significantly different ($P<0.05$) firmness was recorded among two levels of kefir (30 and 50%) with average of 941.5 and 748.8, respectively. Crumb firmness at 50% kefir was 20.5% lower than 30% kefir. Sourdough at 70% level in the presence of 0.8% NaCl significantly affected ($P<0.05$) the firmness with overall mean of 692.9 and 494.8 at 30 and 50% kefir respectively (Appendix Table 51). The firmness at 50% kefir was 28.6% lower than 30% kefir on a day 4. Kefir showed significantly different firmness when sodium chloride was present at 0.8% level.

Effect of kefir on firmness of bread was also studied on a day 7 (Appendix Table 52). Effect of kefir was found to be significantly different among half of the treatment comparisons when sodium chloride was present in 0.8% level. Sourdough at 40% level in the presence of 0.8% sodium chloride, significantly different ($P<0.05$) firmness resulted among 30 and 50% kefir and overall means of 1092.6 and 824.4, respectively. Kefir at 50% level reduced bread firmness by 24.5% compared to 30% kefir bread. Sodium chloride at 1.2% level in the presence of 40 and 70% sourdough, firmness of bread was reported to be significantly similar ($P>0.05$) among two levels of kefir (30 and 50%) (Appendix Table 52). In the presence of 0.8% sodium chloride, 70%

sourdough resulted in significantly different ($P<0.05$) firmness among 30 and 50% kefir with overall mean of 725.2 and 534.7, respectively. Kefir at 50% level gave 26.3% reduction of firmness of breads compared to 30% kefir bread.

4.5 Dough recovery index

Elastic recovery index is the measure of elastic recovery of the dough. It is expressed in percentage of initial height, compressed height and recovered height of dough as measured by the Gluten CORE. Effect of three different variables used in the treatment combinations on compression recovery index was studied.

4.5.1 Effect of NaCl

One out of five treatment combinations showed a significant effect of NaCl on dough elastic recovery index and it showed a clear effect of decreasing elastic recovery with increase in NaCl (Appendix Table 53). The treatment containing kefir at 30% in the presence of 70% sourdough, increase in NaCl decreased elastic recovery with mean values of 13.9 and 11.4 for 0.8 and 1.2% NaCl, respectively. NaCl at 1.2% resulted in decrease of 18% elastic recovery index in comparison to 0.8%. Other treatment combinations did not affect elastic recovery index of dough. The control treatments had up to 57% higher average elastic recovery index than treatments. Overall, a trend was observed to decreased recovery index with all of the treatments compared to the treatments with only NaCl and no kefir or sourdough.

4.5.2 Effect of sourdough

One out of four treatment combinations gave significant increasing effect on compression recovery index with increase in sourdough level from 40 to 70% (Appendix Table 54). The treatment containing 30% kefir in the presence of 0.8% sodium chloride level gave a significantly different ($P<0.05$) elastic recovery index with mean values of 12.1 and 13.9 at 40 and 70%

sourdough, respectively. Elastic recovery index for 70% sourdough was 15% higher than that of 40% sourdough. Significantly different compression recovery index was noticed at lowest level of kefir and NaCl (Appendix Table 54). At higher levels of kefir and NaCl, the effect of sourdough was not significant.

4.5.3 Effect of kefir

Half (two out of four) of the treatment combinations gave significant increasing effect on compression recovery index with increase in kefir from 30 to 50% (Appendix Table 55). The treatment containing 40% sourdough in the presence of 0.8% sodium chloride gave a significantly different ($P<0.05$) compression recovery index with overall means of 12.1 and 13.9% for 30 and 50% kefir, respectively. Elastic recovery was increased by 14.9% when level of kefir was increased from 30% to 50%. Sourdough at 70% level gave significantly different recovery index only at higher NaCl content (1.2%) among 30 and 50% kefir level (Appendix Table 55). Significantly different ($P<0.05$) elastic recovery was recorded with overall means of 11.4 and 14.1 for 30 and 50% kefir, respectively. Kefir at 50% gave a 23.7% increase in dough elastic recovery than 30% kefir containing dough. However, same level of sourdough when present with 0.8% NaCl did not give significantly different observation among two levels of kefir.

4.6 Color of bread crumb

Color of bread crumb is an important parameter to determine the shelf life of bread. Color was measured using a HunterLab LabScan XE Spectrophotometer throughout the storage days of bread with measurement point of 1, 4 and 7. The spectrophotometer measured color in terms of L (lightness), a (redness) and b (yellowness) values.

4.6.1 Effect of storage days in L* a* b* values

4.6.1.1 L* value

L* value ranges from 0 (black) to 100 (white). The L* value of the breads was recorded in the range of 79-83 after baking. With the storage days, slight decrease in L* values of bread was recorded but the difference was not significant (Appendix Table 56). The effect of storage days on L* value of bread crumb was not significant except for one out of ten treatment combination groups. Treatment combinations containing 0% kefir and sourdough in the presence of 0.8% NaCl resulted in significantly different ($P < 0.05$) L* values among three days of measurement during storage. On a day 1, significantly lighter bread was observed with mean value of 82.9 than day 7 with the mean L* value of 80.6. All other treatment combinations did not given any difference in L* values among three days of storage (1, 4 and 7). The result indicated that bread can be stored up to 7 days without any adverse effect on L* value of bread crumb.

4.6.1.2 a* value

a* (-a* = greenness, a* = redness) value signifies the greenness to redness in the color in any food matter. a* value ranges from -120 to 120 in food. In bread crumb a* values were between -0.38 to 1.1. A trend of increase in a* value was seen in half of the treatment comparisons with increase in storage days but the differences were not significant (Appendix Table 57). The result indicated that a* value of bread crumb did not change significantly ($P > 0.05$) with storage days until 7 days among all treatment combinations of kefir (0, 30 and 50%), sourdough (0, 40 and 70%) and sodium chloride (0.8 and 1.2%). Breads can be stored up to 7 days without any effect on a* value of bread crumb.

4.6.1.3 b* value

b* (-b*= blueness, b*= yellowness) value signifies the blueness to yellowness in color. The b* value ranges from -120 to 120 in food matter. In case of bread, b* value was in the range of 15 to 18.1. Control breads were in the range of 15 -15.7 while bread containing fermented products were in the range of 17 to 18.1 (Appendix Table 58). The difference in b* value of controls and treatments suggested that the treatments combinations had more shades of yellowness than control breads. Higher levels of kefir gave a trend to higher b* values and the means were not significantly different. Thus, b* values of the breads were not changed significantly ($P>0.05$) with storage days until 7 days among all treatment combinations of kefir (0, 30 and 50%), sourdough (0, 40 and 70%) and sodium chloride (0.8 and 1.2%). This indicated that bread can be stored up to 7 days without any effect on b* value of the bread crumb.

4.6.2 Effect of NaCl in L* a* b* values of bread crumb

Effect of two levels of sodium chloride (0.8 and 1.2%) on L* a* b* values of bread on storage days of 1, 4 and 7 was studied as a measure of shelf life study of the bread. On day 1, 0.8 and 1.2% of sodium chloride did not result in significantly different ($P>0.05$) L* value (Appendix Table 59), a* value (Appendix Table 62) and b* value (Appendix Table 65) when kefir was present in 0, 30 and 50% level and sourdough in 0, 40 and 70% level. On day 1, L* value ranges from 80.3 to 82.9, a* value from -0.33 to 1.02 and b* value from 15.2 to 18.1. On day 4, similar results were obtained with no significant ($P>0.05$) effect of two levels sodium chloride (0.8 and 1.2%) on L* value (Appendix Table 60), a* value (Appendix Table 63) and b* value (Appendix Table 66) when kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) were present in the treatments. On day 4, L* values range from 79.9 to 81.6, a* value from -0.38 to 1.06 and b* value from 15.3 to 18.1. When storage day reached day 7, no significant effects of sodium chloride (0.8 and 1.2%) on L* value (Appendix table 61), a* value (Appendix Table 64)

and b* value (Appendix Table 67) were observed among treatment combinations of three levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%). On a day 7, L* value ranges from 79.8 to 81.6, a* value from -0.23 to 1.1 and b* value from 15.3 to 18.1. So, NaCl can be used in any level between 0.8 to 1.2% without adverse effect on L* a* b* value up to 7 days of storage.

4.6.3 Effect of sourdough in L* a* b* values of bread crumb

Sourdough also did not give significant difference in L* a* b* values in any day measurement during storage up to 7 days. On a day 1, 40 and 70% sourdough did not give significantly different ($P>0.05$) L* values (Appendix Table 68), a* values (Appendix Table 71) and b* values (Appendix Table 74) among two levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%). On day 1, L* values ranged from 80.3 to 81.8, a* values from 0.62 to 1.02 and b* values from 17.2 to 18.1. On a day 4, significantly similar L* values (Appendix Table 69), a* values (Appendix Table 72) and b* values (Appendix Table 75) were recorded among two levels of sourdough (40 and 70%) in the presence of 30 and 50% kefir and 0.8 and 1.2% sodium chloride. On day 4, L* values ranged from 79.9 to 81.3, a* values from 0.64 to 1.06 and b* values from 17.1 to 18.1. When measurement was taken on day 7, no significant difference ($P>0.05$) on L* values (Appendix Table 70), a* values (Appendix Table 73) and b* values (Appendix Table 76) were recorded among two levels of sourdough (40 and 70%) in the presence of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%). On day 7, L* values ranged from 79.8 to 80.9, a* values from 0.62 to 1.05 and b* values from 17.1 to 18.1. In summary, sourdough can be used in any level between 40 to 70% without adverse effect on L* a* b* values at storage of up to 7 days.

4.6.4 Effect of kefir in L* a* b* values of bread crumb

Two levels of kefir (30 and 50%) did not result in significantly different color attribute of the bread on all measurements during storage. On day 1, 30 and 50% kefir gave significantly similar ($P>0.05$) L* values (Appendix Table 77), a* values (Appendix Table 80) and b* values

(Appendix Table 83) among two levels of kefir (30 and 50%) in the presence of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%). On day 1, L* values ranged from 80.3 to 81.8, a* values from 0.62 to 1.02 and b* values from 17.2 to 18.1. On day 4, similar ($P>0.05$) L* values (Appendix Table 78), a* values (Appendix Table 81) and b* values (Appendix Table 84) were recorded among two levels of kefir (30 and 50%) when sourdough was present in 40 and 70% level and sodium chloride in 0.8 and 1.2% level. On day 4, L* values ranged from 79.9 to 81.4, a* values from 0.64 to 1.06 and b* values from 17.1 to 18.1. When color was measured on day 7, similar color attribute was recorded among different treatment combinations. Sourdough at 40 and 70% level in the presence of 0.8 and 1.2% sodium chloride resulted in significantly similar ($P>0.05$) L* values (Appendix Table 79), a* values (Appendix Table 82) and b* values (Appendix Table 85) among two levels of kefir (30 and 50%). On day 7, L* values ranged from 79.9 to 80.9, a* values from 0.62 to 1.05 and b* values from 17.1 to 18.1. The result indicated that kefir can be used in any amount between 30 to 50% without any effect on L* a* b* value of the bread at storage up to 7 days.

4.7 Loaf height per 100g of bread

After baking height and weight of the bread loaves were measured. Heights were converted to per 100 g basis by dividing with the weight of the bread loaf. Height was expressed in ratio to account for differences in loaf weight. During fermentation and baking, dough rises due to effect of yeast in case of treatment without sourdough and kefir and natural yeast and bacteria in case of sourdough bread. This parameter measured the increase in height of the bread per 100 g weight. As height of the bread increases, reduction of bread density is expected.

4.7.1 Effect of NaCl on loaf height

Two levels of sodium chloride (0.8 and 1.2%) were compared for bread loaf height in the presence of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) (Appendix Table 86). One out

of five treatment combinations showed significantly different ($P<0.05$) height per 100 g bread per. Kefir at 50% level in the presence of 70% sourdough resulted in significantly higher bread height per 100 g at 0.8% sodium chloride than 1.2% NaCl. Height per 100 g of the 1.2% NaCl bread was 8.3% lower than that of 0.8% NaCl. When kefir and sourdough were present in 0% level, 0.8 and 1.2% NaCl gave significantly same height per 100 g with means of 23.3mm and 23.7 mm, respectively. Other treatment combination also did not show significantly different in height of the bread. Overall effect of NaCl on height of the bread was not significant.

4.7.2 Effect of sourdough on loaf height

Among all treatment factors, sourdough had significant effect on loaf height of the bread as well. Higher level of sourdough gave bigger loaf height of breads (Appendix Table 87). Kefir at 30% level in the presence of 0.8% sodium chloride, significantly affected the height/weight ratio of bread among two levels of sourdough (40 and 70%) with overall means of 14.4 and 15.9 mm/100 g respectively. Sourdough at 70% level gave 10.4% higher height per 100 g of bread than 40% sourdough. When NaCl was increased to 1.2% level, similar kefir level resulted in significantly different height per 100 g among 40 and 70% sourdough. Significantly different height per 100 g was observed with means of 14.2 and 16.3 mm/100 g for 40 and 70% sourdough respectively (Appendix Table 87). In this comparison height per 100 g of bread made with 70% sourdough was 14.8% higher than 40% sourdough bread. Kefir at 50% level, 0.8 and 1.2% sodium chloride resulted in significantly different loaf height among two levels of sourdough 40 and 70%. At 0.8% sodium chloride, mean loaf height of 14.1 and 16.8 mm/100 g and at 1.2% sodium chloride, mean loaf height of 14.1 and 15.4 were recorded for 40 and 70% sourdough, respectively. Loaf height of 70% sourdough was 19.2% higher at 0.8% NaCl and 9.2% higher at 1.2% NaCl in comparison to 40% sourdough bread (Appendix Table 87). The result indicated that the effect of sourdough level on height/100 g of the bread was linear as an increase in sourdough resulted in an increased in height/100 g.

4.7.3 Effect of kefir on loaf height

Effect of two levels of kefir was studied for the bread loaf height/ 100 g (Appendix Table 88). Result indicated that kefir did not show any significant difference in height/100 g of the bread loaf in the presence of sourdough (40, 70%) and NaCl (0.8, 1.2%). The mean height (mm) per 100g of bread was in the range of 14.1 to 16.8. The result indicated that kefir can be used at any level between 30 to 50% without any effect on height of the bread.

Discussion

This work described the effect of sourdough, kefir and sodium chloride on flavor attributes, texture, rheology and shelf life of bread. From the first session of sensory analysis, strong influence of sodium chloride (0.1 and 0.4%) on saltiness, sweetness, sourness, pasteboardiness and overall palatability were recorded when kefir and sourdough were at highest and lowest levels. In middle levels of fermented products, panelists were not able to distinguish difference perhaps due to synergistic effect of flavor perception of ingredients on sensory attributes. Thus, NaCl level can be reduced up to 0.1% without any effect on perception when fermented products are present at intermediate levels. Higher sodium chloride gave higher score on sensory attributes which might be explained by the effect of NaCl on giving salty taste and enhancement of other flavors present in bread. Previous studies showed that it is feasible to reduce NaCl up to 50% with substitution levels of 40% by KCl, K-lactate (30%) and glycine (20%) without adverse effect on quality and sensory attributes (Gelabert et al., 2003; Guardia et al., 2006; McGough et al., 2012). Aroma was not significantly affected by two levels of NaCl 0.1 and 0.4% used in this study but bitterness of breads was affected in most of the treatment combinations with high scores at 0.4% NaCl. This could be explained in part by the effect of NaCl in masking the bitterness perception. While umami substances have been proposed to suppress the bitterness of various chemicals in consumer sensory evaluation, the bitter–umami

interaction has not been explored in bitter taste receptors (Kim et al., 2015). Some authors reported that bitterness suppression in mixtures with sucrose occurs less and in mixtures with NaCl occurs both peripherally at the level of receptor by chemical stimulation and centrally in the brain providing more suppression of bitterness (Kroeze and Bartoshuk, 1985). Millers and Hoskeny (2008) have suggested that addition of NaCl enhances the flavor profile of breads and reduces the pasty perception.

In the second sensory analyses, in the absence of fermented products, 1.2% NaCl gave significantly higher scores in comparison to 0.8% NaCl on saltiness, sweetness, sourness, pastyness and overall palatability. This indicated that different levels of sodium chloride significantly affected the sensory perception of bread when none of the flavor contributing compound (sourdough and kefir) was present. At low levels of kefir and sourdough, half of the comparisons had significantly different sensory perception scores and increase in kefir and sourdough did not affect the scores of the sensory attributes tested. This indicated that with the addition and increase of fermented products, different sodium chloride levels did not affect the perception score by the panelists and reduction of NaCl up to 47% can be achieved without any effect on sensory perception of the bread. A proposed explanation of perceiving higher saltiness even at 0.8% NaCl level could be that a high rate of disposal of complex flavor profile compounds from food product took place in the oral cavity that send many stimuli to the brain. Interactions of many stimuli in the test receptor site and at the translated signal in the brain made the consumer feel that they are actually perceived salty food which in reality would be combination of many flavors. Previous studies (Goswami, 2014; Javid, 2014) suggested that the addition of fermented products can affect flavor profile of white bread by producing a complex flavor profile and thus enhance the saltiness perception (with higher saltiness score of 6.4) even with reduced amount of NaCl (0.75%). Javid (2014) and Goswami (2014) proposed that fermentation metabolites such as hydrolyzed protein, carbohydrate and lipids help to improve the

flavor and digestibility of bread. Previous study suggested that NaCl helps to bound effectively the proteins, aromatic and flavor compounds which resulted in effective release of flavor compounds in the oral cavity (Guichard, 2015). Addition of sourdough also enhanced the viscosity of dough which increased the solubility of NaCl and saltiness perception even at lower level of sodium chloride (Guichard, 2002). Mc Gough et al. (2012) reported that the use of a natural flavor enhancer; fermented soy product developed to provide umami-boosting flavor allowed reduction of 30% NaCl with no difference in saltiness and overall liking of frankfurters.

Three levels of sourdough (20, 40 and 70%) in the first session of sensory resulted in significantly different perception of sensory scores except for pasteboardiness of the breads with higher scores obtained for 70% sourdough. These results indicated that consumers could find differences in the flavor profile of white bread when sourdough was present and higher sourdough was preferred (higher score). This result could be explained by a higher amount of flavor compounds in sourdough. Flavor compounds enhanced saltiness and sweetness perception, mask the sourness and bitterness of the bread thereby increased the overall palatability of the bread. Katina et al. (2006) reported the effectiveness of sourdough in enhancing bread flavor attributes and aftertaste. The authors explained this effect by enhanced proteolysis, acidification and formation of volatile compounds provided by sourdough. Even small addition of fermented sourdough (10 g/100 g dough) intensifies the flavor, aftertaste and lower sourness of the bread (Flander et al., 2011). A slightly higher perceived sourness (16-81% of the maximal score) of sourdough breads was reported by Hansen and Hansen (1996) when 5-20% of the total wheat flour was used in the sourdough fermentation with *Lactobacillus plantarum*.

In the second sensory session, sourdough level was maintained at high levels (40 and 70%) since higher scores were obtained for that level in the first consumer acceptance test. Two levels of sourdough (40 and 70%) did not give significant difference in sensory perception except for overall palatability where the combination of 50% kefir in the presence of 1.2% sodium

chloride, 40% sourdough gave 6.4% higher overall palatability than 70% sourdough. The sensory perception and overall palatability of bread has been reported to dependent on the type of microorganisms in sourdough and aroma compounds formed by those microorganisms in each batch. Moroni et al., (2009) reported sourdough fermentation used for baking purposes improved texture, palatability, aroma, shelf life and nutritional value of wheat and rye breads. Axel et al.,(2015) suggested that specific volume, microbial shelf life, firmness of bread and flavor profile were dependent on the type of microorganisms developed during the fermentation of sourdough.

Two levels of kefir (40 and 60%) used in first sensory analysis had similar scores of saltiness and pasteboardiness perception in the presence of sourdough and sodium chloride. This indicated that panelist could not differentiate the flavor profile of bread when kefir was present at 40 and 60% level. We suggest a synergistic effect of flavor compounds in sourdough and NaCl dominated the composition and flavors from sourdough which might mask the flavors contributed by kefir or the type and quantity of flavors from kefir were inherently different compared to sourdough. Half of the combinations effect on other sensory parameters was significantly affected by kefir with higher score for 40% kefir. Liking more the lower level of kefir with sourdough might be due to a different complex flavor formation. Previous study reported that kefir grains can be used successfully for sourdough type bread making and producing bread with improved flavor and extended shelf life (Katina et al., 2006). In the second sensory evaluation, 30 and 50% of kefir did not affect the sensory perception scores of breads. The suggested explanation for this might be the complex flavor combinations in bread and more pronounced effect of sourdough compared to a subtle flavor profile contributed by kefir. Descriptive analysis of bread revealed that bread made without sourdough and kefir was dominated by alcoholic smell and other treatment breads were sweet and sour, cheesy and some were blechy. The possible explanation for this is due to fermentation of dough using yeast for long time produces more ethanol in

control breads. However, complexity of flavor profile in fermented product containing bread give perception of different flavor and depending upon panelist, different flavors are perceived and recorded.

Firmness of bread crumb was increased with increase in storage days of the bread in all treatment comparisons and higher sourdough resulted in significantly softer bread crumb. In similar study (Katina et al., 2006), it was assumed that acidification during fermentation was related to the improved softness, as pH of sourdoughs correlated positively with firmness values. During storage, a decrease in bread freshness parallel to an increase in crumb hardness produced a loss of consumer acceptance (Arendt et al., 2007). Sodium chloride did not significantly affect the firmness of bread in any days of the storage. This suggests a negligible effect of sodium chloride on firmness of the crumb. Texture and salty perceptions were largely influenced by bread structure and texture, denser bread was perceived as being less salty and displayed a less complex texture perception pattern (Panouille et al., 2014). A higher level (70%) of sourdough imparts softer breads than 40% sourdough bread in all measuring days during storage. Since in the experiments with sourdough and kefir yeast was not added, the loaf volume of bread is directly dependent on the amount of sourdough used in bread making. The positive effect of sourdough in bread volume has been linked to better gas holding capacity of gluten in acidic dough containing sourdough (Gobbetti et al., 1995). In a study by Axel et al., (2015) comparison of crumb hardness of the sourdough breads (quinoa and wheat) with the non-acidified controls, the addition of sourdough led to a softer crumb for fresh breads (day 0) as well as stored breads (day 2 and day 5). Another study suggested that the 10g/100g sourdough added and its high fermentation temperature gave significantly softer texture (lowest firmness) and highest specific volume ($3.5 \text{ cm}^3/\text{g}$) after 3 storage days (Flander et al., 2011). In fresh wheat bread, the incorporation of sourdough resulted in a significant decrease of crumb hardness (Sandra et al., 2012). Sourdough is the leading fermentation used for baking purposes and it has been proven to

be ideal for improving the texture, palatability, aroma, shelf life and nutritional value of wheat and rye breads (Moroni et al., 2009). Besides freshness and softness of bread due to sourdough, increase in microbial shelf life of sourdough bread is due to decrease pH of dough. The pH of a ripe sourdough varies with the nature of the process and starter culture used and for wheat sourdoughs it ranges from 3.5 to 4.3 (Arendt et al., 2007).

Two levels of kefir significantly reduced firmness with increase in kefir level on one third of the treatments. Specifically, bread firmness was reduced when 50% kefir in combination with 40 and 70% sourdough and 0.8% NaCl on day 4 and 7 compared to 30% kefir. This result indicated that kefir is a potential ingredient in maintaining softness of bread thereby increasing shelf life at low (0.8%) NaCl. This is supported by the evidence provided by Plessas et al., (2005) which states that kefir grains can be used successfully for sourdough type bread making, producing bread with improved flavor and extended shelf life. The firmness of bread crumb was significantly higher at high kefir level and was distinguished when NaCl was in lower amount (0.8%) in our study in comparison to higher (1.2%) NaCl. However, different observation was reported by Plessas et al., (2005) on firmness of the bread as 3% isolated pressed kefir biomass resulted in low loaf volume and firm bread similar to traditional sourdough bread. The kefir in the study was used to replace yeast and the results supported that yeast produces more (higher volume) which is always related to softer bread crumb.

Elastic recovery index is a new measureable material property, analyzed by a sample's free recovery after an applied compression force. Even though there are many physiochemical and rheological tests available for analyzing wheat dough, better understanding of cultivars can be obtained from a tensile strength and stress relaxation behavior of dough by measuring the degree of elastic recovery (Chapman et al., 2012). The overall trend of this study was that there is no effect of NaCl in elastic recovery of dough. One out of five treatment combinations significantly affected dough elastic recovery due to levels of sodium chloride with 1.2% NaCl

having 18% less elastic recovery than 0.8% NaCl. The result was in accordance with previous reports (McCann and Day, 2013; Tuhumury et al., 2014); which stated that the presence of NaCl (1% or 2%) increased non covalent interactions in gluten proteins and gluten matrix formed with salt and resulted in less elastic network in comparison to 0% NaCl. Study conducted by McCann and Day (2013) suggested that lower amount of NaCl may be required to achieve the desired dough microstructure, optimum dough rheology and stability if the flour contains an appropriate quantity and quality of gluten protein. Another study explained that decreasing salt from 1.2% to 0.6% or 0.3% do not significantly affect the rheological properties and bread-making performances of wheat dough including elastic behavior, viscous modulus, creep and relaxation test (Lynch et al., 2009). Effect of sourdough on elastic recovery index showed that one out of five comparisons significantly affected the means and two levels of sourdough with 70% sourdough resulted in 14.9% higher elastic recovery index than 40% sourdough in the presence of 30% kefir and 0.8% sodium chloride. Studies have shown that exopolysaccharides produced during sourdough fermentation improve the viscoelastic property of dough, increase loaf volume, reduce crumb hardness and extended shelf life of bread (Poutanen et al., 2009; Torrieri et al., 2014). In addition Moroni et al., (2011) stated that in sourdough the presence of acids was the major cause for reduced elasticity and strengthening of the batter, which could be directly related to the increased water-holding capacity of the proteins and/or proteins/starch complexes. Higher kefir (50%) level on the other hand showed significantly higher elastic recovery index on half of the treatment comparisons. There are no studies to my knowledge found to measure the elastic recovery of kefir sourdough. Plessas et al., (2005) study showed the leavening rate of commercial baker's yeast was higher (30 ml/h) and kefir (24 ml/h) when isolated kefir grain was used at 3% level. The result implies that less leavening rate of kefir bread is directly related to the higher elastic recovery of the dough. In this study, higher kefir (50%) in combination with 40% sourdough - 0.8% NaCl and 70% sourdough-1.2% NaCl resulted in higher elastic recovery index in wheat dough in comparison to 30% kefir. Elastic recovery is dependent on wheat class and

gluten strength (Zhao et al., 2010). Other researchers have reported correlation between gluten strength and degree of recovery measured with the Gluten CORE analyzer and suggested applications on doughs as well (Chapman et al., 2012). To the best of our knowledge, this is the first report of dough elastic recovery measured with a compression recovery method using a large deformation and samples containing fermented sourdough and kefir. More studies are needed to understand the effect of those fermented products in wheat dough.

Treatments breads were made using sourdough and kefir and excluded yeast in the formula. Loaf volumes of some of the breads were smaller than the standard loaf made with yeast. Only the height and weight of the bread was measured and the ratio of height (mm)/100 g of bread were statistically analyzed. Two levels (0.8, 1.2%) of sodium chloride did not show significant difference in height/100 g of bread except one treatment comparison. Yeast made breads have approximately 68% higher height than sourdough breads. Two levels of sourdough (40 and 70%) resulted in significantly different height of bread with 70% resulting in significantly higher height than 40% sourdough in all treatment combinations. There is consensus with regard to the positive effects of sourdough addition for bread production, including improvements in bread volume and crumb structure (Clarke et al., 2005; Corsetti et al., 2000). In the study of Katina et al., (2006) sensory attributes were not significantly correlated with bread volume or with bread hardness in any of the studied sourdough breads. Higher sourdough with less firmness, low pH, and higher height of bread gave significantly longer shelf life of the bread. Independently from the microbiological strain performing the fermentation, the combination of 0.3% calcium propionate and sourdough significantly increased the shelf life of bread (Ryan et al., 2008).

In this study, the kefir (30, 50%) did not show any difference in height of the bread. A possible explanation is a larger contribution from sourdough in the treatments. Leavening rate of commercial baker's yeast was higher (30 ml/h) and kefir performed well (24 ml/h) when isolated kefir grain was used at 3% level (Plessas et al., 2005).

Bread crumb color is another important parameter determining shelf life of bread. Color parameter can be used as an auxiliary method for screening in the development of slower staling bread (Popov-Raljić et al., 2009). Crumb color of the bread was measured using HunterLab Colorimeter, Lab system of measurement. L^* (lightness), a^* (redness), b^* (yellowness) give uniformity in color distribution and closeness to human perception as Euclidean distance between two different colors in $L^* a^* b^*$ corresponds approximately to the color difference perceived by the human eye, so it is widely used system of color analysis (Leon et al., 2006). $L^* a^* b^*$ values of our breads were in the range of 79-82, 0.38- 1.1 and 15-18.1, respectively. None of the factors in the study (sourdough, kefir and NaCl) affected the crumb color or the storage days until day 7. L^* values of bread obtained were in the range of 79-83, a^* values -0.38 to 1.1 and b^* values 15 to 18.1. The color (L^* , a^* and b^* values) of the bread is dependent on size of porous bread vs. tighter pores of the cells. Leon et al., (2006) reported the HunterLab L^* , a^* , b^* values of potato chips as 61.7, -1.7 and 26.6, respectively. Mohd Jusoh et al., (2009) reported the L^* , a^* and b^* values of yeast leavened bread were 66.2, 1.3 and 19.9, respectively. In this study, sourdough and yeast leavened breads were lighter than 66.2 while a^* and b^* values are within the range of data presented by Mohd Jusoh et al., (2009). Higher values of lightness (L^*) and yellowness (b^*) and lower values of redness/greenness were obtained when the white bread crumb surfaces were considered than bread crust for color analysis (Angioloni and Collar, 2009).

CHAPTER V

CONCLUSIONS AND FUTURE STUDIES

6.1 Conclusions

First sensory analysis aimed at 1) analyzing the effect of various levels of sodium chloride (0.1 and 0.4%), sourdough (20, 40 and 70%) and kefir (40 and 60%) on flavor profile of white bread and to determine the level of each ingredient for the second study. The results showed that significantly higher ($P < 0.05$) score of white bread saltiness, sweetness, sourness, pasteboardy and overall palatability in 0.4% NaCl compared to 0.1% at lowest and highest levels of kefir and sourdough. At intermediate level of fermented products used in this study, synergistic effect of flavors derived from sourdough and kefir give similar perception of flavor characteristics. NaCl level can be reduced up to 0.1% without any effect on perception of flavor characteristics if fermented products are present in intermediate levels. NaCl affected the bitterness perception in the majority of combinations even in intermediate levels. Even if sourdough was increased up to 70% panelist did not find differences in saltiness, bitterness, aroma, saltiness and overall palatability on half of the combination. However, sourness was noticed with increased level of sourdough. At higher NaCl, panelist could not differentiate saltiness at three levels of sourdough but at lower NaCl, panelist could differentiate saltiness, sweetness, sourness perception of the bread. Sourdough has more significant effect on sensory attributes than NaCl and kefir.

The second study was designed with the lesson learned from the first sensory analysis. It was aimed at analyzing the effect of fermented products and NaCl in the flavor profile, shelf life and rheological properties of white pan bread and wheat dough. With the addition of sourdough and kefir, increase in saltiness, sweetness, overall palatability, decrease in firmness of bread crumb and increase in elastic recovery of dough were observed. However, no effect of fermented products and storage days in color of breads were recorded. In the absence of fermented products, panelist could detect the difference in perception of saltiness, sweetness, sourness, pasteboardiness and overall palatability. NaCl did not affect sourness, pasteboardiness, aroma scores in the presence of fermented products but differences were observed in overall palatability scores. Panelist could not detect differences in saltiness, sourness even if sourdough increases up to 70% and could not tell differences in saltiness when NaCl was decreased up to 47% on the breads. Kefir at 30 and 50% level did not affect sensory attributes of sourdough breads which indicate that addition of kefir between 30 to 50% do not affect the sensory acceptability of the bread. Descriptive analysis revealed that predominant smell on bread excluding sourdough and kefir was alcohol and fermented products containing breads gave predominantly sweet and sour, cheesy and bleachy note.

In all the treatment combinations and within each day of storage, 70% sourdough gave significantly softer bread with lower mean force (g) than 40% sourdough in treatments. All crumb firmness of treatments firmness ranging from 32.4 to 62% at day 4 and from 45 to 78% at day 7 in the treatment containing sourdough, kefir and NaCl. Control breads with 0.8% NaCl showed the highest increase in crumb firmness with 116% at day 7 compared to day 1. Treatments % change is lower than the controls. Control breads leavened with yeast with no fermented products were significantly ($P < 0.05$) softer than treatments. Bread made with 30% kefir, 40% sourdough and 1.2% sodium chloride was identified as the firmest bread at the end of 7 days of storage. But the bread having highest kefir (50%), highest sourdough (70%) at 0.8% sodium chloride was

softest with 104.3% less firm than firmest bread at the end of 7 days of storage. The level of 0.8 and 1.2% NaCl has least effect on firmness of bread. A reduction of bread firmness with 50% kefir in combination with 40 and 70% sourdough and 0.8% NaCl was observed on day 4 and 7 compared to 30% kefir. In this comparison, kefir showed a desirable reduction of bread firmness compared to effect on firmness as 30% kefir gave 25.7% softer bread than 50% kefir.

For the most part, elastic recovery was not affected by NaCl except for one treatment combination. In the combination of kefir 30% and sourdough 70%, elastic recovery of dough was reduced by 18% with 1.2% in comparison to 0.8% NaCl. Effect of sourdough on dough elastic recovery index showed that one out of five comparisons was significantly affected by two levels of sourdough with 70% sourdough resulting in 14.9% increase in elastic recovery index compared to sourdough in the presence of 30% kefir and 0.8% sodium chloride. Higher kefir (50%) resulted in higher elastic recovery index in wheat dough in 50% of treatment combinations. Yeast leavened breads have approximately 68% higher height than sourdough breads. Among treatments, 70% sourdough resulted in significantly higher height of the bread than 40% sourdough. However, kefir and sodium chloride did not show significant effect in height of the bread. Although salt increases the dough strength, level of salt above the optimum level of 1.5-2% of bread do not necessarily improve loaf volume (Miller and Hoseney, 2008).

Reduction of sodium in food is considered a desirable step towards decreasing the risk for hypertension and related health problems in the world population. It is a challenge to reduce sodium from foods. So, substituting NaCl with enriched and natural fermented product appears to be the better option for a more healthy and sustainable food market that includes breads with lower sodium without severely affecting its quality attributes.

6.2 Future Study

This study was approached to understanding the ability of kefir or sourdough to influence flavor perception, shelf life and rheology of wheat dough. Introduction of kefir as a flavor enhancer and improver of shelf life is completely new in the field of baking technology. Also, identification of dough rheology using Gluten CORE was also a novel concept. The amount of kefir and sourdough and the combination of them have not been reported in the literature. There is more research has to be done on this topic. Some of my recommendations are as follows;

1. Monitoring changes in volatiles compound profiles of sourdough bread made with kefir during storage can be investigated to find shelf life of bread over storage period.
2. Microbiological examinations, analysis of organic acid formation and detection of bacteriocins produced during fermentation of kefir or Sourdough can be analyzed.
3. Potential probiotic properties of bread made with kefir can be analyzed as a next step of research.
4. Further studies are required to investigate how a reduction of salt in bread might also lead to changes in the microbial shelf life of these products.
5. In order to gain further insight into the role of NaCl on the gluten protein network formation and associated dough rheology at the molecular level, further research could be done using single variety flours of known protein genetic background, e.g. high molecular weight glutenin subunits.
6. If there is an interest in knowing the concentration of compounds formed during fermentation, instrumental techniques like GC-MS is recommended.

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APPENDICES

1a. Adult consent form and approval from Institute Review Board (IRB).

Oklahoma State University Institutional Review Board

Date: Thursday, March 26, 2015 Protocol Expires: 7/2/2016
IRB Application No: AG1335
Proposal Title: Natural Replacers of Sodium Chloride in Bread and other Baked Goods

Reviewed and Exempt
Processed as: **Modification**

Status Recommended by Reviewer(s) **Approved**

Principal
Investigator(s):

Patricia Rayas Duarte
107 FAPC
Stillwater, OK 74078

Sabitri Sharma Gautam
1719 S Jackson Ave #23G
Tulsa, OK 74107

Sudhir Kumar Pasupuleti
75 S University Place #5
Stillwater, OK 74075

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB.

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

The reviewer(s) had these comments:

Modification to 1) add an "s" in the word "replacer" in the title, 2) remove Subhasree Goswami as a Co-PI as she has graduated, and 3) offer \$15 to judges to participate in the study, 4) add Sudhir Pasupuleti as co-PI, 5) add Sabitri Gautam as Co-PI and 6) remove Rabia Javid as co-PI

Signature :



Hugh Crethar, Chair, Institutional Review Board

Thursday, March 26, 2015
Date

ADULT CONSENT FORM
OKLAHOMA STATE UNIVERSITY

PROJECT TITLE: Sensory evaluation of white bread and tortillas containing sourdough and other fermented products

INVESTIGATORS: Sabitri Gautam Sabitri.gautam@okstate.edu, graduate student assistant
Sudhir Pasupuleti sudhir.pasupuleti@okstate.edu, graduate student assistant
Rayas-Duarte, Patricia pat.rayas_duarte@okstate.edu, principal investigator
Rm 123 Food and Ag Products Center (FAPC)

PURPOSE:

This study will examine the sensory perception of white bread containing sourdough and tortillas containing fermented product.

PROCEDURES

You will complete a questionnaire asking for your perception of the flavor and sensory attributes of white bread and tortillas samples. This study is designed to last approximately 10 minutes. Complete attendance for all 6-7 sessions is expected.

RISKS OF PARTICIPATION:

The breads contain fermented dairy products and **GLUTEN**. If you have allergies to gluten products you cannot participate in the study. The dairy fermented product will be 99% lactose free.

Other than the allergen (gluten), there are no known risks associated with this project which are greater than those ordinarily encountered in daily life.

BENEFITS OF PARTICIPATION:

Your participation will help to assess the sensory attributes of the products along with potential consumer acceptability. The society at large will benefit by having novel fermented products with different flavor profile in the future.

CONFIDENTIALITY:

You will not be identified individually; we will be looking at the group as a whole. Research records will be stored on a password protected computer in a locked office and only researchers and individuals responsible for research oversight will have access to the records.

COMPENSATION:

You will receive a coupon of \$15 for a local vendor for your participation when you complete the study consisting in 6-7 sessions.



CONTACTS:

You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study: Patricia Rayas-Duarte, Ph.D., 123 FAPC, Oklahoma State University, Stillwater, OK 74078, (405) 744-6468. If you have questions about your rights as a research volunteer, you may contact the IRB Office at 219 Cordell North, Stillwater, OK 74078, (405) 744-3377 or irb@okstate.edu

PARTICIPANT RIGHTS:

I understand that my participation is voluntary, that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time, without penalty.

CONSENT DOCUMENTATION:

I have been fully informed about the procedures listed here. I am aware of what I will be asked to do and of the benefits of my participation. I also understand the following statements:

I affirm that I am 18 years of age or older.

Preface the signature lines with the following statement (expand if appropriate):

I have read and fully understand this consent form. I sign it freely and voluntarily. A copy of this form will be given to me. I hereby give permission for my participation in this study.

Signature of Participant

Date

I certify that I have personally explained this document before requesting that the participant sign it.

Signature of Researcher

Date



1b.

Consumer Acceptance Test-Sourdough Bread

Date_____

Age group: Less than 25____, 25-35____, 36 -45____, More than 45 ____

Gender: Male _____ Female _____

Instructions:

1. FOOD ALLERGEN WARNING: contains wheat, fermented milk product
2. Mark **with an “X” or ✓** beside the answer that best describes your response to the sensory attribute at the top of the column. E.g. If you do not find any bitterness in the product, decide if you like it and how much.

Sample number_____

Responses	Salty	Sweet	Sour	Pasteboardy (dry mouth feel)	Aroma	Bitter	Overall palatabilit y
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							

Comments:

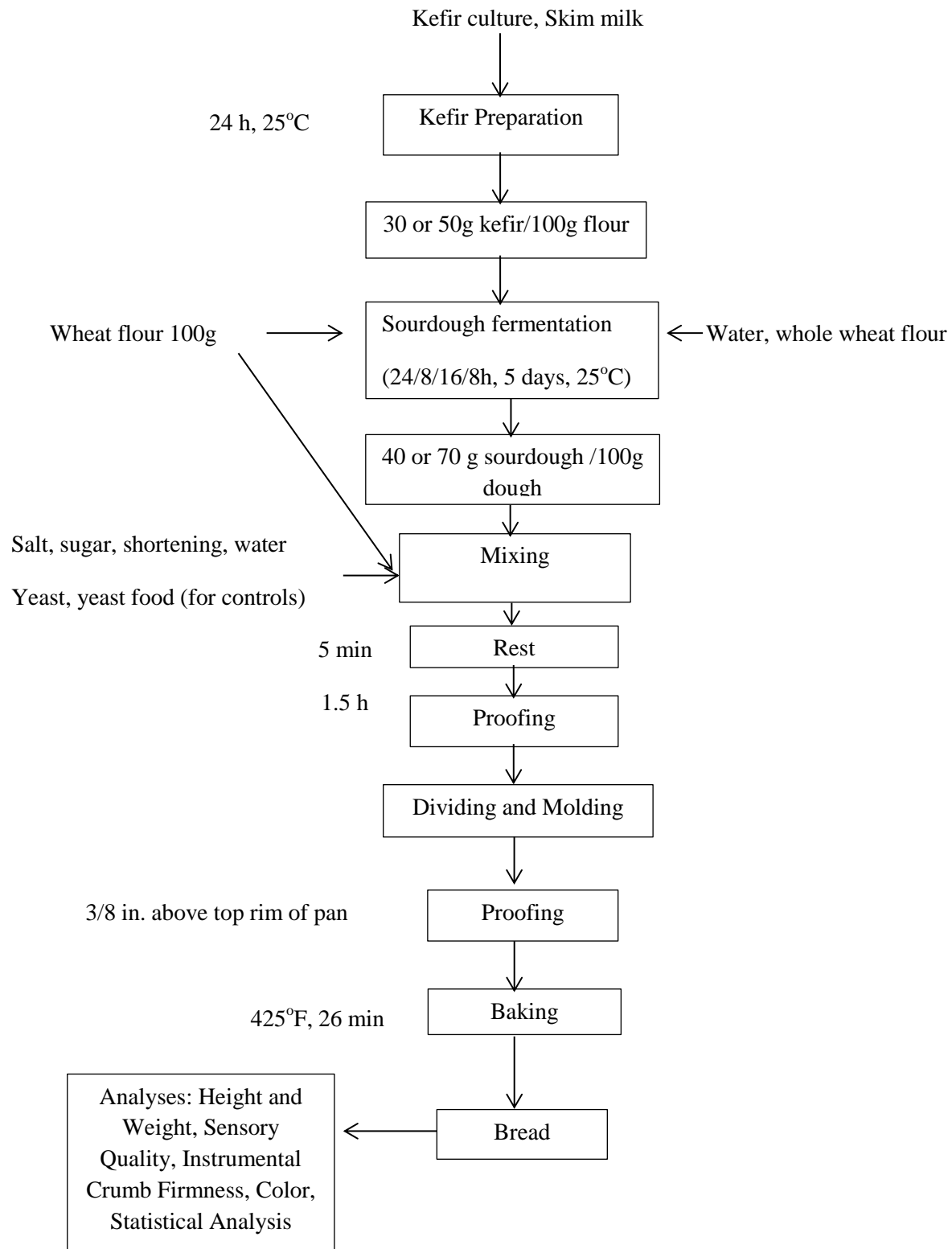


Figure 9. Scheme for processing and analysis of sourdough and bread.

Table 1. Effect of NaCl (0.1 and 0.4%) on saltiness score of white bread at different levels of kefir (40 and 60%) and sourdough (20, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Saltiness			% Change	P-Value
40	20	0.1	4.9	±	0.34 b	20.4	0.0433
40	20	0.4	5.9	±	0.41 a		
40	40	0.1	5.9	±	0.36 a		0.385
40	40	0.4	6.4	±	0.17 a		
40	70	0.1	6.2	±	0.34 a		0.247
40	70	0.4	6.7	±	0.26 a		
60	20	0.1	5.4	±	0.35 a		0.21
60	20	0.4	6.0	±	0.35 a		
60	40	0.1	6.2	±	0.35 a		0.63
60	40	0.4	6.0	±	0.45 a		
60	70	0.1	5.3	±	0.39 b	28.3	0.001
60	70	0.4	6.8	±	0.28 a		

^aMean (n=22)± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are significantly different at a 0.05 level of significance.

Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 2. Effect of sourdough (20, 40 and 70%) on saltiness score of white bread at different levels of kefir (40 and 60%) and sodium chloride (0.1 and 0.4%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Saltiness			% Change	P-Value
40	0.1	20	4.9	±	0.34 b		0.02
40	0.1	40	5.9	±	0.36 a	20.4	
40	0.1	70	6.2	±	0.34 a	26.5	
40	0.4	20	5.9	±	0.41 a		0.21
40	0.4	40	6.4	±	0.17 a		
40	0.4	70	6.7	±	0.26 a		
60	0.1	20	5.4	±	0.35 ab		0.04
60	0.1	40	6.2	±	0.35 a		
60	0.1	70	5.3	±	0.39 b	-14.5	
60	0.4	20	6.0	±	0.35 a		0.13
60	0.4	40	6.0	±	0.45 a		
60	0.4	70	6.8	±	0.28 a		

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 3. Effect of kefir (40 and 60%) on saltiness score of white bread at different levels of sourdough (20, 40 and 70%) and sodium chloride (0.1 and 0.4%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Saltiness			P-Value
20	0.1	40	4.9	±	0.34 a	0.28
20	0.1	60	5.4	±	0.35 a	
20	0.4	40	5.9	±	0.41 a	0.77
20	0.4	60	6.0	±	0.35 a	
40	0.1	40	5.9	±	0.36 a	0.56
40	0.1	60	6.2	±	0.35 a	
40	0.4	40	6.4	±	0.17 a	0.44
40	0.4	60	6.0	±	0.45 a	
70	0.1	40	6.2	±	0.34 a	0.07
70	0.1	60	5.3	±	0.39 a	
70	0.4	40	6.7	±	0.26 a	0.77
70	0.4	60	6.8	±	0.28 a	

^aMean (n=22)± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are significantly different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 4. Effect of NaCl (0.1 and 0.2%) in sweetness score of white bread at different levels of kefir (40 and 60%) and sourdough (20, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Sweetness			% Change	P-Value
40	20	0.1	5.0	±	0.22 b		0.021
40	20	0.4	6.0	±	0.36 a	20.0	
40	40	0.1	5.6	±	0.34 b		0.047
40	40	0.4	6.5	±	0.22 a	16.1	
40	70	0.1	6.2	±	0.36 a		0.29
40	70	0.4	6.7	±	0.29 a		
60	20	0.1	5.9	±	0.31 a		0.46
60	20	0.4	6.2	±	0.35 a		
60	40	0.1	6.2	±	0.38 a		0.12
60	40	0.4	5.5	±	0.39 a		
60	70	0.1	5.1	±	0.35 b		0.0002
60	70	0.4	6.7	±	0.24 a	31.4	

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 5. Effect of sourdough (20, 40 and 70%) on sweetness score of white bread at different levels of kefir (40 and 60%) and sodium chloride (0.1 and 0.4%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Sweetness			% Change	P-value
40	0.1	20	5.0	±	0.22 b		0.018
40	0.1	40	5.6	±	0.34 ab		
40	0.1	70	6.2	±	0.36 a	24.0	
40	0.4	20	6.0	±	0.36 a		0.265
40	0.4	40	6.5	±	0.22 a		
40	0.4	70	6.7	±	0.29 a		
60	0.1	20	5.9	±	0.31 ab		0.02
60	0.1	40	6.2	±	0.38 a		
60	0.1	70	5.1	±	0.35 b	-17.7	
60	0.4	20	6.2	±	0.35 ab		0.03
60	0.4	40	5.5	±	0.39 b		
60	0.4	70	6.7	±	0.24 a	21.8	

^aMean (n=22)± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 6. Effect of kefir (40 and 60%) on sweetness score of white bread at different levels of sourdough (20, 40 and 70%) and sodium chloride (0.1 and 0.4%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Sweetness			% Change	P-Value
20	0.1	40	5.0	±	0.22 b	18.0	0.046
20	0.1	60	5.9	±	0.31 a		
20	0.4	40	6.0	±	0.36 a		0.67
20	0.4	60	6.2	±	0.35 a		
40	0.1	40	5.6	±	0.34 a		0.17
40	0.1	60	6.2	±	0.38 a		
40	0.4	40	6.5	±	0.22 a	-15.4	0.028
40	0.4	60	5.5	±	0.39 b		
70	0.1	40	6.2	±	0.36 a	-17.7	0.0067
70	0.1	60	5.1	±	0.35 b		
70	0.4	40	6.7	±	0.29 a		1
70	0.4	60	6.7	±	0.24 a		

^aMean (n=22) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 7. Effect of NaCl (0.1 and 0.4%) on sourness score of white bread at different levels of kefir (40 and 60%) and sourdough (20, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Sourness			% Change	P-Value
40	20	0.1	4.8	±	0.26 b	23.0	0.02
40	20	0.4	5.9	±	0.36 a		
40	40	0.1	6.1	±	0.34 a		0.086
40	40	0.4	5.3	±	0.25 a		
40	70	0.1	5.9	±	0.38 a		0.36
40	70	0.4	6.3	±	0.31 a		
60	20	0.1	5.4	±	0.27 a		0.26
60	20	0.4	4.9	±	0.37 a		
60	40	0.1	6.1	±	0.42 a		0.68
60	40	0.4	5.9	±	0.41 a		
60	70	0.1	5.2	±	0.38 b	27.0	0.0013
60	70	0.4	6.6	±	0.29 a		

^aMean (n=22)± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are significantly different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 8. Effect of sourdough (20, 40 and 70%) on sourness score of white bread at different levels of kefir (40 and 60%) and sodium chloride (0.1 and 0.4%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Sourness		% Change	P-Value
40	0.1	20	4.8	± 0.26 b		0.013
40	0.1	40	6.1	± 0.34 a	27.1	
40	0.1	70	5.9	± 0.38 a	23.0	
40	0.4	20	5.9	± 0.36 ab		0.04
40	0.4	40	5.3	± 0.25 b		
40	0.4	70	6.3	± 0.31 a	18.9	
60	0.1	20	5.4	± 0.27 ab		0.04
60	0.1	40	6.1	± 0.42 a		
60	0.1	70	5.2	± 0.38 b	-14.7	
60	0.4	20	4.9	± 0.37 b		0.0006
60	0.4	40	5.9	± 0.41 a	20.4	
60	0.4	70	6.6	± 0.29 a	34.7	

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 9. Effect of kefir (40 and 60%) on sourness score of white bread at different levels of sourdough (20, 40 and 70%) and sodium chloride (0.1 and 0.4%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Sourness			% Change	P-Value
20	0.1	40	4.8	±	0.26 a		0.18
20	0.1	60	5.4	±	0.27 a		
20	0.4	40	5.9	±	0.36 a		0.03
20	0.4	60	4.9	±	0.37 b	-17.0	
40	0.1	40	6.1	±	0.34 a		0.83
40	0.1	60	6.1	±	0.42 a		
40	0.4	40	5.3	±	0.25 a		0.13
40	0.4	60	5.9	±	0.41 a		
70	0.1	40	5.9	±	0.38 a		0.13
70	0.1	60	5.2	±	0.38 a		
70	0.4	40	6.3	±	0.31 a		0.417
70	0.4	60	6.6	±	0.29 a		

^aMean (n=22)± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 10. Effect of NaCl (0.1 and 0.4%) on pasteboardy score of white bread at different levels of kefir (40 and 60%) and sourdough (20, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Pasteboardy			% Change	P-Value
40	20	0.1	5.1	±	0.33 b		0.0218
40	20	0.4	6.2	±	0.31 a	21.6	
40	40	0.1	5.4	±	0.44 a		0.2124
40	40	0.4	5.9	±	0.34 a		
40	70	0.1	5.2	±	0.33 a		0.084
40	70	0.4	6.0	±	0.28 a		
60	20	0.1	5.9	±	0.39 a		0.847
60	20	0.4	5.8	±	0.31 a		
60	40	0.1	6.0	±	0.41 a		1
60	40	0.4	6.0	±	0.34 a		
60	70	0.1	5.4	±	0.30 b		0.0075
60	70	0.4	6.6	±	0.30 a	22.2	

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 11. Effect of sourdough (20, 40 and 70%) on pasteboardy score of white bread at different levels of kefir (40 and 60%) and sodium chloride (0.1 and 0.4%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Pasteboardy			P-Value
40	0.1	20	5.1	±	0.33 a	0.8416
40	0.1	40	5.4	±	0.44 a	
40	0.1	70	5.2	±	0.33 a	
40	0.4	20	6.2	±	0.31 a	0.8787
40	0.4	40	5.9	±	0.34 a	
40	0.4	70	6.0	±	0.28 a	
60	0.1	20	5.9	±	0.39 a	0.3676
60	0.1	40	6.0	±	0.41 a	
60	0.1	70	5.4	±	0.30 a	
60	0.4	20	5.8	±	0.31 a	0.1683
60	0.4	40	6.0	±	0.34 a	
60	0.4	70	6.6	±	0.30 a	

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 12. Effect of kefir (40 and 60%) on pasteboardy score of white bread at different levels of sourdough (20, 40 and 70%) and sodium chloride (0.1 and 0.4%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Pasteboardy			P-Value
20	0.1	40	5.1	±	0.33 a	0.103
20	0.1	60	5.9	±	0.39 a	
20	0.4	40	6.2	±	0.31 a	0.388
20	0.4	60	5.8	±	0.31 a	
40	0.1	40	5.4	±	0.44 a	0.179
40	0.1	60	6.0	±	0.41 a	
40	0.4	40	5.9	±	0.34 a	0.924
40	0.4	60	6.0	±	0.34 a	
70	0.1	40	5.2	±	0.33 a	0.7
70	0.1	60	5.4	±	0.30 a	
70	0.4	40	6.0	±	0.28 a	0.179
70	0.4	60	6.6	±	0.30 a	

^aMean (n=22)± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 13. Effect of NaCl (0.1 and 0.4%) on aroma score of white bread at different levels of kefir (40 and 60%) and sourdough (20, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Aroma			P-Value
40	20	0.1	5.7	±	0.39 a	0.197
40	20	0.4	5.1	±	0.42 a	
40	40	0.1	5.6	±	0.41 a	0.197
40	40	0.4	5.0	±	0.44 a	
40	70	0.1	6.1	±	0.36 a	0.066
40	70	0.4	6.9	±	0.22 a	
60	20	0.1	6.3	±	0.35 a	0.645
60	20	0.4	6.1	±	0.38 a	
60	40	0.1	6.5	±	0.36 a	0.926
60	40	0.4	6.5	±	0.32 a	
60	70	0.1	5.5	±	0.36 a	0.054
60	70	0.4	6.4	±	0.27 a	

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 14. Effect of sourdough (20, 40 and 70%) on aroma score of white bread at different levels of kefir (40 and 60%) and sodium chloride (0.1 and 0.4%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Aroma			% Change I ^b	% Change II ^c	P-Value
40	0.1	20	5.7	±	0.39 a			0.68
40	0.1	40	5.6	±	0.41 a			
40	0.1	70	6.1	±	0.36 a			
40	0.4	20	5.1	±	0.42 b			<0.0001
40	0.4	40	5.0	±	0.44 b			
40	0.4	70	6.9	±	0.22 a	35.3	38.0	
60	0.1	20	6.3	±	0.35 ab			0.045
60	0.1	40	6.5	±	0.36 a			
60	0.1	70	5.5	±	0.36 b	-15.4		
60	0.4	20	6.1	±	0.38 a			0.66
60	0.4	40	6.5	±	0.32 a			
60	0.4	70	6.4	±	0.27 a			

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

^b% change= Change in aroma score from 20 to 70% and 40 to 70% sourdough.

^c% change= Change in aroma score from 40 to 70% sourdough.

Table 15. Effect of kefir (40 and 60%) on aroma score of white bread at different levels of sourdough (20, 40 and 70%) and sodium chloride (0.1 and 0.4%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Aroma			% Change	P-Value
20	0.1	40	5.7	±	0.39 a		0.269
20	0.1	60	6.3	±	0.35 a		
20	0.4	40	5.1	±	0.42 a		0.037
20	0.4	60	6.1	±	0.38 a		
40	0.1	40	5.6	±	0.41 a		0.081
40	0.1	60	6.5	±	0.36 a		
40	0.4	40	5.0	±	0.44 b		0.003
40	0.4	60	6.1	±	0.32 a	22.0	
70	0.1	40	6.1	±	0.36 a		0.232
70	0.1	60	5.5	±	0.36 a		
70	0.4	40	6.9	±	0.22 a		0.269
70	0.4	60	6.4	±	0.27 a		

^aMean (n=22) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 16. Effect of NaCl (0.1 and 0.4%) on bitterness score of white bread at different levels of kefir (40 and 60%) and sourdough (20, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Bitterness			% Change	P-Value
40	20	0.1	3.9	±	0.37 b		<0.0001
40	20	0.4	6.1	±	0.36 a	56.1	
40	40	0.1	5.6	±	0.26 a		0.69
40	40	0.4	5.8	±	0.26 a		
40	70	0.1	5.8	±	0.33 b		0.038
40	70	0.4	6.7	±	0.28 a	15.5	
60	20	0.1	5.8	±	0.33 a		0.0078
60	20	0.4	4.6	±	0.39 b	-20.7	
60	40	0.1	5.9	±	0.38 a		0.0001
60	40	0.4	4.1	±	0.39 b	-30.5	
60	70	0.1	5.4	±	0.39 a		0.62
60	70	0.4	5.6	±	0.31 a		

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 17. Effect of sourdough (20, 40 and 70%) on bitterness score of white bread at different levels kefir (40 and 60%) and sodium chloride (0.1 and 0.4%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Bitterness			% Change I ^b	% Change II ^c	P-Value
40	0.1	20	3.9	±	0.37 b			<0.0001
40	0.1	40	5.6	±	0.26 a	43.6		
40	0.1	70	5.8	±	0.33 a	48.7		
40	0.4	20	6.1	±	0.36 ab			0.02
40	0.4	40	5.8	±	0.26 b			
40	0.4	70	6.7	±	0.28 a	15.5		
60	0.1	20	5.8	±	0.33 a			0.509
60	0.1	40	5.9	±	0.38 a			
60	0.1	70	5.4	±	0.39 a			
60	0.4	20	4.6	±	0.39 b			0.004
60	0.4	40	4.1	±	0.39 b			
60	0.4	70	5.6	±	0.31 a	21.7	36.6	

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

^b% change= Change in bitterness score from 20 to 40%, 20 to 70% and 40 to 70% sourdough.

^c% change= Change in bitterness score from 40 to 70% sourdough.

Table 18. Effect of kefir (40 and 60%) on bitterness score of white bread at different levels of sourdough (20, 40 and 70%) and sodium chloride (0.1 and 0.4%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Bitterness			% Change	P-Value
20	0.1	40	3.9	±	0.37 b		<0.0001
20	0.1	60	5.8	±	0.33 a	48.7	
20	0.4	40	6.1	±	0.36 a		0.0017
20	0.4	60	4.6	±	0.39 b	-24.6	
40	0.1	40	5.6	±	0.26 a		0.487
40	0.1	60	5.9	±	0.38 a		
40	0.4	40	5.8	±	0.26 a		0.0004
40	0.4	60	4.1	±	0.39 b	-29.3	
70	0.1	40	5.8	±	0.33 a		0.428
70	0.1	60	5.4	±	0.39 a		
70	0.4	40	6.7	±	0.28 a		0.017
70	0.4	60	5.6	±	0.31 b	-16.4	

^aMean (n=22)± standard error. Means in the same column and within same sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 19. Effect of NaCl (0.1 and 0.4%) on overall Palatability score of white bread at different levels of kefir (40 and 60%) and sourdough (20, 40 and 60%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Overall Palatability			% Change	P-Value
40	20	0.1	4.6	±	0.21 b		0.0006
40	20	0.4	6.1	±	0.34 a	32.6	
40	40	0.1	5.3	±	0.34 a		0.448
40	40	0.4	5.6	±	0.26 a		
40	70	0.1	6.0	±	0.32 a		0.278
40	70	0.4	6.5	±	0.26 a		
60	20	0.1	5.9	±	0.34 a		0.515
60	20	0.4	5.6	±	0.36 a		
60	40	0.1	6.1	±	0.38 a		0.04
60	40	0.4	5.2	±	0.33 b	-14.7	
60	70	0.1	5.4	±	0.33 b		0.0037
60	70	0.4	6.6	±	0.31 a	22.2	

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 20. Effect of sourdough (20, 40 and 70%) on overall palatability score of white bread at different levels of kefir (40 and 60%) and sodium chloride (0.1 and 0.4%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Overall Palatability			% Change I ^b	% Change II ^c	P-Value
40	0.1	20	4.6	±	0.21 b			0.0055
40	0.1	40	5.3	±	0.34 ab			
40	0.1	70	6.0	±	0.32 a	30.4		
40	0.4	20	6.1	±	0.34 ab			0.049
40	0.4	40	5.6	±	0.26 b			
40	0.4	70	6.5	±	0.26 a	16.1		
60	0.1	20	5.9	±	0.34 a			0.254
60	0.1	40	6.1	±	0.38 a			
60	0.1	70	5.4	±	0.33 a			
60	0.4	20	5.6	±	0.36 b			0.0026
60	0.4	40	5.2	±	0.33 b			
60	0.4	70	6.6	±	0.31 a	17.9	27.0	

^aMean (n=22) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

^b% change= Change in overall palatability score from 20 to 70% and 40 to 70% sourdough.

^c% change= Change in overall palatability score from 40 to 70% sourdough.

Table 21. Effect of kefir (40 and 60%) on overall palatability score of white bread at different levels of sourdough (20, 40 and 70%) and sodium chloride (0.1 and 0.4%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Overall Palatability			% Change	P-Value
20	0.1	40	4.6	±	0.21 b	28.3	0.0037
20	0.1	60	5.9	±	0.34 a		
20	0.4	40	6.1	±	0.34 a		0.233
20	0.4	60	5.6	±	0.36 a		
40	0.1	40	5.3	±	0.34 a		0.066
40	0.1	60	6.1	±	0.38 a		
40	0.4	40	5.6	±	0.26 a		0.33
40	0.4	60	5.2	±	0.33 a		
70	0.1	40	6.0	±	0.32 a		0.159
70	0.1	60	5.4	±	0.33 a		
70	0.4	40	6.5	±	0.26 a		0.66
70	0.4	60	6.6	±	0.31 a		

^aMean (n=22)± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 22. Effect of NaCl (0.8 and 1.2%) on saltiness score of white bread at different levels of sourdough (0, 40 and 70%) and kefir (0, 30 and 50%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Saltiness			% Change	P-value
0	0	0.8	5.2	±	0.13 b		0.004
0	0	1.2	5.6	±	0.12 a	8.0	
30	40	0.8	5.9	±	0.10 b		0.02
30	40	1.2	6.4	±	0.09 a	8.5	
30	70	0.8	5.9	±	0.11 a		0.06
30	70	1.2	6.2	±	0.10 a		
50	40	0.8	6.1	±	0.11 b		0.04
50	40	1.2	6.4	±	0.10 a	5.1	
50	70	0.8	6.1	±	0.12 a		0.84
50	70	1.2	6.1	±	0.11 a		

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 23. Effect of sourdough (40 and 70%) on saltiness score of white bread at different levels of sodium chloride (0.8 and 1.2%) and kefir (30 and 50%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Saltiness			P-value
30	0.8	40	6.0	±	0.10 a	0.46
30	0.8	70	5.9	±	0.11 a	
30	1.2	40	6.4	±	0.09 a	0.25
30	1.2	70	6.2	±	0.1 a	
50	0.8	40	6.1	±	0.11 a	0.92
50	0.8	70	6.1	±	0.12 a	
50	1.2	40	6.4	±	0.1 a	0.082
50	1.2	70	6.1	±	0.11 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 24. Effect of kefir (30 and 50%) on saltiness score of white bread at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Saltiness			P-value
40	0.8	30	6.0	±	0.11 a	0.54
40	0.8	50	6.1	±	0.12 a	
40	1.2	30	6.3	±	0.09 a	0.76
40	1.2	50	6.4	±	0.10 a	
70	0.8	30	5.8	±	0.11 a	0.15
70	0.8	50	6.1	±	0.12 a	
70	1.2	30	6.2	±	0.10 a	0.78
70	1.2	50	6.1	±	0.11 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 25. Effect of NaCl (0.8 and 1.2%) on sweetness score of white bread at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Sweetness			% Change	P-value
0	0	0.8	5.1	±	0.14 b	9.8	0.0019
0	0	1.2	5.6	±	0.13 a		
30	40	0.8	6.3	±	0.11 a		0.12
30	40	1.2	6.5	±	0.11 a		
30	70	0.8	6.1	±	0.11 b	6.6	0.036
30	70	1.2	6.5	±	0.10 a		
50	40	0.8	6.4	±	0.11 a		0.15
50	40	1.2	6.6	±	0.09 a		
50	70	0.8	6.3	±	0.12 a		0.91
50	70	1.2	6.3	±	0.12 a		

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 26. Effect of sourdough (40 and 70%) on sweetness score of white bread at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Sweetness			P-value
30	0.8	40	6.3	±	0.11 a	0.33
30	0.8	70	6.1	±	0.12 a	
30	1.2	40	6.5	±	0.11 a	0.66
30	1.2	70	6.4	±	0.10 a	
50	0.8	40	6.4	±	0.11 a	0.59
50	0.8	70	6.3	±	0.12 a	
50	1.2	40	6.6	±	0.09 a	0.06
50	1.2	70	6.3	±	0.12 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 27. Effect of kefir (30 and 50%) on sweetness score of white bread at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2 %)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Sweetness			P-value
40	0.8	30	6.3	±	0.11 a	0.36
40	0.8	50	6.4	±	0.12 a	
40	1.2	30	6.5	±	0.11 a	0.44
40	1.2	50	6.6	±	0.09 a	
70	0.8	30	6.1	±	0.11 a	0.17
70	0.8	50	6.3	±	0.12 a	
70	1.2	30	6.4	±	0.10 a	0.54
70	1.2	50	6.3	±	0.12 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 28. Effect of NaCl (0.8 and 1.2%) on sourness score of white bread at different levels of sourdough (0, 40 and 70%) and kefir (0, 30 and 50%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Sourness			% Change	P-value
0	0	0.8	5.0	±	0.13 b		0.009
0	0	1.2	5.5	±	0.14 a	10.0	
30	40	0.8	5.9	±	0.11 a		0.097
30	40	1.2	6.2	±	0.10 a		
30	70	0.8	5.9	±	0.12 a		0.35
30	70	1.2	6.1	±	0.11 a		
50	40	0.8	6.1	±	0.12 a		0.3
50	40	1.2	6.3	±	0.11 a		
50	70	0.8	6.1	±	0.12 a		0.62
50	70	1.2	5.9	±	0.12 a		

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 29. Effect of sourdough (40 and 70%) on sourness score of white bread at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Sourness			P-value
30	0.8	40	5.9	±	0.11 a	0.97
30	0.8	70	5.9	±	0.12 a	
30	1.2	40	6.2	±	0.10 a	0.49
30	1.2	70	6.1	±	0.11 a	
50	0.8	40	6.1	±	0.12 a	0.97
50	0.8	70	6.1	±	0.12 a	
50	1.2	40	6.3	±	0.11 a	0.12
50	1.2	70	6.0	±	0.12 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 30. Effect of kefir (30 and 50%) on sourness score of white bread at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Sourness			P-value
40	0.8	30	5.9	±	0.11 a	0.3
40	0.8	50	6.1	±	0.12 a	
40	1.2	30	6.2	±	0.10 a	0.69
40	1.2	50	6.3	±	0.11 a	
70	0.8	30	5.9	±	0.12 a	0.33
70	0.8	50	6.1	±	0.12 a	
70	1.2	30	6.1	±	0.11 a	0.64
70	1.2	50	6.0	±	0.12 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 31. Effect of NaCl (0.8 and 1.2%) on pasteboardy score of white bread at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Pasteboardy			% Change	P-value
0	0	0.8	5.3	±	0.14 b	9.4	0.006
0	0	1.2	5.8	±	0.14 a		
30	40	0.8	5.8	±	0.12 b	7.0	0.012
30	40	1.2	6.2	±	0.12 a		
30	70	0.8	6.0	±	0.12 a		0.14
30	70	1.2	6.2	±	0.11 a		
50	40	0.8	6.1	±	0.13 a		0.13
50	40	1.2	6.3	±	0.12 a		
50	70	0.8	6.3	±	0.12 a		0.28
50	70	1.2	6.1	±	0.11 a		

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 32. Effect of sourdough (40 and 70%) on pasteboardy score of white bread at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Pasteboardy			P-value
30	0.8	40	5.8	±	0.12 a	0.31
30	0.8	70	6.0	±	0.12 a	
30	1.2	40	6.2	±	0.12 a	1
30	1.2	70	6.2	±	0.11 a	
50	0.8	40	6.1	±	0.13 a	0.15
50	0.8	70	6.3	±	0.12 a	
50	1.2	40	6.3	±	0.12 a	0.26
50	1.2	70	6.1	±	0.11 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 33. Effect of kefir (30 and 50%) on pasteboardy score of white bread at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Pasteboardy			%	P-value
						Change	
40	0.8	30	5.8	±	0.12 a		0.12
40	0.8	50	6.1	±	0.13 a		
40	1.2	30	6.2	±	0.12 a		0.57
40	1.2	50	6.3	±	0.12 a		
70	0.8	30	5.9	±	0.12 b		0.047
70	0.8	50	6.3	±	0.12 a	7.0	
70	1.2	30	6.2	±	0.11 a		0.57
70	1.2	50	6.2	±	0.11 a		

^aMean (n=64) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 34. Effect of NaCl (0.8 and 1.2%) on aroma score of white bread at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Aroma			P-value
0	0	0.8	5.1	±	0.16 a	0.23
0	0	1.2	5.6	±	0.15 a	
30	40	0.8	6.1	±	0.12 a	0.1
30	40	1.2	6.4	±	0.12 a	
30	70	0.8	6.1	±	0.12 a	0.19
30	70	1.2	6.3	±	0.13 a	
50	40	0.8	6.3	±	0.12 a	0.93
50	40	1.2	6.5	±	0.11 a	
50	70	0.8	6.3	±	0.13 a	0.53
50	70	1.2	6.2	±	0.14 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 35. Effect of sourdough (40 and 70%) on aroma score of white bread at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Aroma			P-value
30	0.8	40	6.1	±	0.12 a	0.96
30	0.8	70	6.1	±	0.12 a	
30	1.2	40	6.4	±	0.12 a	0.78
30	1.2	70	6.3	±	0.13 a	
50	0.8	40	6.2	±	0.12 a	0.69
50	0.8	70	6.3	±	0.13 a	
50	1.2	40	6.5	±	0.11 a	0.56
50	1.2	70	6.2	±	0.14 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 36. Effect of kefir (30 and 50%) on aroma score of white bread at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Aroma			P-value
40	0.8	30	6.1	±	0.12 a	0.31
40	0.8	50	6.2	±	0.12 a	
40	1.2	30	6.4	±	0.12 a	0.29
40	1.2	50	6.5	±	0.11 a	
70	0.8	30	6.1	±	0.12 a	0.18
70	0.8	50	6.3	±	0.13 a	
70	1.2	30	6.3	±	0.13 a	0.56
70	1.2	50	6.2	±	0.14 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 37. Effect of NaCl (0.8 and 1.2%) on bitterness score of white bread at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Bitterness			P-value
0	0	0.8	4.9	±	0.14 a	0.34
0	0	1.2	5.2	±	0.13 a	
30	40	0.8	5.8	±	0.10 a	0.12
30	40	1.2	6.3	±	0.10 a	
30	70	0.8	5.7	±	0.12 a	0.58
30	70	1.2	6.1	±	0.11 a	
50	40	0.8	6.1	±	0.11 a	0.39
50	40	1.2	6.2	±	0.11 a	
50	70	0.8	6.1	±	0.13 a	0.21
50	70	1.2	5.9	±	0.12 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 38. Effect of sourdough (40 and 70%) on bitterness score of white bread at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Bitterness			P-value
30	0.8	40	5.8	±	0.10 a	0.51
30	0.8	70	5.7	±	0.12 a	
30	1.2	40	6.3	±	0.10 a	0.21
30	1.2	70	6.1	±	0.11 a	
50	0.8	40	6.1	±	0.11 a	0.83
50	0.8	70	6.1	±	0.13 a	
50	1.2	40	6.2	±	0.11 a	0.58
50	1.2	70	5.9	±	0.12 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are significantly different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 39. Effect of kefir (30 and 50%) on bitterness score of white bread at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Bitterness			P-value
40	0.8	30	5.8	±	0.10 a	0.15
40	0.8	50	6.1	±	0.11 a	
40	1.2	30	6.3	±	0.10 a	0.82
40	1.2	50	6.2	±	0.11 a	
70	0.8	30	5.7	±	0.12 a	0.21
70	0.8	50	6.1	±	0.13 a	
70	1.2	30	6.1	±	0.11 a	0.39
70	1.2	50	5.9	±	0.12 a	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 40. Effect of NaCl (0.8 and 1.2%) on overall palatability score of white bread at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Overall Palatability			% Change	P-value
0	0	0.8	4.9	±	0.15 b		0.0003
0	0	1.2	5.6	±	0.14 a	14.3	
30	40	0.8	6.1	±	0.11 b		0.026
30	40	1.2	6.5	±	0.09 a	6.6	
30	70	0.8	5.9	±	0.12 a		0.056
30	70	1.2	6.3	±	0.11 a		
50	40	0.8	6.2	±	0.12 b		0.025
50	40	1.2	6.6	±	0.10 a	6.5	
50	70	0.8	6.3	±	0.13 a		0.66
50	70	1.2	6.3	±	0.12 a		

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 41. Effect of sourdough (40 and 70%) on overall palatability score of white bread at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Overall Palatability			% Change	P-value
30	0.8	40	6.1	±	0.11 a		0.34
30	0.8	70	6.0	±	0.12 a		
30	1.2	40	6.5	±	0.09 a		0.21
30	1.2	70	6.3	±	0.11 a		
50	0.8	40	6.2	±	0.12 a		0.54
50	0.8	70	6.3	±	0.12 a		
50	1.2	40	6.6	±	0.18 a		0.039
50	1.2	70	6.3	±	0.12 b	-5.0	

^aMean (n=64) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 42. Effect of kefir (30 and 50%) on overall palatability score of white bread at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Overall Palatability			% Change	P-value
40	0.8	30	6.1	±	0.10 a		0.58
40	0.8	50	6.2	±	0.12 a		
40	1.2	30	6.5	±	0.09 a		0.57
40	1.2	50	6.6	±	0.09 a		
70	0.8	30	6.0	±	0.12 b		0.034
70	0.8	50	6.4	±	0.12 a	6.7	
70	1.2	30	6.3	±	0.11 a		0.82
70	1.2	50	6.3	±	0.12 a		

^aMean (n=64) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance. Sensory score in 9-point hedonic scale with 1=dislike extremely and 9=like extremely.

Table 43. Effect of storage days on firmness (g) of bread crumb containing different levels of kefir (0, 30 and 50%), sourdough (0, 40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Kefir(%)	Sourdough(%)	NaCl(%)	Day	Force (g)			%Change	%Change	P-value
0	0	0.8	1	160.8	±	19.1 b			0.048
0	0	0.8	4	263.4	±	22.5 ab			
0	0	0.8	7	347.7	±	23.4 a	116.3		
0	0	1.2	1	159.04	±	10.3 a			0.087
0	0	1.2	4	264.6	±	27.3 a			
0	0	1.2	7	324.2	±	16.9 a			
30	40	0.8	1	682.9	±	53.1 c			<0.0001
30	40	0.8	4	941.5	±	29.6 b	37.8		
30	40	0.8	7	1092.6	±	78.4 a	60.0	16.1	
30	40	1.2	1	669.6	±	44.1 b			<0.0001
30	40	1.2	4	959.4	±	105.9 a	43.3		
30	40	1.2	7	1067.8	±	67.7 a	59.5		
30	70	0.8	1	428.2	±	7.9 b			0.0002
30	70	0.8	4	692.9	±	48.7 a	61.8		
30	70	0.8	7	725.2	±	42.3 a	69.4		
30	70	1.2	1	426.5	±	39.4 b			0.0001
30	70	1.2	4	651.5	±	100.7 a	52.8		
30	70	1.2	7	757.9	±	94.2 a	77.7		
50	40	0.8	1	535.4	±	31.2 b			0.0007
50	40	0.8	4	748.8	±	77.1 a	39.8		
50	40	0.8	7	824.4	±	68.6 a	54.0		
50	40	1.2	1	668.5	±	33.4 b			0.0005
50	40	1.2	4	885.4	±	80.9 a	32.4		
50	40	1.2	7	969.4	±	48.2 a	45.1		
50	70	0.8	1	336.4	±	10.4 b			0.023
50	70	0.8	4	494.8	±	31.8 a	47.1		
50	70	0.8	7	534.7	±	26.2 a	59.0		
50	70	1.2	1	458.8	±	38.5 b			0.007
50	70	1.2	4	651.9	±	37.5 a	42.1		
50	70	1.2	7	680.1	±	36.1 a	48.2		

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir, sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 44. Effect of NaCl (0.8 and 1.2%) on firmness (g) of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in Day 1^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	Force (g)			P-value
1	0	0	0.8	160.8	±	19.1 a	0.98
1	0	0	1.2	159.1	±	10.3 a	
1	30	40	0.8	682.9	±	53.1 a	0.86
1	30	40	1.2	669.6	±	44.1 a	
1	30	70	0.8	428.2	±	7.9 a	0.98
1	30	70	1.2	426.5	±	39.4 a	
1	50	40	0.8	535.4	±	31.1 a	0.078
1	50	40	1.2	668.5	±	33.4 a	
1	50	70	0.8	336.4	±	10.4 a	0.104
1	50	70	1.2	458.8	±	38.5 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 45. Effect of NaCl (0.8 and 1.2%) on firmness (g) bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 4^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	Force (g)			% Change	P-value
4	0	0	0.8	263.4	±	22.5 a		0.99
4	0	0	1.2	264.6	±	27.3 a		
4	30	40	0.8	941.5	±	29.6 a		0.81
4	30	40	1.2	959.4	±	105.9 a		
4	30	70	0.8	692.9	±	48.7 a		0.58
4	30	70	1.2	651.5	±	100.7 a		
4	50	40	0.8	748.8	±	77.1 a		0.07
4	50	40	1.2	885.4	±	80.9 a		
4	50	70	0.8	494.8	±	31.8 b		0.038
4	50	70	1.2	651.9	±	37.5 a	32.0	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 46. Effect of NaCl (0.8 and 1.2%) on firmness (g) of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 7^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	Force (g)			P-value
7	0	0	0.8	347.7	±	23.3 a	0.75
7	0	0	1.2	324.2	±	16.9 a	
7	30	40	0.8	1092.6	±	78.4 a	0.74
7	30	40	1.2	1067.8	±	67.7 a	
7	30	70	0.8	725.2	±	42.3 a	0.66
7	30	70	1.2	757.9	±	94.2 a	
7	50	40	0.8	824.4	±	68.6 a	0.06
7	50	40	1.2	969.4	±	48.2 a	
7	50	70	0.8	534.7	±	26.2 a	0.05
7	50	70	1.2	680.1	±	36.1 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 47. Effect of sourdough (40 and 70%) on firmness (g) of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 1^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	Force (g)			% Change	P-value
1	30	0.8	40	682.9	±	53.1a	-37.3	0.001
1	30	0.8	70	428.2	±	7.9 b		
1	30	1.2	40	669.6	±	44.1 a	-36.3	0.002
1	30	1.2	70	426.5	±	39.4 b		
1	50	0.8	40	535.4	±	31.1 a	-37.2	0.009
1	50	0.8	70	336.4	±	10.4 b		
1	50	1.2	40	668.5	±	33.4 a	-31.4	0.006
1	50	1.2	70	458.8	±	38.5 b		

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 48. Effect of sourdough (40 and 70%) on firmness (g) of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 4^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	Force (g)			% Change	P-value
4	30	0.8	40	941.5	±	29.6 a		0.001
4	30	0.8	70	692.9	±	48.7 b	-26.4	
4	30	1.2	40	959.4	±	105.9 a		0.0001
4	30	1.2	70	651.5	±	100.7 b	-32.1	
4	50	0.8	40	748.8	±	77.1 a		0.0011
4	50	0.8	70	494.8	±	31.8 b	-34.0	
4	50	1.2	40	885.4	±	80.9 a		0.003
4	50	1.2	70	651.9	±	37.5 b	-26.4	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 49. Effect of sourdough (40 and 70%) on firmness (g) of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 7^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	Force (g)			% Change	P- value
7	30	0.8	40	1092.6	±	78.4 a		<0.0001
7	30	0.8	70	725.2	±	42.3 b	-33.6	
7	30	1.2	40	1067.8	±	67.7 a		<0.0001
7	30	1.2	70	757.9	±	94.2 b	-29.1	
7	50	0.8	40	824.4	±	68.6 a		0.0002
7	50	0.8	70	534.7	±	26.2 b	-35.1	
7	50	1.2	40	969.4	±	48.2 a		0.0002
7	50	1.2	70	680.1	±	36.1 b	-29.8	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 50. Effect of kefir (30 and 50%) on firmness (g) of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 1^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	Force (g)			P-value
1	40	0.8	30	682.9	±	53.1 a	0.051
1	40	0.8	50	535.4	±	31.1 a	
1	40	1.2	30	669.6	±	44.1 a	0.99
1	40	1.2	50	668.5	±	33.4 a	
1	70	0.8	30	428.2	±	7.9 a	0.22
1	70	0.8	50	336.4	±	10.4 a	
1	70	1.2	30	426.5	±	39.4 a	0.66
1	70	1.2	50	458.8	±	38.5 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 51. Effect of kefir (30 and 50%) on firmness (g) of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 4^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	Force (g)			% Change	P-value
4	40	0.8	30	941.5	±	29.6 a	-20.5	0.012
4	40	0.8	50	748.8	±	77.1 b		
4	40	1.2	30	959.4	±	105.9 a		0.32
4	40	1.2	50	885.4	±	80.9 a		
4	70	0.8	30	692.9	±	48.7 a	-28.6	0.009
4	70	0.8	50	494.8	±	31.8 b		
4	70	1.2	30	651.5	±	100.7 a		0.99
4	70	1.2	50	651.9	±	37.5 a		

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 52. Effect of kefir (30 and 50%) on firmness (g) of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 7^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	Force (g)			% Change	P-value
7	40	0.8	30	1092.6	±	78.4 a		0.0006
7	40	0.8	50	824.4	±	68.6 b	-24.5	
7	40	1.2	30	1067.8	±	67.7 a		0.19
7	40	1.2	50	969.4	±	48.2 a		
7	70	0.8	30	725.2	±	42.3 a		0.013
7	70	0.8	50	534.7	±	26.2 b	-26.3	
7	70	1.2	30	757.9	±	94.2 a		0.29
7	70	1.2	50	680.1	±	36.1 a		

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 53. Effect of NaCl (0.8 and 1.2%) on dough recovery index (%) of wheat dough at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Dough recovery index			% Change	P-value
0	0	0.8	17.9	±	0.39 a		0.6824
0	0	1.2	17.6	±	0.41 a		
30	40	0.8	12.1	±	0.64 a		0.712
30	40	1.2	12.3	±	0.39 a		
30	70	0.8	13.9	±	0.49 a		0.0005
30	70	1.2	11.4	±	0.29 b	-18.0	
50	40	0.8	13.9	±	0.34 a		0.2242
50	40	1.2	13.1	±	0.28 a		
50	70	0.8	13.5	±	0.63 a		0.3354
50	70	1.2	14.1	±	0.37 a		

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 54. Effect of sourdough (40 and 70%) on dough recovery index (%) of wheat dough at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Dough recovery index			% Change	P-value
30	0.8	40	12.1	±	0.63 b		0.0076
30	0.8	70	13.9	±	0.49 a	14.9	
30	1.2	40	12.3	±	0.39 a		0.1441
30	1.2	70	11.4	±	0.29 a		
50	0.8	40	13.9	±	0.34 a		0.523
50	0.8	70	13.5	±	0.63a		
50	1.2	40	13.1	±	0.28 a		0.1273
50	1.2	70	14.1	±	0.37 a		

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 55. Effect of kefir (30 and 50%) on dough recovery index (%) of wheat dough at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Dough recovery index			% Change	P-value
40	0.8	30	12.1	±	0.64 b		0.0082
40	0.8	50	13.9	±	0.34 a	14.9	
40	1.2	30	12.3	±	0.39 a		0.2061
40	1.2	50	13.1	±	0.28 a		
70	0.8	30	13.9	±	0.49 a		0.5008
70	0.8	50	13.5	±	0.63 a		
70	1.2	30	11.4	±	0.29 b		0.0003
70	1.2	50	14.1	±	0.37 a	23.7	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 56. Effect of storage days on L* value of bread crumb at different levels of kefir (0, 30 and 50%), sourdough (0, 40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Day	L* value			P-value
0	0	0.8	1	82.9	±	0.97 a	0.0448
0	0	0.8	4	81.6	±	0.76 ab	
0	0	0.8	7	80.6	±	0.57 b	
0	0	1.2	1	82.3	±	0.92 a	0.6131
0	0	1.2	4	81.5	±	0.79 a	
0	0	1.2	7	81.6	±	0.85 a	
30	40	0.8	1	81.5	±	0.69 a	0.2793
30	40	0.8	4	80.5	±	0.81 a	
30	40	0.8	7	80.1	±	1.15 a	
30	40	1.2	1	80.8	±	0.37 a	0.8585
30	40	1.2	4	80.6	±	0.39 a	
30	40	1.2	7	80.3	±	0.51 a	
30	70	0.8	1	81.2	±	0.61 a	0.8501
30	70	0.8	4	80.9	±	0.55 a	
30	70	0.8	7	80.7	±	0.84 a	
30	70	1.2	1	81.8	±	0.5 a	0.6553
30	70	1.2	4	81.3	±	0.39 a	
30	70	1.2	7	80.9	±	0.26 a	
50	40	0.8	1	80.3	±	0.05 a	0.8147
50	40	0.8	4	79.9	±	0.18 a	
50	40	0.8	7	79.8	±	0.13 a	
50	40	1.2	1	80.5	±	0.31 a	0.9638
50	40	1.2	4	80.2	±	0.15 a	
50	40	1.2	7	80.3	±	0.41 a	
50	70	0.8	1	81.7	±	0.8 a	0.6136
50	70	0.8	4	81.4	±	0.68 a	
50	70	0.8	7	80.8	±	0.79 a	
50	70	1.2	1	81.1	±	0.39 a	0.8837
50	70	1.2	4	81.1	±	0.54 a	
50	70	1.2	7	80.7	±	1.0 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir, sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 57. Effect of storage days on a* value of bread crumb at different levels of kefir (0, 30 and 50%), sourdough (0, 40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Day	a* value			P-Value
0	0	0.8	1	-0.23	±	0.19 a	0.999
0	0	0.8	4	-0.23	±	0.12 a	
0	0	0.8	7	-0.22	±	0.10 a	
0	0	1.2	1	-0.33	±	0.18 a	0.8337
0	0	1.2	4	-0.38	±	0.08 a	
0	0	1.2	7	-0.23	±	0.08 a	
30	40	0.8	1	0.87	±	0.11 a	0.873
30	40	0.8	4	0.92	±	0.13 a	
30	40	0.8	7	1	±	0.15 a	
30	40	1.2	1	0.95	±	0.10 a	0.9665
30	40	1.2	4	0.95	±	0.07 a	
30	40	1.2	7	1	±	0.08 a	
30	70	0.8	1	0.62	±	0.19 a	0.9494
30	70	0.8	4	0.65	±	0.14 a	
30	70	0.8	7	0.7	±	0.21 a	
30	70	1.2	1	0.65	±	0.10 a	0.9952
30	70	1.2	4	0.64	±	0.12 a	
30	70	1.2	7	0.62	±	0.13 a	
50	40	0.8	1	1.02	±	0.12 a	0.9886
50	40	0.8	4	1.06	±	0.12 a	
50	40	0.8	7	1.05	±	0.13 a	
50	40	1.2	1	0.91	±	0.18 a	0.9504
50	40	1.2	4	0.97	±	0.19 a	
50	40	1.2	7	0.99	±	0.17 a	
50	70	0.8	1	0.67	±	0.24 a	0.9952
50	70	0.8	4	0.64	±	0.32 a	
50	70	0.8	7	0.65	±	0.29 a	
50	70	1.2	1	0.71	±	0.28 a	0.9701
50	70	1.2	4	0.65	±	0.29 a	
50	70	1.2	7	0.69	±	0.30 a	

^aMean (n=5) ± standard error. Means in the same column and within same kefir, sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 58. Effect of storage days on b* value of bread crumb at different levels of kefir (0, 30 and 50%), sourdough (0, 40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Day	b* value			P-value
0	0	0.8	1	15.5	±	0.57 a	0.9209
0	0	0.8	4	15.5	±	0.53 a	
0	0	0.8	7	15.7	±	0.46 a	
0	0	1.2	1	15.2	±	0.47 a	0.9285
0	0	1.2	4	15.3	±	0.45 a	
0	0	1.2	7	15.3	±	0.31 a	
30	40	0.8	1	17.6	±	0.22 a	0.7598
30	40	0.8	4	17.8	±	0.21 a	
30	40	0.8	7	17.9	±	0.37 a	
30	40	1.2	1	17.9	±	0.10 a	0.8609
30	40	1.2	4	17.8	±	0.07 a	
30	40	1.2	7	18.1	±	0.16 a	
30	70	0.8	1	17.5	±	0.15 a	0.8688
30	70	0.8	4	17.3	±	0.05 a	
30	70	0.8	7	17.4	±	0.36 a	
30	70	1.2	1	17.2	±	0.11 a	0.9893
30	70	1.2	4	17.2	±	0.10 a	
30	70	1.2	7	17.2	±	0.14 a	
50	40	0.8	1	18.1	±	0.09 a	0.9972
50	40	0.8	4	18.1	±	0.26 a	
50	40	0.8	7	18.1	±	0.18 a	
50	40	1.2	1	17.9	±	0.13 a	0.9903
50	40	1.2	4	17.9	±	0.09 a	
50	40	1.2	7	17.9	±	0.05 a	
50	70	0.8	1	17.2	±	0.35 a	0.9397
50	70	0.8	4	17.1	±	0.37 a	
50	70	0.8	7	17.1	±	0.45 a	
50	70	1.2	1	17.4	±	0.44 a	0.7951
50	70	1.2	4	17.1	±	0.40 a	
50	70	1.2	7	17.2	±	0.55 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir, sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 59. Effect of NaCl (0.8 and 1.2%) on L* value of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 1^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	L* value			P-value
1	0	0	0.8	82.9	±	0.97 a	0.5302
1	0	0	1.2	82.3	±	0.92 a	
1	30	40	0.8	81.5	±	0.69 a	0.4303
1	30	40	1.2	80.8	±	0.37 a	
1	30	70	0.8	81.2	±	0.61 a	0.5464
1	30	70	1.2	81.7	±	0.50 a	
1	50	40	0.8	80.3	±	0.05 a	0.8942
1	50	40	1.2	80.5	±	0.31 a	
1	50	70	0.8	81.6	±	0.80 a	0.5198
1	50	70	1.2	81.1	±	0.39 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir, sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 60. Effect of NaCl (0.8 and 1.2%) on L* value of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 4^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	L* value			P-value
4	0	0	0.8	81.6	±	0.76 a	0.8861
4	0	0	1.2	81.5	±	0.79 a	
4	30	40	0.8	80.5	±	0.81 a	0.9065
4	30	40	1.2	80.6	±	0.39 a	
4	30	70	0.8	80.9	±	0.55 a	0.7102
4	30	70	1.2	81.3	±	0.39 a	
4	50	40	0.8	79.9	±	0.18 a	0.7021
4	50	40	1.2	80.2	±	0.15 a	
4	50	70	0.8	81.4	±	0.68 a	0.6962
4	50	70	1.2	81.1	±	0.54 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir, sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 61. Effect of NaCl (0.8 and 1.2%) on L* value of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 7^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	L* value			P-value
7	0	0	0.8	80.6	±	0.57 a	0.2456
7	0	0	1.2	81.6	±	0.85 a	
7	30	40	0.8	80.1	±	1.15 a	0.8229
7	30	40	1.2	80.3	±	0.51 a	
7	30	70	0.8	80.7	±	0.84 a	0.8026
7	30	70	1.2	80.9	±	0.26 a	
7	50	40	0.8	79.8	±	0.13 a	0.611
7	50	40	1.2	80.3	±	0.41 a	
7	50	70	0.8	80.8	±	0.79 a	0.9005
7	50	70	1.2	80.7	±	1.01a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 62. Effect of NaCl (0.8 and 1.2%) in a* value of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 1^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	a* value			P-value
1	0	0	0.8	-0.23	±	0.19 a	0.6781
1	0	0	1.2	-0.33	±	0.18 a	
1	30	40	0.8	0.87	±	0.11 a	0.7622
1	30	40	1.2	0.95	±	0.10 a	
1	30	70	0.8	0.62	±	0.19 a	0.9175
1	30	70	1.2	0.65	±	0.10 a	
1	50	40	0.8	1.02	±	0.12 a	0.6651
1	50	40	1.2	0.91	±	0.18 a	
1	50	70	0.8	0.66	±	0.24 a	0.8561
1	50	70	1.2	0.71	±	0.28 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 63. Effect of NaCl (0.8 and 1.2%) in a* value of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 4^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	a* value			P-value
4	0	0	0.8	-0.23	±	0.12 a	0.5517
4	0	0	1.2	-0.38	±	0.08 a	
4	30	40	0.8	0.92	±	0.13 a	0.8928
4	30	40	1.2	0.95	±	0.07 a	
4	30	70	0.8	0.65	±	0.14 a	0.9667
4	30	70	1.2	0.64	±	0.12 a	
4	50	40	0.8	1.06	±	0.12 a	0.7063
4	50	40	1.2	0.97	±	0.19 a	
4	50	70	0.8	0.64	±	0.32 a	0.9639
4	50	70	1.2	0.65	±	0.29 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 64. Effect of NaCl (0.8 and 1.2%) in a* value of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 7^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	a* value			P-value
7	0	0	0.8	-0.2	±	0.09 a	0.9637
7	0	0	1.2	-0.23	±	0.08 a	
7	30	40	0.8	1	±	0.15 a	0.982
7	30	40	1.2	1	±	0.08 a	
7	30	70	0.8	0.7	±	0.21 a	0.7569
7	30	70	1.2	0.6	±	0.13 a	
7	50	40	0.8	1.1	±	0.13 a	0.8336
7	50	40	1.2	0.99	±	0.17 a	
7	50	70	0.8	0.7	±	0.29 a	0.8527
7	50	70	1.2	0.7	±	0.30 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 65. Effect of NaCl (0.8 and 1.2%) in b* value of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 1^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	b* value			P-value
1	0	0	0.8	15.5	±	0.58 a	0.419
1	0	0	1.2	15.2	±	0.47 a	
1	30	40	0.8	17.6	±	0.22 a	0.4604
1	30	40	1.2	17.9	±	0.08 a	
1	30	70	0.8	17.5	±	0.15 a	0.4995
1	30	70	1.2	17.2	±	0.11 a	
1	50	40	0.8	18.1	±	0.096 a	0.6906
1	50	40	1.2	17.9	±	0.13 a	
1	50	70	0.8	17.2	±	0.35 a	0.7189
1	50	70	1.2	17.4	±	0.44 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 66. Effect of NaCl (0.8 and 1.2%) in b* value of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 4^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	b* value			P-value
4	0	0	0.8	15.5	±	0.53 a	0.6389
4	0	0	1.2	15.3	±	0.45 a	
4	30	40	0.8	17.8	±	0.21 a	0.954
4	30	40	1.2	17.8	±	0.07 a	
4	30	70	0.8	17.3	±	0.05 a	0.7756
4	30	70	1.2	17.2	±	0.09 a	
4	50	40	0.8	18.1	±	0.26 a	0.7835
4	50	40	1.2	17.9	±	0.09 a	
4	50	70	0.8	17.1	±	0.37 a	0.9385
4	50	70	1.2	17.1	±	0.40 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 67. Effect of NaCl (0.8 and 1.2%) in b* value of bread crumb at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%) in day 7^a.

Day	Kefir (%)	Sourdough (%)	NaCl (%)	b* value			P-value
7	0	0	0.8	15.7	±	0.45 a	0.4645
7	0	0	1.2	15.3	±	0.31 a	
7	30	40	0.8	17.9	±	0.37 a	0.9289
7	30	40	1.2	18.1	±	0.16 a	
7	30	70	0.8	17.4	±	0.36 a	0.7319
7	30	70	1.2	17.2	±	0.14 a	
7	50	40	0.8	18.1	±	0.18 a	0.6608
7	50	40	1.2	17.9	±	0.05 a	
7	50	70	0.8	17.1	±	0.45 a	0.9568
7	50	70	1.2	17.2	±	0.55 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and sourdough followed by different letter are statistically different at a 0.05 level of significance.

Table 68. Effect of sourdough (40 and 70%) on L* value of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 1^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	L* value			P-value
1	30	0.8	40	81.5	±	0.69 a	0.7322
1	30	0.8	70	81.2	±	0.61 a	
1	30	1.2	40	80.8	±	0.37 a	0.2949
1	30	1.2	70	81.8	±	0.50 a	
1	50	0.8	40	80.3	±	0.05 a	0.1494
1	50	0.8	70	81.7	±	0.80 a	
1	50	1.2	40	80.5	±	0.31 a	0.4995
1	50	1.2	70	81.1	±	0.39 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 69. Effect of sourdough (40 and 70%) on L* value of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 4^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	L* value			P-value
4	30	0.8	40	80.5	±	0.81 a	0.5856
4	30	0.8	70	80.9	±	0.55 a	
4	30	1.2	40	80.6	±	0.39 a	0.4248
4	30	1.2	70	81.3	±	0.38 a	
4	50	0.8	40	79.9	±	0.18 a	0.0983
4	50	0.8	70	81.4	±	0.68 a	
4	50	1.2	40	80.2	±	0.15 a	0.3702
4	50	1.2	70	81.1	±	0.54 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 70. Effect of sourdough (40 and 70%) on L* value of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 7^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	L* value			P-value
7	30	0.8	40	80.1	±	1.15 a	0.5145
7	30	0.8	70	80.7	±	0.84 a	
7	30	1.2	40	80.3	±	0.51 a	0.4978
7	30	1.2	70	80.9	±	0.26 a	
7	50	0.8	40	79.8	±	0.13 a	0.2775
7	50	0.8	70	80.8	±	0.79 a	
7	50	1.2	40	80.3	±	0.41 a	0.6477
7	50	1.2	70	80.7	±	1.0 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 71. Effect of sourdough (40 and 70%) on a* value of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 1^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	a* value			P-value
1	30	0.8	40	0.87	±	0.11 a	0.331
1	30	0.8	70	0.62	±	0.19 a	
1	30	1.2	40	0.95	±	0.10 a	0.2426
1	30	1.2	70	0.65	±	0.10 a	
1	50	0.8	40	1.02	±	0.12 a	0.164
1	50	0.8	70	0.67	±	0.24 a	
1	50	1.2	40	0.91	±	0.18 a	0.4315
1	50	1.2	70	0.71	±	0.28 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 72. Effect of sourdough (40 and 70%) on a* value of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 4^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	a* value			P-value
4	30	0.8	40	0.92	±	0.13 a	0.2957
4	30	0.8	70	0.65	±	0.14 a	
4	30	1.2	40	0.95	±	0.07 a	0.2227
4	30	1.2	70	0.64	±	0.12 a	
4	50	0.8	40	1.06	±	0.12 a	0.1027
4	50	0.8	70	0.64	±	0.32 a	
4	50	1.2	40	0.96	±	0.19 a	0.2224
4	50	1.2	70	0.65	±	0.29 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 73. Effect of sourdough (40 and 70%) on a* value of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 7^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	a* value			P-value
7	30	0.8	40	1	±	0.15 a	0.2437
7	30	0.8	70	0.7	±	0.21 a	
7	30	1.2	40	1	±	0.08 a	0.136
7	30	1.2	70	0.62	±	0.13 a	
7	50	0.8	40	1.05	±	0.13 a	0.1256
7	50	0.8	70	0.65	±	0.29 a	
7	50	1.2	40	0.99	±	0.17 a	0.2523
7	50	1.2	70	0.69	±	0.30 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 74. Effect of sourdough (40 and 70%) on b* value of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 1^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	b* value			P-value
1	30	0.8	40	17.6	±	0.22 a	0.8038
1	30	0.8	70	17.5	±	0.15 a	
1	30	1.2	40	17.9	±	0.08 a	0.0997
1	30	1.2	70	17.2	±	0.11 a	
1	50	0.8	40	18.1	±	0.09 a	0.0658
1	50	0.8	70	17.2	±	0.35 a	
1	50	1.2	40	17.9	±	0.13 a	0.2705
1	50	1.2	70	17.4	±	0.44 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 75. Effect of sourdough (40 and 70%) on b* value of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 4^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	b* value			% Change	P-value
4	30	0.8	40	17.8	±	0.21 a		0.3085
4	30	0.8	70	17.3	±	0.05 a		
4	30	1.2	40	17.8	±	0.07 a		0.1754
4	30	1.2	70	17.2	±	0.09 a		
4	50	0.8	40	18.1	±	0.26 a	- 5.5	0.0357
4	50	0.8	70	17.1	±	0.37 b		
4	50	1.2	40	17.9	±	0.09 a		0.0777
4	50	1.2	70	17.1	±	0.40 a		

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 76. Effect of sourdough (40 and 70%) on b* value of bread crumb at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%) in day 7^a.

Day	Kefir (%)	NaCl (%)	Sourdough (%)	b* value			% Change	P-value
7	30	0.8	40	17.9	±	0.37 a		0.1911
7	30	0.8	70	17.4	±	0.36 a		
7	30	1.2	40	18	±	0.16 a		0.0842
7	30	1.2	70	17.2	±	0.14 a		
7	50	0.8	40	18.1	±	0.18 a	-5.5	0.045
7	50	0.8	70	17.1	±	0.45 b		
7	50	1.2	40	17.9	±	0.05 a		0.126
7	50	1.2	70	17.2	±	0.55 a		

^aMean (n=5) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 77. Effect of kefir (30 and 50%) on L* value of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 1^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	L* value			P-value
1	40	0.8	30	81.5	±	0.69 a	0.2014
1	40	0.8	50	80.3	±	0.05 a	
1	40	1.2	30	80.8	±	0.37 a	0.7169
1	40	1.2	50	80.5	±	0.31 a	
1	70	0.8	30	81.2	±	0.61 a	0.6103
1	70	0.8	50	81.7	±	0.80 a	
1	70	1.2	30	81.8	±	0.50 a	0.4612
1	70	1.2	50	81.1	±	0.39 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 78. Effect of kefir (30 and 50%) on L* value of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 4^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	L* value			P-value
4	40	0.8	30	80.5	±	0.81 a	0.5061
4	40	0.8	50	79.9	±	0.18 a	
4	40	1.2	30	80.6	±	0.39 a	0.6887
4	40	1.2	50	80.2	±	0.15 a	
4	70	0.8	30	80.9	±	0.55 a	0.6456
4	70	0.8	50	81.4	±	0.67 a	
4	70	1.2	30	81.3	±	0.39 a	0.7626
4	70	1.2	50	81.1	±	0.54 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 79. Effect of kefir (30 and 50%) on L* value of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 7^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	L* value			P-value
7	40	0.8	30	80.1	±	1.15 a	0.7465
7	40	0.8	50	79.8	±	0.13 a	
7	40	1.2	30	80.3	±	0.51 a	0.9695
7	40	1.2	50	80.3	±	0.41 a	
7	70	0.8	30	80.7	±	0.84 a	0.9084
7	70	0.8	50	80.8	±	0.79 a	
7	70	1.2	30	80.9	±	0.26 a	0.7949
7	70	1.2	50	80.7	±	1.0 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 80. Effect of kefir (30 and 50%) on a* value of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 1^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	a* value			P-value
1	40	0.8	30	0.9	±	0.11 a	0.5459
1	40	0.8	50	1.02	±	0.12 a	
1	40	1.2	30	0.95	±	0.10 a	0.8957
1	40	1.2	50	0.91	±	0.18 a	
1	70	0.8	30	0.62	±	0.19 a	0.8591
1	70	0.8	50	0.67	±	0.24 a	
1	70	1.2	30	0.65	±	0.10 a	0.7985
1	70	1.2	50	0.71	±	0.28 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 81. Effect of kefir (30 and 50%) on a* value of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 4^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	a* value			P-value
4	40	0.8	30	0.92	±	0.13 a	0.5683
4	40	0.8	50	1.06	±	0.12 a	
4	40	1.2	30	0.95	±	0.07 a	0.9525
4	40	1.2	50	0.97	±	0.19 a	
4	70	0.8	30	0.65	±	0.14 a	0.9774
4	70	0.8	50	0.64	±	0.32 a	
4	70	1.2	30	0.64	±	0.12 a	0.9532
4	70	1.2	50	0.65	±	0.29 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 82. Effect of kefir (30 and 50%) on a* value of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 7^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	a* value			P- value
7	40	0.8	30	1	±	0.15 a	0.856
7	40	0.8	50	1.05	±	0.12 a	
7	40	1.2	30	1.01	±	0.08 a	0.9592
7	40	1.2	50	0.99	±	0.17 a	
7	70	0.8	30	0.7	±	0.21 a	0.8471
7	70	0.8	50	0.65	±	0.29 a	
7	70	1.2	30	0.62	±	0.13 a	0.7624
7	70	1.2	50	0.69	±	0.30 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 83. Effect of kefir (30 and 50%) on b* value of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 1^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	b* value			P-value
1	40	0.8	30	17.6	±	0.22 a	0.3173
1	40	0.8	50	18.1	±	0.09 a	
1	40	1.2	30	17.9	±	0.08 a	0.8934
1	40	1.2	50	17.9	±	0.13 a	
1	70	0.8	30	17.5	±	0.15 a	0.5403
1	70	0.8	50	17.2	±	0.35 a	
1	70	1.2	30	17.2	±	0.11 a	0.6722
1	70	1.2	50	17.4	±	0.44 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 84. Effect of kefir (30 and 50%) on b* value of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 4^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	b* value			P-value
4	40	0.8	30	17.8	±	0.21 a	0.4995
4	40	0.8	50	18.1	±	0.26 a	
4	40	1.2	30	17.8	±	0.07 a	0.7309
4	40	1.2	50	17.9	±	0.09 a	
4	70	0.8	30	17.3	±	0.05 a	0.6602
4	70	0.8	50	17.1	±	0.37 a	
4	70	1.2	30	17.2	±	0.10 a	0.9381
4	70	1.2	50	17.1	±	0.40 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 85. Effect of kefir (30 and 50%) on b* value of bread crumb at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%) in day 7^a.

Day	Sourdough (%)	NaCl (%)	Kefir (%)	b* value			P-value
7	40	0.8	30	17.9	±	0.37 a	0.8194
7	40	0.8	50	18.1	±	0.18 a	
7	40	1.2	30	18	±	0.16 a	0.7642
7	40	1.2	50	17.9	±	0.05 a	
7	70	0.8	30	17.4	±	0.36 a	0.6218
7	70	0.8	50	17.1	±	0.45 a	
7	70	1.2	30	17.2	±	0.14 a	0.923
7	70	1.2	50	17.2	±	0.55 a	

^aMean (n=5) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 86. Effect of NaCl (0.8 and 1.2%) on loaf height (per 100g) of white breads at different levels of kefir (0, 30 and 50%) and sourdough (0, 40 and 70%)^a.

Kefir (%)	Sourdough (%)	NaCl (%)	Height (mm)			% Change	P-value
0	0	0.8	23.3	±	0.47 a	0.5504	
0	0	1.2	23.7	±	0.81 a		
30	40	0.8	14.4	±	0.48 a	0.7645	
30	40	1.2	14.2	±	0.39 a		
30	70	0.8	15.9	±	0.41 a	0.518	
30	70	1.2	16.3	±	0.4 a		
50	40	0.8	14.1	±	0.17 a	0.9601	
50	40	1.2	14.1	±	0.13 a		
50	70	0.8	16.8	±	0.61 a	0.0461	
50	70	1.2	15.4	±	0.4 b		

^aMean (n=2) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 87. Effect of sourdough (40 and 70%) on loaf height (per 100g) of white breads at different levels of kefir (30 and 50%) and sodium chloride (0.8 and 1.2%)^a.

Kefir (%)	NaCl (%)	Sourdough (%)	Height (mm)			% Change	P-value
30	0.8	40	14.4	±	0.48 b		0.0338
30	0.8	70	15.9	±	0.41 a	10.4	
30	1.2	40	14.2	±	0.39 b		0.0041
30	1.2	70	16.3	±	0.41 a	14.8	
50	0.8	40	14.1	±	0.17 b		0.0005
50	0.8	70	16.8	±	0.61 a	19.1	
50	1.2	40	14.1	±	0.13 b		0.05
50	1.2	70	15.4	±	0.41 a	9.2	

^aMean (n=2) ± standard error. Means in the same column and within same treatment of kefir and NaCl followed by different letter are statistically different at a 0.05 level of significance.

Table 88. Effect of kefir (30 and 50%) on loaf height (per 100g) of white breads at different levels of sourdough (40 and 70%) and sodium chloride (0.8 and 1.2%)^a.

Sourdough (%)	NaCl (%)	Kefir (%)	Height (mm)			P-value
40	0.8	30	14.4	±	0.48 a	0.6536
40	0.8	50	14.1	±	0.17 a	
40	1.2	30	14.2	±	0.39 a	0.1717
40	1.2	50	14.1	±	0.13 a	
70	0.8	30	15.9	±	0.41 a	0.8416
70	0.8	50	16.8	±	0.61 a	
70	1.2	30	16.3	±	0.41 a	0.1868
70	1.2	50	15.4	±	0.41 a	

^aMean (n=2) ± standard error. Means in the same column and within same treatment of sourdough and NaCl followed by different letter are statistically different at a 0.05 level of significance.

VITA

SABITRI SHARMA GAUTAM

Candidate for the Degree of

Master of Science

Thesis: ASSESSMENT OF KEFIR AND SOURDOUGH ON THE FLAVOR PROFILE,
QUALITY OF WHITE WHEAT BREAD AND RHEOLOGY OF WHEAT DOUGH

Major Field: Food Science

Biographical: Sabitri Sharma Gautam was born in Kathmandu, Nepal on November 9th. She is a daughter of Ananta Raj Sharma and Meena Sharma. After finishing the bachelor degree from Tribhuvan University, Nepal she decided to pursue higher education and moved to Oklahoma in May, 2013. She started her masters in Food Science at Oklahoma State University in fall 2013.

Education:

Completed the requirements for the Master of Science in Food Science at Oklahoma State University, Stillwater, Oklahoma in July, 2015.

Completed the requirements for the Bachelor of Science in Food Science and Technology at Tribhuvan University, Nepal in April, 2012.

Professional Memberships:

Institute of Food Technologist (2015-Present)

ADVISER'S APPROVAL: Dr. Patricia Rayas-Duarte