EFFECTS OF COMPOSITE FLOURS ON QUALITY AND NUTRITIONAL PROFILE OF FLOUR TORTILLAS

A Thesis

by

MARIA GRITSENKO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2009

Major Subject: Food Science and Technology

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ABSTRACT

Effects of Composite Flours on Quality and Nutritional Profile of Flour Tortillas.

(May 2009)

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Obesity, glucose intolerance or insulin resistance and elevated blood pressure are now prevalent in the U.S. Increased intake of dietary fiber, omega-3 fatty acids, and antioxidants may help prevent or manage these diseases. Tortillas are now part of the American diet, and are excellent carriers of higher amounts of fiber and other nutraceutical ingredients. This study was conducted to determine the effects of incorporating nutraceutical ingredients (flaxseed, sorghum bran, oat flour, buckwheat flour) on whole white wheat tortilla quality. Tortillas were prepared using a hot-press, gas-fired oven and were evaluated for physical properties, texture and shelf-stability.

Objective and subjective tests demonstrated that whole white wheat and multigrain tortilla doughs were harder, rougher and less extensible than refined flour tortilla dough. Multigrain flour tortillas were thinner, larger and more translucent than the refined flour treatment. Incorporation of whole multigrain flours affected color of the product, giving darker tortillas. Tortilla flexibility decreased over time. After 16 days of storage rollability scores of tortillas decreased drastically. The most pronounced decrease in tortilla flexibility was observed for 5% sorghum bran, 10% buckwheat, and for the treatment prepared with of 5% flax, 5% sorghum, 5% oat, 5% buckwheat. The flexibility loss was higher for whole white wheat and multigrain tortillas than for the refined one which was confirmed with objective and subjective tests. To extend shelf stability of whole multigrain tortillas various amounts of commercial hydrocolloid and α-amylase were added to the formulation. Tortillas with 75 ppm, 100 ppm of α-amylase, 1% and 1.5% of gum retained their flexibility during 16 days of storage. Consumer acceptability of the whole multigrain tortillas (5% flaxseed, 5% sorghum bran, 5% oat, 5% buckwheat) was compared with commercial multigrain tortillas and whole white wheat flour tortillas using an untrained sensory panel. The multigrain tortillas were liked by the panel as much as the other samples. Prepared multigrain tortillas had improved nutritional value. Each multigrain treatment contained at least 3 g of dietary fiber, 0.29 g of α-linolenic fatty acid, lignans and antioxidants. It makes possible to claim them as a “good source of dietary fiber” and “an excellent source of α-linolenic fatty acid”. The formulations tested, together with future refinements, provide more options to consumers seeking healthier alternatives to refined wheat flour tortillas.

DEDICATION

“Dance like nobody is watching; love like you've never been hurt. Sing like nobody is listening; live like it's heaven on earth”

Mark Twain

To my family for their support, help, advice, understanding and accepting me in the way I am. With time, I am beginning to fully understand and appreciate values you gave me. I believe, the ideals you inspired helped me to avoid many rush actions, that I would regret about in the future. Mama, special thanks to you. You can’t imagine how much I care about you. I realize how difficult it must have been for you to cope with us and how many things you have sacrificed. I am trying to be better, I really do try.

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Special thanks to the Fulbright program that gave me a chance to study in the USA and to develop myself professionally and personally. I believe that such programs, by opening people’s minds, help to make our world a little bit better. I am sure, by learning about each other’s cultures, we will be able to build the world of democracy without racial and religious prejudices, oppression and terrorism.

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CHAPTER I

INTRODUCTION

A tortilla is a flat, round unfermented bread. It can be produced from wheat (*Triticum aestivum* L.) flour or lime cooked maize (*Zea mays* L.) (Serna-Saldivar at el 1988). Good quality wheat flour tortillas are symmetrical, uniform, opaque, and white, with toast spots and they puff during baking (Cepeda et al. 2000). They should be flexible without tearing and cracking when folded and soft without sticking together (Bello et al. 1991). The formula for a traditional wheat flour tortilla includes flour, water, shortening and salt.

Mexican cuisine has a great impact on North American eating habits. According to the Tortilla Industry Association (TIA) in 1998 consumption in the US was more than 75 billion tortillas (Juttlestad 1999). In 2000, tortilla sales reached the $4.4 billion mark, representing a growth rate of 57% over the past four years. There is a growing interest in healthy products. Various chronic diseases can be prevented by lifestyle interventions including changes in diet composition and increase in physical activity. The ingredients that help achieve this goal are whole grains and fibers, specialty oils, especially those containing omega-3 fatty acids, low trans fats levels with low content of saturated fats, many different sources of antioxidants, and protein sources. Whole grains are rich in nutrients and phytochemicals such as dietary fiber, resistant starch, oligosaccharides and antioxidants, including trace minerals and phenolic compounds. Other protective compounds include phytate, phytoestrogens such as lignin, plant stanols, sterols, vitamins and minerals (Slavin, 2007).

This thesis follows the style of Cereal Chemistry.

Traditionally tortillas are consumed the same day of baking. Fresh tortillas are soft, extensible, and flexible.

In the U.S. however, consumption of tortillas usually occurs 1-180 days later. One of the major problems in tortilla quality is the deterioration of texture with time due to staling (Waniska 1999). Staling is the process of reassociation of the starch molecules during storage that causes loss of freshness and increased structure or firmness of bakery products (Zobel and Kulp 1996). To prevent microbial deterioration and increase tortilla shelf-stability reformulation of tortillas has occurred (Cepeda et al. 2000). The addition of antimicrobial agents, leavening agents, acidulants, emulsifiers, and reducing agents promotes improved shelf life (Serna-Saldivar et al. 1988, Waniska 1999). Friend and associates (1993) said that cracking and breaking of tortillas can be postponed by using flour with higher protein quality, adding gluten and some hydrocolloids.

Objectives

1. To develop and characterize whole multigrain flour tortillas containing grains other than wheat in different ratios.

2. To determine the effect of different rates of α-amylase and a commercial hydrocolloid on the dough properties, the overall quality and shelf stability of whole multigrain tortillas.

3. To conduct sensory evaluation of tortillas using a consumer panel.

CHAPTER II

REVIEW OF LITERATURE

U.S. market for tortillas

Tortillas, bagels, English muffins and pita breads are the most popular ethnic breads in the U.S., according to the Tortilla Industry Association (Juttelstad 1999). In 2000, the tortilla sales reached the $4.4 billion mark, representing a growth rate of 57% over the past four years. Currently, more than 300 companies in the U.S. produce tortillas. The Tortilla Industry Association (TIA) estimates that Americans consumed approximately 85 billion tortillas in 2000, almost one tortilla a day/American (TIA 2002). The growing popularity of tortillas can be explained by the low cost, versatility, healthy ingredients and the "bread-like" acceptance of them by non-Hispanic cultures (Mabin 1999). They are often consumed as hand foods and many consumers utilize breakfast. tortillas several times per week

Protective role of whole grains

The major grains, based on the consumption worldwide, include wheat, rice and corn. Cereals such as oats, rye, barley, triticale, sorghum and millet are recognized as minor grains (Slavin, 2007). The structure of whole grains is similar and consists of endosperm, germ and bran. During the grain-refining process the bran is removed, causing loss of dietary fiber, vitamins, minerals, lignans, phyto-estrogens, phenolic compounds and phytic acid.

Whole grains are a good source of fermentable carbohydrates such as dietary fiber, resistant starch, oligosaccharides and antioxidants. Other protective compounds include phytate; phytoestrogens such as lignan; plant stanols and sterols; vitamins and minerals (Slavin, 2007).

Soluble and insoluble fibers constitute dietary fiber. Soluble fiber is associated with cholesterol lowering and improved glucose response while insoluble fiber improves bowel emptying (Slavin, 2003). Dietary fiber from cereals such as wheat and oats increases stool weight and speed s transit (Marlet et al. 2002).

Oligosaccharides in the human gut can act like dietary fiber (Slavin 2003). Gibson and coworkers (1995) stated that intake of fructooligosaccharides increased bifida bacteria in the gut while reducing concentrations of *Escherichia coli*, clostridia and bacteroides.

There is an inverse correlation between whole grain consumption and risk for type 2 diabetes (Van Dam et al. 2002, Truswell 2002) and CHD. In addition, whole grain foods retard digestion and absorption of carbohydrates (Slavin 2003) and therefore can lower the glycaemic index.

Whole grains have relatively high antioxidant activity (Slavin 2003). Free radicals attack DNA, lipids and protein, and are initiating factors for several chronic diseases (Miller 2001). Antioxidants are able to react with free radicals, reducing their activity, and protecting DNA from oxidative damage and mutations that can lead to cancer (Slavin 2003).

Overview and health implications of the selected grains

Oats

Oats and barley are both known for their beta-glucans. Glucans are linear β-(1-3)(1-4) glucose polysaccharides that are located mainly in cell walls of the grains (Hoseney 1994). They are indigestible and thus considered fibers. Beta glucans are present in water-extractable and water-unextaractable forms (Lifschitz et al. 2002). Due to the ability to bind water they are classified as gums (Aspinall 1980; Serna-Saldivar 1996).

The viscosity forming potential depends on the molecular conformation, molecular weight and concentration (Bengtsson 1990; Wood 1991; Bohm and Kulicke 1999; Izydorczyk 2000). Due to their high viscosity they lower cholesterol and blood glucose levels. According to the various sources, oat fiber tends to lower plasma total and LDL cholesterol (Jenkins et al. 2003). It has been shown to reduce blood pressure in hypertensives (Pins et al. 2002; Keenan et al. 2002).

Oat are also rich in antioxidants called avenanthramides (Dykes et al. 2007). These compounds are bioavailable and have anti-inflammatory, anti-atherogenic, and antioxidant properties (Bratt et al. 2003; Chen et al. 2004; Peterson et al. 2002). The FDA announced that foods containing at least 0.75 grams per serving of soluble fiber from oats or barley are beneficial for heart-health when consumed as part of diets low in saturated fat and cholesterol.

Buckwheat

Buckwheat (*Fagopyrum esculentum* and *Fagopyrum tataricum*) originated in North and Eastern Asia and was adapted in North America (Li and Zhang 2001). Buckwheat belongs to Polygonaceae family, but is typically grouped along with other cereals because of its methods of cultivation and utilization (Zielinski et al. 2006).

Li and Zhang (2001) reported that buckwheat contains 100-125 mg/g of proteins, 650-750 mg/g of fat, and 20-25 mg/g of minerals. It has essentially more protein than wheat, rice, millet, sorghum and maize.

Buckwheat protein has a good amino acid composition; it is rich in arginine and, relatively low in lysine. Low Lys/Arg and Met/Gly ratios are critical factors that determine the cholesterol-lowering effects of plant protein (Sugiyama et al. 1985; Carroll and Kurowska 1995). Thus, buckwheat proteins are supposed to have pronounced cholesterol lowering effects. Buckwheat can be added to other crops to improve the amino acid content to meet the need for amino acids by humans. Zielinski and associates (2006) reported that buckwheat has many biologically active compounds for humans. Among them are flavonoids such as cathechins (Watanabe 1998) rutin, quercitin, orientin, isoorientin (Dietrych-Szostak and Oleszek, 1999), phytosterols, unique fagopirines such as fagopyritol A1 and fagopyritol B1(Horbowicz et al. 1998), and thiamin-binding proteins. Flavonoids and flavonols are the predominant phenolic compounds in buckwheat groats (Zielinski et al. 2006). The flavonoid content in *Fagopyrum esculentum* is about 10 mg/g where rutin is a main flavonoid (Li and Zhang, 2001). Flavonoids may be beneficial for human health by lowering the cholesterol level in blood, maintaining strong , flexible capillaries and arteries reducing high blood pressure (Li and Zhang 2001). Flavonoids are strong antioxidants. They prevent human lymphocyte DNA from oxidative damage (Noroozi 1998). In addition, buckwheat may be helpful in the management of diabetes mellitus (Kawa et al. 2003). According to various sources, consumption of buckwheat as flour or biscuits made from buckwheat have hypoglycemic effects in patients with diabetes (Lu. et al. 1992; Wang et al. 1992).

Kayashita (1995) reported cholesterol lowering effects in rats with cholesterol enriched diets. Buckwheat groats may have large content of retrograded starch (Skrabanja and Kreft, 1998), making them suitable for diabetic patients and in prevention of colon cancer. Buckwheat products have relatively high levels of the resistant starch.

Flaxseed

Flaxseed was one of the first plants domesticated by humans about 8000-10,000 years ago (Morris and Vaisey-Genser 2003). Flaxseed is rich in fat, dietary fiber, and protein .The composition of Canadian-grown flaxseed averages 41% fat, 28% total dietary fiber, 20% protein, 7.7 moisture, 3.5 ash, and 1% simple sugars (Morris and Vaisey-Genser 2003). Flaxseed has a unique fatty acid profile where saturated fatty acids constitute 9%; monounsaturated fatty acids, 18% and polyunsaturated fatty acids, 73% of the total fatty acids. The largest part (75%) of the polyunsaturated fatty acids is α-linolenic acid (ALA), the essential ω-3 fatty acid. Linoleic acid (LA), the essential ω-6 fatty acid, in contrast, is present in the smaller amount (16%). ALA content gives the ratio of ω-6/ ω-3 fatty acids of 0.3:1(Morris and Vaisey-Genser 2003).

Western populations have a low intake of ω-3 fatty acids relative to the ω-6 fatty acids (Kromhout et al. 1985; Norrel et al. 1986). A joint Food and Agriculture Organization/World Health Organization committee recommends dietary ω-6 / ω-3 ratio between 5:1 and 10:1. Aside from being an excellent carrier of the polyunsaturated α-linolenic acid, flaxseed is also a great source of insoluble and particularly soluble dietary fiber. It provides about 28 g of total dietary fiber per 100-g dry weight (Morris and Vaisey-Genser 2003). Flaxseed proteins are mainly albumins and globulins (Morris and Vaisey-Genser 2003).

Over the last twenty years there has been enough accumulated evidence showing the protective effects of flaxseed against a variety of chronic diseases and risk factors including breast and colon carcinogenesis, atherosclerosis and insulin dependent diabetes mellitus (Daun et al.., 2003; Thompson, 2003; Prasad, 2000). Clinical studies showed that daily consumption of 50 g of the ground flaxseed can help to reduce the plasma total cholesterol and low-density-lipoprotein (LDL) cholesterol (Morris and Vaisey-Genser 2003). The US Institute of Medicine established a daily Adequate Intake of 1.1 g of ALA for women and 1.6 g of ALA for men. This goal can be achieved by consuming at least 8 g of ground flaxseed or 2.5 g of flaxseed oil per day (Morris and Vaisey-Genser 2003).

Sorghum Bran

Sorghum (*Sorghum bicolor* L. Moench) is an important source of dietary energy and a main food staple in semi-arid regions of Africa and Asia (Ezeogu et al. 2005). According to the U.S. Grains Council (2008), sorghum is the fifth most important cereal crop grown in the world.

Sorghum contains phenolic compounds in the form of phenolic acids, flavonoids, and condensed tannins (Waniska, 2000). The phenolic compounds are concentrated in the pericarp and testa (Beta et al. 1999; Rooney et al. 1980; Yousef, 1998) and because of their structural features have the ability to form chelates with metals and thus have good antioxidant properties (Awika et al. 2003; Awika et al. 2004; Hagerman et al. 1998). Remarkably, sorghum has the widest variety of phenolic acids and flavonoids reported (Dykes and Rooney. 2007). Dykes and Rooney (2007) found that sorghum contains unique anthocyanins called 3-deoxyanthocyanins. Decortication to produce sorghum bran increases the concentration of 3-deoxyanthocyanin by three- seven fold (Dykes and Rooney 2007).

Tannin sorghums have the highest level of phenols and antioxidant activity. Condensed tannins are the prevalent phenolic compounds of sorghums with pigmented testa (De Castro, 2006). Awika (2003) reported that during grain decortications the condensed tannins are concentrated in the bran fraction. Sorghum containing condensed tannins has shown the highest antioxidant activity in vitro. According to various observations, consumption of high tannin sorghum reduces weight gain of animals (Muriu et al. 2002).

Tannin sorghum bran includes pericarp and testa. It contains 36-50% dietary fiber (Rooney and Waniska 2000) and has high antioxidant potential that exceeds those of high-antioxidant fruits such as blueberries and strawberries on a dry weight basis (Awika 2003). High tannin sorghum bran has been successfully incorporated into good quality breads (Gordon 2001) and bread mixes (Rudiger 2003), as a natural source of brown color, antioxidants and dietary fiber.

Whole grain consumption in the U.S.

There is mounting evidence of the positive influence of whole grains on human health. The 2005 Dietary Guidelines for Americans recommends at least 1-ounce servings of whole grain. However, only 10% of the U.S. population consumes the recommended three servings per day of whole grains and the average intake is less than one serving daily (Cleveland et al. 2000). One of the probable barriers for sufficient whole grain consumption is the prejudice against their taste and brown color. Besides, many people suppose that they do not have the necessary skills to prepare and cook whole grain food (Lang and Jebb 2003).

Marquat and associates (2005) suggested six possible ways that may be helpful in introducing whole grain foods into the diet.

1. In order to mask brown appearance use white whole wheat instead of red whole wheat.
2. Let consumers adapt to changes in palatability by gradually increasing the amount of whole grain into formulations.
3. Use fine-particle-size flour to minimize texture changes.
4. Create more 100% whole grain food options.
5. Improve flavor and goodness of whole grain products using blends of white wheat and other grains.
6. Develop innovative products, containing whole grains in foods other than cereals

Functional food is a relatively new direction in the food industry. Morris and Vaisey-Genser (2003) defined functional foods as those that have not only favorable nutrient content, but also offer health benefits.

Currently, consumers tend to choose fortified foods over dietary supplements. The number of people searching for foods enriched with vitamins, minerals, antioxidants, and fiber is increasing (Pascoe and Fulcher, 2007). These “bioactive” components are all found in whole grains (Pascoe and

Fulcher, 2007). Production of whole multigrain wheat flour tortillas may be an opportunity to enrich them with nutraceuticals to provide more options for consumers seeking healthier alternatives for traditional wheat flour tortillas.

Production of wheat flour tortillas

Wheat flour, water, fat and salt are the basic ingredients needed for the production of wheat tortillas (Serna-Saldivar et al. 1988). However, tortillas may contain several other ingredients to improve efficiency, uniformity and shelf life of the product. These ingredients include acidulants, antimicrobial and leavening agents, emulsifiers, yeasts, non-fat dry milk and hydrocolloids (Friend et al. 1993; Suhendro et al. 1993).

Based on dough sheeting operations, three commercial processing methods are implemented, namely hot press; die cut or hand-stretch procedures (Serna-Saldivar et al. 1988). Each operation requires different flour specifications, dough preparations and baking conditions, which in turn, lead to various tortilla characteristics.

The most common and the fastest growing method in the United States is the hot press procedure (Janson, 1990). It is not the most efficient way, but it gives tortillas a better quality. Hot-press tortillas are slightly off-round, elastic, resistant to tearing, with a soft texture with more flexibility retained during storage (Serna-Saldivar et al. 1988).

Wheat flour tortilla ingredients

Wheat Flour

Wheat flour is the most important ingredient and is usually enriched, bleached, hard wheat flour with protein content ranging from 9.5-14%. The main characteristics taken into account are the protein quality, water absorption, mixing time and stability (Serna-Saldivar et al. 1988, Gomez 1992). Protein quality is defined as the property of flour proteins that cause different baking performances for flours that contain the same protein content (Bushuk et al. 1969). Tortillas made with high protein quality flour are usually more shelf stable, than those made with low protein quality flour. However, high protein quality of tortillas tends to make them more difficult to process and affects diameter during hot pressing (Serna-Saldivar et al. 1988; Dally and Navarro 1999; Waniska 1999).

Water

Water (45-55%) is required to form the gluten complex, to incorporate and distribute the ingredients, to activate the chemical leavening agents, salt, acid, and preservatives. The amount of water depends on the type of flour, protein quality and content, type of production, and presence of other ingredients (Serna-Saldivar et al. 1988). In comparison to bread, flour tortillas are processed into dough with less water and more shortening (Serna-Saldivar et al. 1988). Water temperature is usually adjusted to provide a dough at 82°F (28°C), which is optimum for resting.

Shortening

Shortening (5-15% of flour weight) is incorporated into the gluten network, decreasing its strength by binding to hydrophobic proteins. Shortening functions as a lubricant and interacts with protein and starch during mixing, baking and cooling (Serna-Saldivar et al.. 1988). It also improves machinability of the dough and decreases stickiness. Shortening retards staling and gives a softer, more flexible tortilla with improved rollability (Serna-Saldivar et al. 1988; Adams 2001).

Salt

Most formulations contain 1.3-2% salt. It is added for taste and to strengthen the gluten complex. Salt also influences the shelf-life by decreasing water-activity, and improves the machinability of the dough (Serna-Saldivar et al. 1988).

Leavening Agents

Chemical leavening agents are used at 1-2% level in tortilla formulations. The most common leavening bases used in baked cereal products are sodium bicarbonate, potassium bicarbonate, and ammonium bicarbonate (Bejosano and Waniska 2004). Usually baking powder used in tortilla production is the mixture of sodium bicarbonate, starch, monocalcium phosphate and sodium aluminum phosphate (Bejosano and Waniska, 2004). The soda dissolves in the aqueous phase of the dough and releases carbon dioxide, which expands the product. A chemical leavened tortilla has 1.2-2.2 cm^3/g specific volume, spongy texture and is white (opaque) in appearance (Adams 2001).

Emulsifiers

Surfactants used in the production of bakery foods are referred to as emulsifiers and dough strengtheners. Emulsifiers interact with gluten proteins and improve rheological properties of the dough during mixing and baking. Emulsifiers such as sodium stearoyl lactylate (SSL) strengthen the dough and facilitate emulsification, air-incorporation and softness retention. SSL, an anionic surfactant, interacts with gluten during mixing, resulting in improved dough strength and then forms a complex with amylase and amylopectin during baking (Akdogan et al. 2006). This retards the starch staling process and results in crumb softening (De Stefanis 1977). It is supposed that strong association between SSL and gluten at the dough might delay denaturation and setting of gluten during baking (Stauffer 1999). Typically, in tortilla production SSL is used as powder in levels ranging from 0.1 to 0.4% (based on flour weight) (Serna-Saldivar et al. 1988).

Glyceryl monostearate (GMS) is a derivative from α-monoglycerides that can also improve texture (Akdogan et al. 2006). Similar to SSL, GMS forms complexes with amylose, inhibiting the firming of baked products due to staling (Krog and Nybu-Jensen 1970). The N-alkyl portion of GMS forms a complex with the helical regions of amylose which is supposed to delay starch crystallization, slowing the staling process. The interaction between GMS and amylose occurs at the surface of the granules, and the amylose-emulsion complex serves to stabilize the granule, retarding water penetration and swelling as the temperature is raised (Stauffer 1999).

Sodium lecithin is a natural emulsifier and a mixture of phosphatides. It has amphotheric properties and unlike SSL or GMS does not form complex with starch (Stampfli and Nersten 1995). Lecithin is classified as a GRAS substance and has a been used for a long time in the food industry

Preservatives and Acidulants

Preservatives are used to inhibit fungal growth and to extend shelf-life of tortillas. The most commonly used antimicrobial agents are sodium and calcium propionates, potassium sorbates and sorbic acid. Calcium propionates and sorbate are recommended when using baking powder and yeasts respectively. Calcium propionate is quite reactive and may interfere with some chemical leavening agents. Potassium sorbate is soluble in water and is more effective than propionates (Serna-Saldivar et al. 1988). Optimum pH for propionate activity is 5.5 and for sorbate is 6.0; however, dough mixing is more difficult below pH 5.8 (Serna-Saldivar et al. 1988). Acetic, citric, and phosphoric acids are added to the tortilla to decrease pH (Serna-Saldívar et al. 1988). However, fumaric acid is the most common, since it is less soluble in the dough and does not interfere as much with the leavening reaction (Waniska 1999). Encapsulated acids with “high melting point” edible coatings offer delayed release until baking (Dally and Navarro 1999).

Enzymes

Enzymes are proteins that are produced by all living organisms (Law, 2002). They can hasten the chemical reactions necessary to complete their life cycle (Klahorst, 1998) and thus are considered biological catalysts. Almost all foods represent living systems and thus they are subject to various enzymatic reactions (Klahorst, 1998).

The baking industry has a long history of successful enzyme application (Hegenbart 1994). Due to their high selectivity enzymes can degrade each component of the flour, including starch, protein, and xylans. This property provides the opportunity for combining all the activities in one product.

Amylases are inherent to wheat and thus to wheat flour (Qi Si and Drost-Lustenberger 2002). The α-amylase enzymes hydrolyze starch into soluble dextrins. The amount of α-amylases in wheat or rye grain is extremely low (Van Dam and Hille 1992). Thus, most bakery products require supplementation with α-amylases, added in form of malt or fungal enzymes. Fungal α-amylases act only on starch granules that have been damaged or on granules that have been gelatinized (Qi Si and Drost-Lustenberger, 2002; Hegenbart 1994).

Damage starch granules absorb more water than intact granules. Amylase reduces the starch's water absorbing capacity and hence affects the consistency of the dough. Since the ability to hold water of the damaged starch granules is reduced the free water softens the dough and makes it more mobile (Hegenbart 1994).

In addition, α-amylases are able to delay staling and thus maintain softness and improve shelf-stability by hydrolyzing the amylopectin into smaller units (Hegenbart 1994). Despite all the benefits enzymes can deliver, their application can be challenging. Some of them continue to be active in the finished bakery products and it is possible that their activity will go too far (Hegenbart 1994). Choosing the correct dose is crucial for the successful enzyme application. Over-dose of α-amylase can lead to the extensive degradation of the damaged starch that produces too sticky dough (Qi Si and Drost-Lustenberger, 2002). Temperature plays a very important role in enzyme application. Increase in temperature cause increase in the enzyme activity, but too high temperature results in enzyme denaturation. Acidity has also a great influence on enzyme behavior. Different enzymes have various optimum range of pH under which they are the most active (Hegenbart 1994).

Limited amount of works regarding the effect of α-amylase on flour tortilla staling have been published. Arora (2003) reported that bacterial α-amylase could extend the shelf-stability of flour tortillas from 12 to 28 days. Alviola and Waniska (2008) had similar results where addition of α-amylase led to longer retention of flexibility.

Gums

Arendt and Moore (2006) defined hydrocolloids (gums) as long-chain polymers with hydrophilic properties. In water they form colloidal solutions (gels) that are suspensions with low dry substance content. The sources of gums include seeds, fruits, plant extracts, seaweed and microorganisms. Arendt and Moore (2006). They are usually straight or branched polysaccharides with hydrophilic properties (Kuntz, 1999). They can be neutral or anionic. Kuntz (1999) stated that hydrocolloid structure is the main determinant of its properties.

In food systems, hydrocolloids are able to stabilize the product and affect its texture. These properties make them very popular in the food industry. Addition of gums to foods can improve texture, postpone starch retrogradation, increase moisture retention and extend product shelf-stability over time (Armero and Collar 1996; Davidou et al. 1996). In bakery products gums form hydrophilic complexes with gluten proteins, bind water, and decrease moisture migration in the dough (Ribotta et al. 2005).

In tortilla gums like guar, carboxymethylcellulose, xanthan, and gum arabic improve machinability, decrease dough stickiness, delay staling, improve rollability and water holding capacity, improve freeze/thaw stability and decrease moisture loss (Juttelstad, 1999). However, the high viscosity of some hydrocolloids can create dough that is difficult to work with.

Reducing Agents

The reducing agents frequently used are L-cysteine, glutathione and different salts of bisulphite. These substances react with disulfide bonds of proteins; break them with subsequent formation of sulphydryl groups. The main mechanism is to reduce the average protein molecular weight by decreasing degree of polymerization (Stauffer 1999). The addition of the reductants shortens the mixing and resting time of dough and improves its machinability owing to increased extensibility and reduced elasticity of the protein (Friend et al.., 1995). Consequently, tortillas with bigger diameter are obtained. Doughs that contain cysteine require precise mixing and resting times. According to Benitez and associates (1996) cysteine and metabisulfite help produce pliable doughs that are significantly more extensible. They also noticed that erythorbic acid gives larger diameter tortillas than those with ascorbic acid.

CHAPTER III

MATERIALS AND METHODS

General approach

Multigrain flour tortillas were produced by substituting whole white wheat flour with 0-20% of non-wheat cereals. Tortillas were made by hot-pressing, and done on four processing days (i.e., four replicates). To determine the effects of non-wheat cereal replacement on flour tortilla quality, dough characteristics and tortilla texture changes were evaluated. To improve tortilla texture and shelf-stability different rates of α-amylase and commercial hydrocolloid were applied and their effect was evaluated. Sensory evaluation of the selected multigrain flour tortillas was conducted.

Developing whole multigrain flour tortillas

Several prototypes of whole multigrain flour tortillas were prepared in a commercial hot press, triple pass gas oven (Table I) during four processing days. Whole white wheat flour was substituted with the corresponding amount of multigrain components. Grains used to substitute whole white wheat flour were flaxseed, high tannin sorghum bran, oat flour and buckwheat flour with sources and nutritional profiles listed in Tables II and III. Whole white wheat and refined wheat flour tortillas were used as controls. Using the nutrient data for raw materials, nutrition values were calculated for the selected multigrain prototypes.

Dough and Tortilla Preparation

Tortillas were prepared according to the method described by Bello et al. (1991) with modifications. The dry ingredients were mixed (Hobart mixer model A-200, Hobart Co., Troy, OH) with a paddle at low speed for two minutes. Then shortening was added and mixed for 6 min at low speed. Warm distilled water

(35±1°C) was added to develop the dough by mixing with a hook for 1 min at low speed, followed by 6 min at medium speed. Placing an electrically heated jacket around the mixing bowl warmed the dough (32-33°C). Once dough was formed, subjective and objective dough measurements were performed and temperature was recorded. The dough was rested for 5 min in a proof chamber (model 57638, National Manufacturing Co., Lincoln, NE) at 70±3%RH, 32±3°C. After proofing, the dough was divided into dough balls (Be&SCO Bakery Equipment and Service Co. San Antonio) and proofed for 10 min. After final proofing, the dough balls were placed on the hot-press (188±2°C, 1100 psi, 1.35 sec) and baked (380±5°C, 30 sec) on a three-tier gas fired oven (model 0P01004-02, Lawrence Equipment, El Monte, CA), and then cooled on a 3-tier conveyor belt (model 3106-INF, Superior Food Machinery Inc., Pico Rivera, CA). The freshly prepared tortillas were cooled on a clean table for 1-2 min on each side. The tortillas were packed in low density polyethylene plastic bags and stored at room temperature (22°C). All treatments were processed and evaluated four times (i.e., four replicates) on different days.

Effect of different rates of hydrocolloids and α-amylase on shelf-stability of whole multigrain flour tortillas

In the last treatment (5F5S5O5B Table I) 20% of the whole white wheat flour was replaced by non-wheat flours. None of the incorporated flours contained gluten. On the other hand, some of them had more fiber and larger particle sizes that adversely affected texture, shelf-stability and overall quality of the tortillas. Bacterial α-amylase from *Bacillus amyloliquefaciens* (SIGMA, Sigma-Aldrich Inc., St. Louis, MO) and commercial hydrocolloid (TIC PRETESTED® Ticaloid LC T2 Stabilizer, TIC GUMS, Inc., White Marsh, MD) were added and evaluated. The concentrations used were 50 ppm, 75 ppm, 100 ppm of α-amylase and 0.5%, 1% and 1.5% of gum. To assure a homogenous mix both gum and α-amylase were dissolved in water and then incorporated into the dough during mixing.

Evaluation of dough properties

Subjective Evaluation

Right after mixing the dough temperature was measured and smoothness, softness, extensibility and force to extend were evaluated subjectively. Smoothness is associated with the appearance of the dough, while softness refers to the ease with which the dough flows when compressed. Force to extend and press rating represent dough toughness. This test was performed once for each of the four processing days. Each of these characteristics was graded on a subjective scale from 1 to 5 (Table IV).

Objective Rheological Test

Rheological tests were conducted using a texture analyzer (model TA-XT2i, Texture Technologies Corp, Scarsdale, NY/Stable Micro System, Godalming Surrey, UK). Compression force and stress relaxation were measured immediately after proofing,

Compression Force

A dough ball (average weight 45 g) was placed on a flat stationary aluminum platform and compressed by an aluminum cylindrical probe to 70% of its original height and had a surface area of 2000 mm^2. Three dough balls were evaluated per processing day.

Stress Relaxation

Instantaneous strain (4%) was applied to the dough ball. The test settings used were as follows: test speed 10 mm/s; force of 80 N, hold time of 100 sec. Two dough balls were used for each treatment per processing day, giving eight balls for the whole study. Force versus time plots were recorded for all further data processing

Table I

Whole multigrain flour tortilla formulations

Ingredients [1] (g)	Control Refined	Control Whole	5S[2]	15O[3]	10B[4]	5F[5]	5F5S5O5B[6]
Refined wheat flour	1000	0	0	0	0	0	0
Whole wheat flour	0	1000	900	800	850	950	800
Flax	0	0	50	50	50	50	50
Sorghum bran	0	0	50	0	0	0	50
Oat flour	0	0	0	150	0	0	50
Buckwheat flour	0	0	0	0	100	0	50
Vital wheat gluten	0	0	0	10	6	0	10
Salt	15	15	15	15	15	15	15
SSL	5	5	5	5	5	5	5
Potassium sorbate	4	4	4	4	4	4	4
Sodium Propionate	4	4	4	4	4	4	4
Baking soda	6	6	6	6	6	6	6
SAS	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Fumaric acid	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Shortening	60	60	60	60	60	60	60
Water	520	540	540	550	550	540	560

[2] High tannin sorghum bran
[3] Whole oat flour
[4] Whole buckwheat flour
[5] Golden stabilized ground whole-grain flaxseed
[6] 5% Flax, 5% Sorghum bran, 5% Oat, 5% Buckwheat

Table II

Sources of ingredients

Ingredient	Purpose	Source
Refined wheat flour	main ingredient	ADM Milling Co, Atchison, Kansas
Whole white wheat flour	main ingredient	Farmer Direct Foods, Inc., Atchison, Kansas
Golden, stabilized, ground, whole-grain flaxseed	main ingredient	ENRECO Inc., Newton, Wisconsin
High tannin sorghum bran	main ingredient	ADM Milling Co, Atchison, Kansas
Whole grain buckwheat flour	main ingredient	Bob's Red Mill Natural Foods, Milwaukie, Oregon
Whole grain oat flour	main ingredient	Bob's Red Mill Natural Foods, Milwaukie, Oregon
Salt	main ingredient	United Salt Corp., Houston, Texas
Vital wheat gluten	dough strengthener	MGP Co, Atchison Kansas
Sodium stearoyl lactylate (SSL)	emulsifier	Caravan Ingredients Co., Lenexa, Kansas
Potassium sorbate	preservative	American Ingredients Co., Kansas City
Sodium propionate	preservative	Niacet Corporation, Niagara Falls, New York
Sodium bicarbonate	leavening base	Balchem Co., Slate Hill, New York
Sodium aluminum sulfate	leavening acid	Equisa-Budenheim, Santa Catarina, Nuevo León, MX
Fumaric acid	pH, leavening acid	Balchem Co., Slate Hill, New York

Table III

Nutritional profile of cereal grains (g per 100 g)

Parameter	Refined Wheat Flour	Whole White Wheat Flour	High Tannin Sorghum	Golden, Stabilized, Ground, Whole – Grain Flaxseed	Whole Oat Flour	Whole Buckwheat Flour
Protein	10.3	13.7	12.7	20-23	14.8	14.8
Total Fat	1.5	1.9	10.4	37.4	7.4	7.4
Total Carbohydrate	76,2	72.6	15.6	28-30	59.3	59.3
Ash	0.6	1.9	5.1	3-4	N/D	N/D
Moisture	12.0	10.3	11.2	6-8	N/D	N/D
Total Dietary Fiber	0.0	12.2	45.0	25-27	11.2	11.1
ω-3 Linolenic Acid (ALA)	0.0	0.0	0.0	18-22	0.0	0.0
ω-Linoleic Acid	0.0	0.0	0.0	4.5	0.0	0.0
Trans-Fat	0.0	0.0	0.0	0.0	0.0	0.0

[a] Serna-Saldivar and Rooney (1995).
[b] Proximate composition for golden ground flaxseed, Enreco®
[c] Proximate composition for whole oat flour, Bob Red's Mill®
[c] Proximate composition for whole buckwheat flour, Bob Red's Mill®
[d] Proximate composition fro whole wheat flour, USDA Nutrient Data Laboratory
[e] Not Determined

Table IV

Subjective evaluation scale of dough properties

Scale	Smoothness	Softness	Force to extend	Extensibility	Press Rating
1	very smooth	very soft	less force	Breaks immediately	less force
2	smooth	soft	slight force	some extension	slight force
3	slightly smooth	slightly hard	some force	extension	some force
4	rough	hard	more force	more extension	more force
5	very rough	very hard	extreme force	extends readily	extreme force

Evaluation of tortilla properties

Physical Properties

After processing ten tortillas were selected randomly and their weight, diameter, height, opacity, moisture and pH were evaluated (Bello et al.., 1991). Diameter of ten tortillas was measured using a ruler at two points across the tortilla. Height of 10 tortillas were measured with a digital caliper (Chicago Brand 12" Electronic Digital Caliper, Chicago, IL). Weight of ten randomly selected tortillas was determined using an analytical scale (Ohaus, Houston, TX). Opacity was measured subjectively on ten tortillas. Opaque tortillas were rated as 100%, whereas completely translucent tortillas were rated as 0%. The values were averaged. Tortilla specific volume (cm^3/g) was calculated as follows:

Specific Volume = (height)(πr^2)/weight; where

Height = height of 10 tortillas /10; (cm)

Weight = weight of 10 tortillas / 10; (g)

r = average radius of 10 tortillas (cm)

A colorimeter (model CR 310, Minolta Co., Ramsey, NJ) was used to measure the color of the tortilla samples. L*, a* and b* values were recorded. L*- value corresponds to lightness (0 = black and 100 = white). The a* refers to red and green colors (+a = red and –a = green), and the b*- value indicates yellow (+b) and blue (-b) colors. Moisture content of each tortilla sample was obtained using a two step AACC method 44-15A; pH measurements were determined for each sample using the approved method 02-52 (AACC 2000).

Subjective Rollability Test

Rollability test, also known as a dowel test was used to evaluate shelf-stability in a subjective way (Friend et al. 1991). Two tortillas were individually rolled around a dowel (1.0 cm diameter) after 4, 8, 12 and 16 days of storage. Cepeda et al. (2000) used a continuous scale for rollability score: 5 = no cracking; 4 = signs of cracking but no breaking; 3 = cracking and breaking beginning on the surface; 2 = cracking and breaking imminent on both sides;

and 1 = unrollable, breaks easily. Shelf stability is unsatisfactory when the dowel score reaches 3 (e.g. several cracks and breaks on the surface) during storage.

Objective Rheological Test

Textural changes were evaluated using the TA.XT2i Texture Analyzer (Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK) using a 3D extensibility method. This analysis was performed using two tortillas per treatment, every fourth day during 16 days of storage. The TA-108 fixture and an acrylic probe of 7/16 in. diameter with a flat edge were used. Pretest, test and post-test speeds were 5.0, 1.0 and 5.0 mm/s with distance set at 25 mm. Deformation modulus, work, maximum force and distance needed to rupture the tortilla were calculated.

Sensory evaluation

To determine consumer acceptability the whole multigrain flour tortilla was compared with whole white wheat flour tortilla and a commercial multigrain flour tortilla (Mission Multigrain Wrap). The consumer panel consisted of 36 untrained panelists. Demographic data of the panelists were collected, namely: age, gender, ethnicity and frequency of tortilla consumption. Each sample was placed on white paper plates with an assigned random three-digit number code. The panelists were asked to evaluate each sample for texture, flavor, color, and overall acceptability. Consumers were also given a chance to write additional comments on the ballot. Summary for all the analysis performed in this study is given in Table V.

Statistical analysis

The SPSS 15.0 (SPSS Inc., Chicago, IL) software package was used to statistically evaluate the effects of non-wheat cereals and shelf-stability extenders on dough and tortilla quality. Analysis of variance in a completely randomized design was done to determine any significant contribution of the treatments. The difference between means of the treatments was compared using Tukey’s test.

Table V

Experimental design

Test	Replicates for each treatment
Dough subjective evaluation	4
Objective rheological test	
Compression force	12
Stress relaxation	8
Tortilla physical properties	
Weight	4
Height	4
Diameter	40
Moisture	4
pH	4
Opacity	40
L*-value	48
a*-value	48
b*-value	48
Subjective rollability test (every 4th day)	8
Objective rheological test (every 4th day)	8
Sensory evaluation	36

CHAPTER IV

FORMULATING WHOLE MULTIGRAIN FLOUR TORTILLAS

Whole multigrain flour doughs containing up to 20% of non-wheat cereals could be used to prepare flour tortillas. The multigrain components affected dough characteristics. In general whole white wheat and multigrain doughs were stiffer, more viscous and less elastic than the refined wheat flour doughs.

Subjective dough properties

Refined wheat flour dough was smooth, soft, and extensible and required slight force to extend and to press (Table VI). There were no significant differences in extensibility, and force to extend among all the treatments. Softness, smoothness and press rating scores were comparable for all multigrain treatments. Overall, the control refined dough was easier to handle and process than the other treatments.

Objective dough properties

Table VII shows the effect of whole white wheat and multigrain components on dough rheological properties. Hardness was measured as the force required to compress the dough ball to a certain distance. This was affected by the dough composition and varied significantly among samples. It was significantly higher for the whole and multigrain flour tortillas than for the refined control dough. Treatments with 15% oat and treatment with 5% flax, 5% sorghum bran, 5% oat, 5% buckwheat gave the hardest dough with force of 260.6 N and 227.1 N, respectively.

Table VI

Subjective dough measurements

Treatment	Smoothness	Softness	Extensibility	Force to extend	Press rating
Refined Wheat Control	2.0^{a}	2.0^{a}	2.4^{a}	2.3^{a}	2.0^{a}
Whole White Wheat Control	2.5^{ab}	2.6^{b}	2.8^{a}	2.9^{a}	3.0^{b}
5% Flax	2.4^{ab}	2.6^{b}	2.5^{a}	2.9^{a}	2.8^{b}
5% Sorghum Bran	2.8^{ab}	2.9^{b}	2.6^{a}	3.0^{a}	2.8^{b}
15% Oat	2.1^{ab}	2.4^{ab}	2.6^{a}	2.5^{a}	2.9^{b}
10% Buckwheat	2.6^{ab}	2.5^{ab}	2.6^{a}	2.3^{a}	2.5^{ab}
5% Flax, 5% Sorghum Bran, 5% Oat, 5% Buckwheat	2.9^{b}	2.6^{b}	2.4^{a}	2.9^{a}	3.0^{b}
HSD	0.9	0.6	1.0	1.0	0.6

Means from four replicates; means in a column followed by the same letter are not significantly different ($p<0.05$).

Table VII

Objective dough measurements

Treatment	Compression Force (N)	Fmax[1] (N)	F20[2] (N)	F100[3] (N)	SR%[4] (%)	RT [5] (s)
Refined Wheat Control	75.6^{a}	82.4^{c}	13.1^{c}	9.4^{c}	15.9^{c}	10.8^{c}
Whole White Wheat Control	176.6^{b}	81.9^{ab}	11.5^{b}	7.5^{ab}	14.0^{b}	8.9^{b}
5% Flax	160.6^{b}	82.1^{bc}	11.6^{b}	7.6^{ab}	14.2^{b}	8.9^{b}
5% Sorghum Bran	184.4^{bc}	81.7^{a}	10.6^{ab}	6.9^{a}	12.9^{ab}	8.1^{ab}
15% Oat	260.6^{d}	81.7^{ab}	11.6^{b}	8.7^{bc}	14.2^{b}	9.0^{b}
10% Buckwheat	182.9^{bc}	81.9^{ab}	9.9^{a}	6.3^{a}	12.1^{a}	7.5^{a}
5% Flax, 5% Sorghum Bran, 5% Oat 5% Buckwheat	227.1^{d}	81.6^{a}	11.3^{b}	7.4^{ab}	13.8^{b}	8.7^{b}
HSD	50.4	0.35	1.10	1.58	1.33	0.99

Means from four replicates; means in a column followed by the same letter are not significantly different ($p<0.05$).

[1] Maximum force

[2] Force at 20s

[3] Force at 100s

[4] % stress relaxation

[5] Time at which the force reached 36.8% of Fmax

Stress relaxation showed differences in dough rheology (Table VII). Maximum force (Fmax) was significantly higher for refined wheat flour dough than the other treatments except for dough with 5% flax. Force at 20 s (F20) differed significantly among the samples. The highest value was observed for the refined wheat dough (13.1 N) and the lowest for 10% buckwheat. Equilibrium force (F100) is the residual force left in the dough ball after 100 s of relaxation. Equilibrium force was affected by the dough type. It was highest for refined wheat dough and lowest for 5% sorghum bran and 10% buckwheat prototypes (6.9 N and 6.3 N respectively). A similar trend was observed with the percent stress relaxation (SR), which indicates the percentage of internal fracture that occurs during deformation of the material (Singh et al. 2006). A % SR close to 100% indicates a perfect elastic product, and less than 100% SR value indicates a more viscous component in the material. This parameter was significantly higher for refined wheat flour doughs than for the other treatments. Relaxation time (RT) signifies the time in which the force reached 36.8% of Fmax. Higher time means more time to relax, which is an indicator of the greater elasticity of the product. RT ranged from 7.5 s (10% buckwheat) to 10.8 s (refined wheat flour tortillas).

Tortilla general characteristics

Table VIII shows some physical characteristics, pH and moisture content of whole multigrain flour tortillas. Weights of prepared tortillas were not significantly different. The moisture content of tortillas made with whole white wheat and multigrain flours was significantly lower than that of tortillas made with refined wheat flour. The diameter of tortillas ranged from 158 mm (refined wheat flour tortilla) to 181mm (10% buckwheat). Tortilla diameters correlated negatively with tortilla moisture content (r = -0.927). Tortilla thickness varied from 2.14 mm (refined wheat) to 1.71 mm (10% buckwheat) and positively correlated (r = 0.93) with moisture content.

Multigrain flours used in the formulation had different impact on multigrain tortilla appearance (Fig. 1). Opacity scores (Fig. 2.) and color values (Figs. 3, 4 and 5) varied significantly among the samples. Refined wheat flour tortillas and 15% oat treatment had the highest opacity scores. Tortillas enriched with 5% flax and whole white wheat flour had opacity scores comparable to those of 15% oat. L* scores correlated with opacity scores (r = 0.84) and refined wheat flour tortillas were significantly lighter than other samples (80.7). Treatments with 5% sorghum bran (53.3), 10% buckwheat (54.5) and mix of 5% flax, 5% sorghum, 5% oat, 5% buckwheat (52.4) were the darkest samples.

For a*- values, 5% sorghum bran (7.63) was significantly higher than the other samples. This result was expected since 5% sorghum bran contained high tannin sorghum bran. Prototypes enriched with 5% flax were the second highest in redness with a* value of 7.1. The b* values ranged from 14. 48 (5% flax, 5% sorghum, 5% oat, 5% buckwheat) to 21.77 whole wheat flour tortilla.

Rollability score

The rollability of tortillas is a good indicator of their quality. Higher dowel scores mean rollable, flexible tortillas. Overall, mean dowel scores of refined wheat flour tortillas (4.2) were significantly higher than those of whole wheat or whole multigrain prototypes (Fig 6*)*. Tortillas with the mix of 5% flax, 5% sorghum, 5% oat, 5% buckwheat had the lowest overall rollability score (3.7)

Tortilla flexibility decreased gradually during storage as expressed by increased breaking and cracking during rolling and folding. Figure 6 shows the dowel scores of tortillas stored for 16 days. Control refined wheat flour tortillas lost flexibility at a slower rate than whole wheat and whole multigrain tortillas. At the 16th day of storage refined wheat, whole wheat and tortillas enriched with 5%

flax tortillas had rollability scores greater than 3, while dowel scores of other treatments were lower.

Tortilla texture profile

Objective rheological test revealed similar tendency in changes of tortilla texture over time. The modulus of deformation (firmness) was highest for whole wheat tortillas and treatment prepared with 5% sorghum bran (Fig. 7). In contrast, 10% buckwheat and 5% flax, 5% sorghum, 5% oat, 5% buckwheat prototypes were less firm than other trials, which might indicate a slower rate of staling. Tortilla firmness increased over time. Deformation moduli recorded at the 4th, 8th, and 12th days of storage were not significantly different. Deformation modulus was highest on the 16th day for all the treatments, showing that all tortillas decreased in flexibility during storage.

The distance to which the tortilla was extended before rupture was greatest for the refined wheat tortillas and significantly smaller for whole wheat and multigrain treatments. The greatest distance to rupture was recorded immediately after processing. Decrease in distance to rupture was observed up to 8 days of storage, but no significant changes in distance occurred at 8-16 days (Fig. 8). Similarly, the work required to rupture was greater for the refined wheat flour tortilla than for whole and whole multigrain prototypes (Fig. 9). The tortilla right after processing needed the greatest work. Reduction in work to rupture was detected during the 8 days of storage; there were no significant changes up to the end of the storage period.

Table VIII

Physical characteristics of refined wheat, whole white wheat and whole multigrain flour tortillas

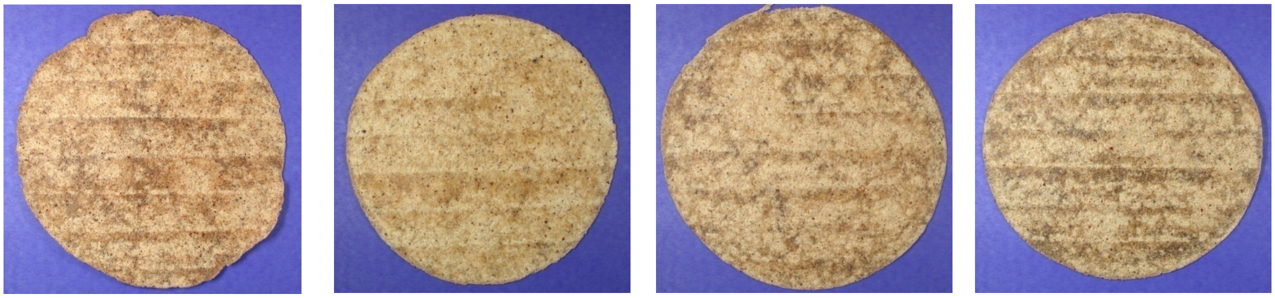
Treatment	Weight (g)	Thickness (mm)	Diameter (mm)	pH	Moisture (%)
Refined Wheat Control	39.69^{a}	2.14^{b}	158^{a}	5.4^{a}	35.3^{b}
Whole Wheat Control	39.31^{a}	1.90^{ab}	170^{b}	5.6^{ab}	32.8^{a}
5% Flax	40.72^{a}	1.84^{a}	174^{bc}	5.7^{ab}	32.2^{a}
5% Sorghum Bran	41.23^{a}	1.73^{a}	178^{cd}	5.6^{ab}	31.8^{a}
15% Oat	40.59^{a}	1.86^{a}	177^{cd}	5.8^{ab}	31.5^{a}
10% Buckwheat	39.46^{a}	1.71^{a}	181^{d}	5.9^{b}	31.9^{a}
5%Flax 5%Sorghum Bran 5%Oat 5%Buckwheat	41.83^{a}	1.85^{a}	177^{cd}	5.9^{b}	32.8^{a}
HSD	4.42	0.35	0.62	0.36	1.77

Means from four replicates; means in a column followed by the same letter are not significantly different ($p<0.05$).

Refined Wheat

Whole White Wheat

5% Stabilized
Ground Flaxseed



5% Sorghum Bran,
5% Flax

15% Whole Oat
Flour, 5% Flax

10% Whole
Buckwheat Flour,
5% Flax

5% Flax, 5%Sorghum,
5% Oat, 5% Buckwheat ,

Fig. 1. Refined wheat, whole white wheat and whole multigrain flour tortillas.
The ingredients indicated were substituted for whole white wheat flour

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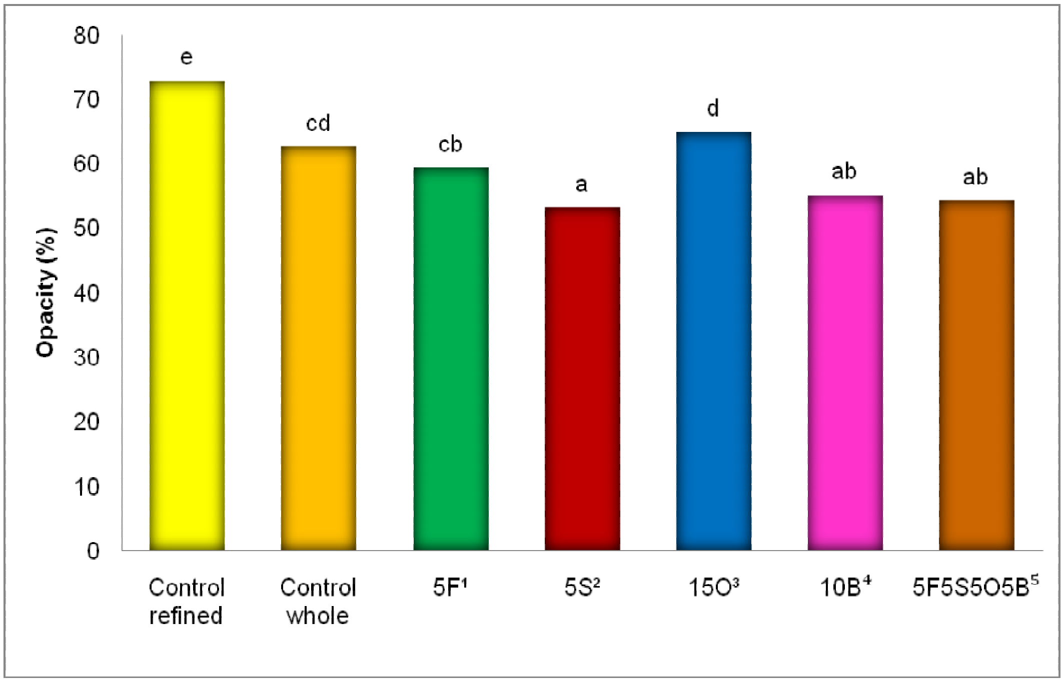

Fig. 2. Mean opacity scores of whole multigrain flour tortillas.

Ten tortillas were evaluated for each treament, and replicated by four processing days. The ingredients indicated were substituted for whole white wheat flour.

[1] 5% Golden stabilized ground flaxseed

[2] 5% High tannin sorghum bran

[3] 15% Whole oat flour

[4] 10% Whole buckwheat flour

[5] 5% Flax, 5% Sorghum bran, 5%Oat, 5%Buckwheat

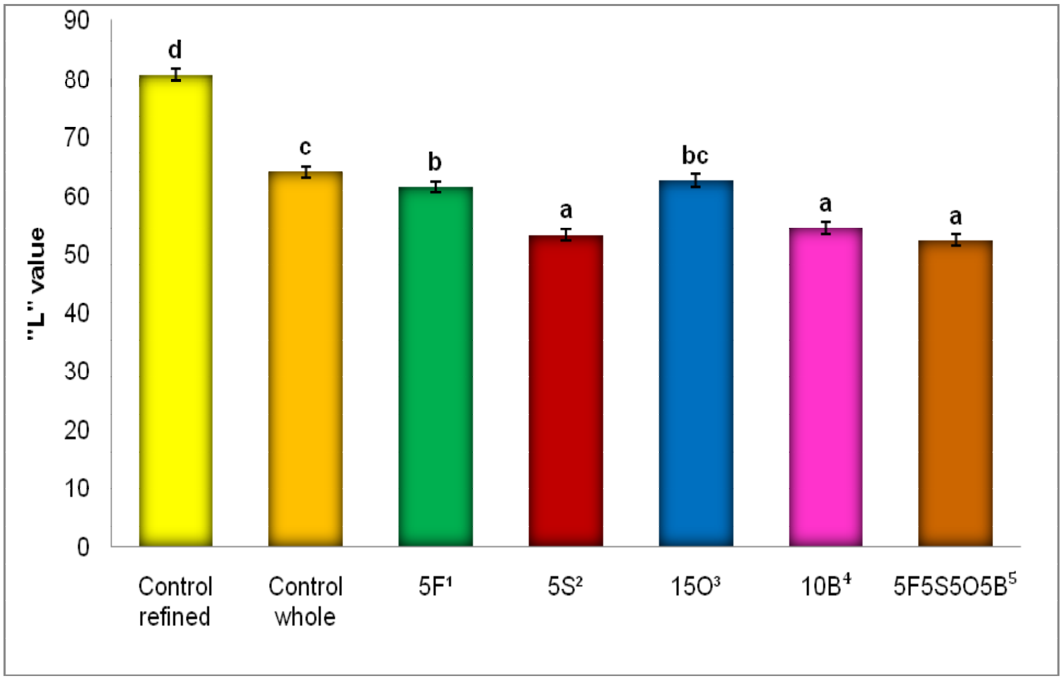

Fig. 3. Mean L*-values of whole multigrain flour tortillas.

Two tortillas were evaluated for each treament, and replicated by four processing days. The ingredients indicated were substituted for whole white wheat flour.

[1] 5% Golden stabilized ground flaxseed

[2] 5% High tannin sorghum bran

[3] 15% Whole oat flour

[4] 10% Whole buckwheat flour

[5] 5% Flax, 5% Sorghum bran, 5%Oat, 5%Buckwheat

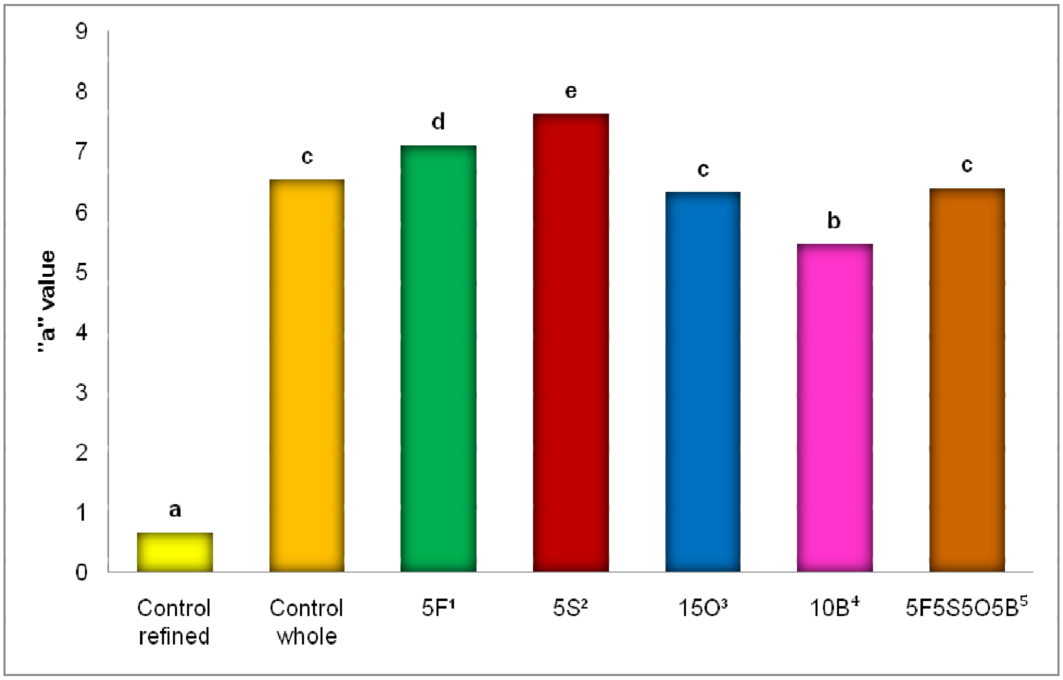

Fig. 4. Mean a*-values of whole multigrain flour tortillas.

Two tortillas were evaluated for each treament, and replicated by four processing days. The ingredients indicated were substituted for whole white wheat flour.

[1] 5% Golden stabilized ground flaxseed
[2] 5% High tannin sorghum bran
[3] 15% Whole oat flour
[4] 10% Whole buckwheat flour
[5] 5% Flax, 5% Sorghum bran, 5%Oat, 5%Buckwheat

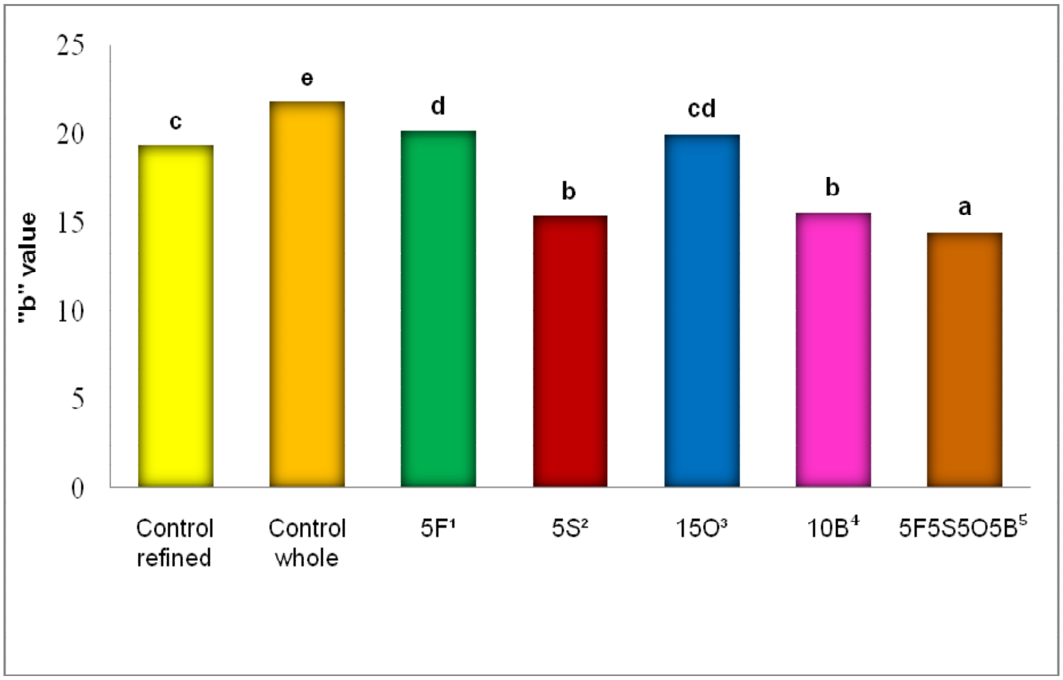

Fig. 5. Mean b*-values of whole multigrain flour tortillas.

Two tortillas were evaluated for each treament, and replicated by four processing days. The ingredients indicated were substituted for whole white wheat flour.

[1] 5% Golden stabilized ground flaxseed

[2] 5% High tannin sorghum bran

[3] 15% Whole oat flour

[4] 10% Whole buckwheat flour

[5] 5% Flax, 5% Sorghum bran, 5%Oat, 5%Buckwheat

Tortilla elasticity decreased with time. Force to rupture varied significantly among the treatments(Fig. 10). Control refined tortilla required the highest force to rupture (8.56) followed by the whole white wheat treatment (7.35). Tortillas made with 15% oat, 10% buckwheat, and mix of 5% flax, 5% sorghum, 5% oat, 5% buckwheat required similar force to rupture. After 4 days of storage this parameter decreased significantly and did not show any essential changes till day 12, when it decreased drastically.

Discussion

Dough characteristics were affected by the incorporation of non-wheat cereals. Subjective measurements demonstrated that whole white wheat and whole multigrain flours, due to their coarse texture made tortilla dough rougher, harder, and less extensible. The same tendency was observed using objective measurements. It indicated a reduced elasticity in the wheat dough. The possible explanation for this phenomenon includes dilution and disruption of the gluten matrix by fibers of the incorporated flours as well as increased dough water absorption (Seetharaman et al. 1998). None of the multigrain flours contained gluten; fibers and non-gluten proteins diluted the wheat gluten and reduced dough elasticity. Also, despite the higher water levels used in formulations of whole wheat and whole multigrain flour tortillas these treatments tended to have harder dough. Water absorption in wheat dough increases with increased fiber (Wang et al.., 2002; Anil, 2007) and non-gluten proteins (Ribotta et al. 2005). Fiber molecules contain many hydroxyl groups which facilitate water interactions through hydrogen bonding (Wang et al. 2002).

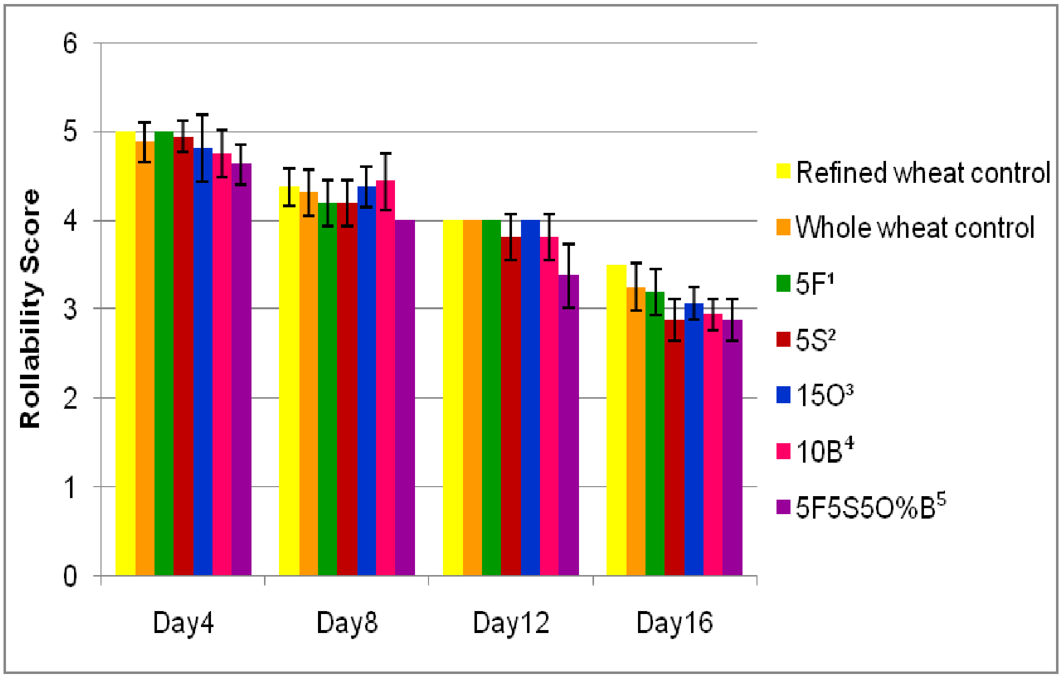

Fig. 6. Mean rollability scores of control and whole multigrain flour tortillas stored for 16 days.

Error bars represent standard deviations. Test was performed with two tortillas for each of the four processing days. The ingredients indicated were substituted for whole white wheat flour.

[1] 5% Golden stabilized ground flaxseed

[2] 5% High tannin sorghum bran

[3] 15% Whole oat flour

[4] 10% Whole buckwheat flour

[5] 5%Flax, 5% Sorghum bran, 5% Oat, 5%Buckwheat

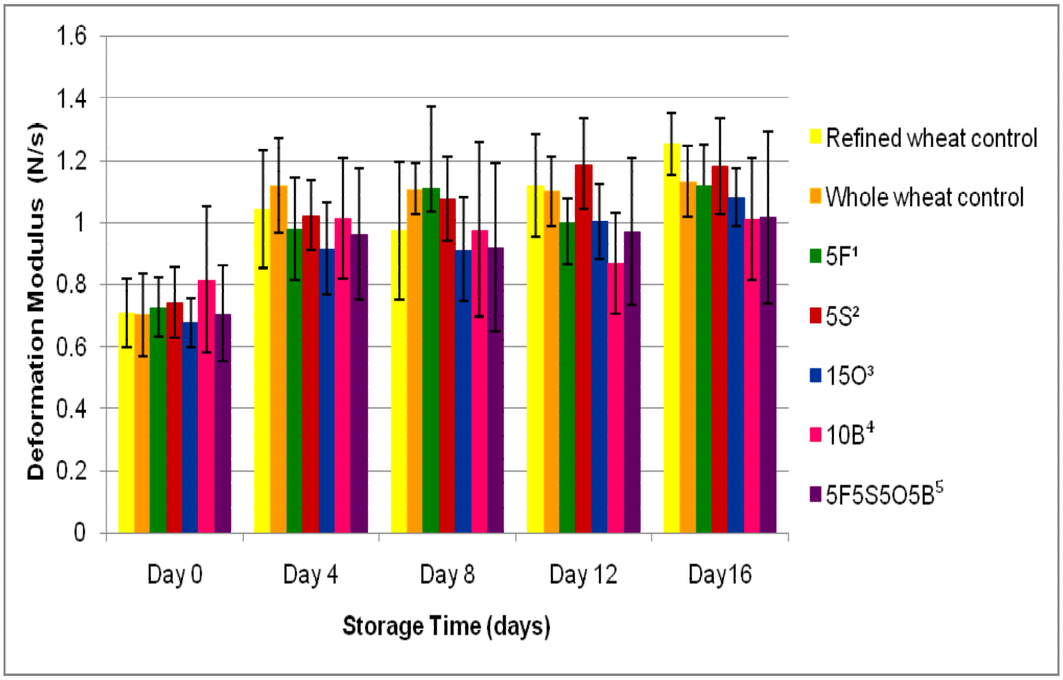

Fig 7. Deformation modulus of refined wheat, whole white wheat and whole multigrain flour tortillas stored for 16 days.

Error bars represent standard deviations. Test was performed with two tortillas for each of the four processing days. The ingredients indicated were substituted for whole white wheat flour.

[1] 5% Golden stabilized ground flaxseed
[2] 5% High tannin sorghum bran
[3] 15% Whole oat flour
[4] 10% Whole buckwheat flour
[5] 5%Flax, 5% Sorghum bran, 5% Oat, 5%Buckwheat

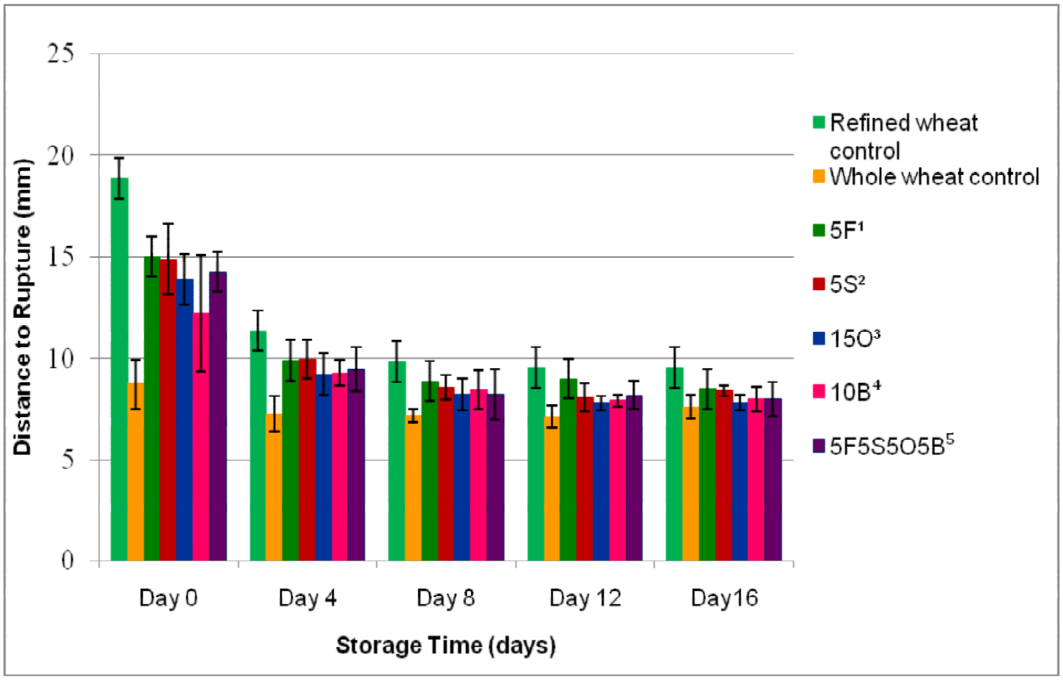

Fig 8. Distance to rupture of refined wheat, whole white wheat and whole multigrain flour tortillas stored for 16 days.

Error bars represent standard deviations. Test was performed with two tortillas for each of the four processing days. The ingredients indicated were substituted for whole white wheat flour.

[1] 5% Golden stabilized ground flaxseed

[2] 5% High tannin sorghum bran

[3] 15% Whole oat flour

[4] 10% Whole buckwheat flour

[5] 5%Flax, 5% Sorghum bran, 5% Oat, 5%Buckwheat

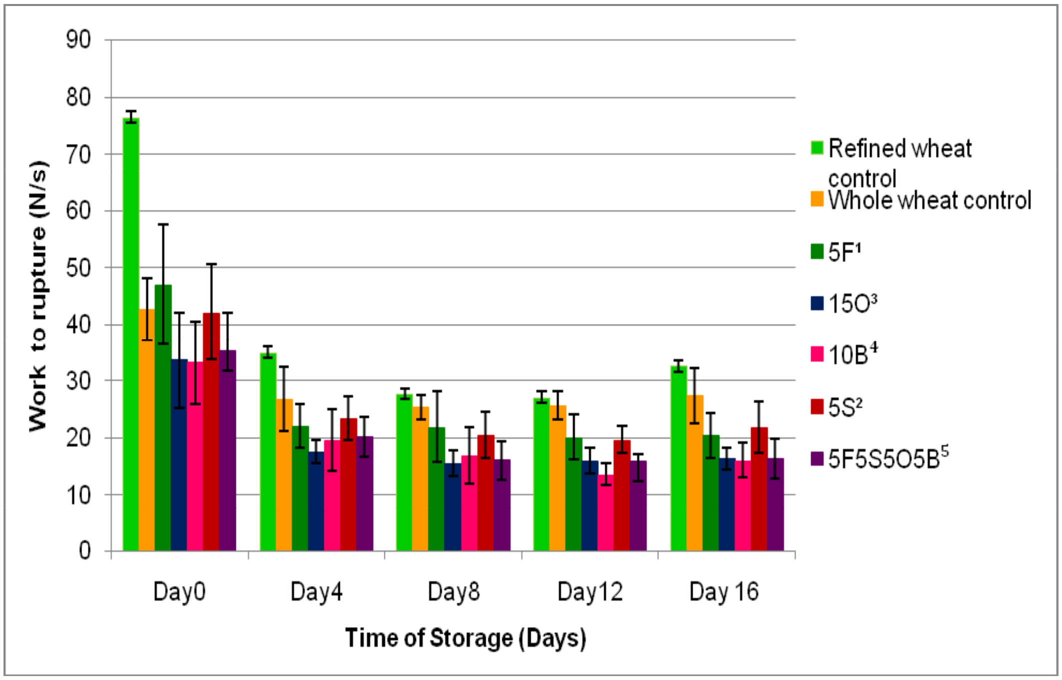

Fig 9. Work to rupture of refined wheat, whole white wheat and whole multigrain flour tortillas stored for 16 days.

Error bars represent standard deviations. Test was performed with two tortillas for each of the four processing days. The ingredients indicated were substituted for whole white wheat flour.

[1] 5% Golden stabilized ground flaxseed
[2] 5% High tannin sorghum bran
[3] 15% Whole oat flour
[4] 10% Whole buckwheat flour
[5] 5%Flax, 5% Sorghum bran, 5% Oat, 5%Buckwheat

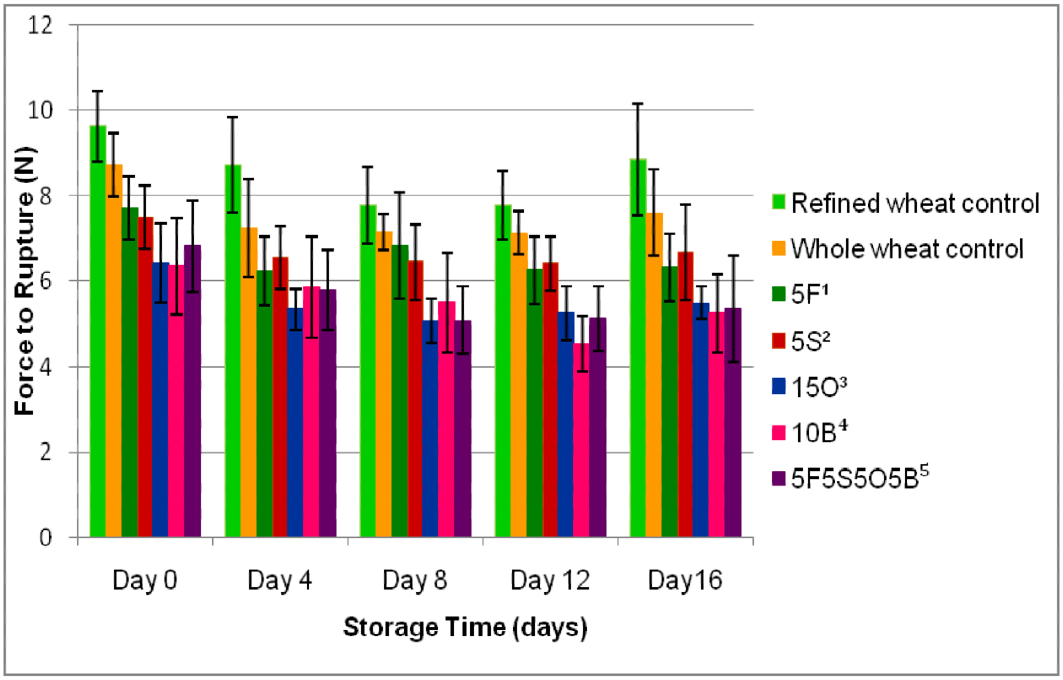

Fig 10. Force to rupture of refined wheat, whole white wheat and whole multigrain flour tortillas stored for 16 days.

Error bars represent standard deviations. Test was performed with two tortillas for each of the four processing days. The ingredients indicated were substituted for whole white wheat flour.

[1] 5% Golden stabilized ground flaxseed

[2] 5% High tannin sorghum bran

[3] 15% Whole oat flour

[4] 10% Whole buckwheat flour

[5] 5%Flax, 5% Sorghum bran, 5% Oat, 5%Buckwheat

According to Ribotta et al. (2004) and Maforimbo et al. (2006) the addition of non-gluten proteins causes the competition between the non-gluten proteins and gluten for water molecules. Lorimer and coworkers (1991) found that the incorporation of non-gluten proteins results in the disruption of starch-protein complexes and disulphide interchange with the non gluten proteins.

Incorporation of multigrain flours did not cause a significant impact on weight of prepared tortillas. Thickness, however, was visibly reduced by the incorporation of non-wheat flours, reflecting the poor dough structure that does not allow puffiness. The characteristic fluffy texture of the tortilla depends on the retention of steam and leavening gases by the gluten matrix (McDonough et al. 1996). All of the incorporated flours were whole grain, gluten free. These caused the disruption of the gluten structure and gave thinner tortillas with larger diameter.

The opacity score, which is affected by the degree of tortilla puffiness, was also affected by the addition of non-wheat flours. Tortilla air bubbles are able to diffract the light thus increasing the opacity (Adams and Waniska 2002). Thus, fluffy tortillas tend to be more opaque whereas the flatter ones are more translucent. Multigrain components dilute the gluten matrix, and prevent bubble formation. Hence, refined wheat flour tortillas were significantly more opaque than whole wheat and multigrain prototypes.

Multigrain flour addition had a significant impact on tortilla color. Whole grain flours are made from the intact kernel. High fiber content, high level of antioxidants and other substances naturally present in the kernel are responsible for the dark color of the flour, which affects the appearance of the final product. In addition, positive correlation between tortilla moisture content and tortilla lightness was observed ($r = 0.82$). This contradicts the study of Wang and Flores (2000) where moisture content had a negative impact on tortilla lightness.

Objective and subjective methods were performed to evaluate the effect of formulation and storage time on tortilla texture. Both objective and subjective tests showed that tortillas lost their flexibility over time. Tortilla extensibility was highest for the refined wheat flour tortillas and decreased over time. Tortilla firmness, expressed as deformation modulus was similar for all the treatments and increased over time. The low firmness of tortillas with a mix of 5% flax, 5% sorghum, 5% oat, 5% buckwheat indicates the reduced level of gluten which reduces tortilla flexibility. Subjective test also showed decrease in tortilla flexibility over time. After 16 days of storage dowel scores of tortillas with 5% sorghum bran, 10% buckwheat and the mix of four cereals were significantly lower than 3. The flexibility loss for refined wheat flour tortillas was less pronounced than for whole white wheat and multigrain trials. These results can be explained as a dilution effect. With incorporation of gluten-free cereals the proportion of gluten was reduced, therefore the tortilla structure was affected. Besides, low water holding capacity of multigrain treatments had a negative effect on tortilla texture. The reduced tortilla flexibility translated into lower rollability scores.

Nutritional value of multigrain tortillas (Table IX) showed obvious advantage over those of refined wheat flour tortillas. Each multigrain treatment was enriched with omega-3 fatty acids, dietary fiber and antioxidants. The tortillas with the mix of 5% flax, 5% sorghum, 5% oat, 5% buckwheat contained the highest amount of dietary fiber (4.4 g per tortilla) while refined wheat tortillas had the lowest (1.2 g per tortilla). Any product that contains at least 3 g of dietary fiber per serving can be labeled “good source of fiber”, while 4.5 g of dietary fiber allows to claim “excellent source of fiber”. Thus, the amount of fiber in this particular treatment satisfies the requirements for having a label “good source of fiber” and in fact is very close for labeling as an “excellent source of fiber”. Furthermore, this treatment combined the health benefits not only of the whole white wheat, but also of 4 different cereals. Oats are an excellent food for lowering cholesterol and reducing risk of heart disease because of the high soluble fiber content. Almost one third of total fatty acids present in oats are polyunsaturated which are required for good health. Oats are rich in B vitamins, minerals and contain the antioxidant avenathramide. Oat bran is rich in ß-glucans, and these viscous polysaccharides lower the rate of carbohydrate and lipid absorption (Lifschitz, 2002). Oats are a good choice for diabetics and people conscious about their weight.

Sorghum bran is great source of flavonoids and condensed tannins. These substances have very strong antioxidant properties and protect against cardiovascular disease and certain types of cancer *(Dykes and Rooney 2007).* Sorghum bran has slow digestibility, which can be helpful in weight management (Awika 2003).

Golden flaxseed has a pleasant, slightly sweet, slightly nutty taste and as flour, incorporates well into many foods. It represents one of the richest natural sources of α-linolenic acid (ALA) and plant lignans. In addition, it is rich in fat, dietary fiber and protein. It has been called a functional food due to ALA and lignan content. It can help in chronic conditions such as cardiovascular disease, stroke and certain type of cancer (Morris and Vaisey-Genser, 2003).

Buckwheat is known as a healthy food because of its large amounts of protein and minerals. It is also rich in B vitamins and antioxidants. Zielinski and Kozlowska (2000) reported that buckwheat groats have a higher antioxidant activity than other cereals. Among antioxidants rutin is of particular interest because it prevents the elevation of blood pressure (Matsubura et al. 1985). Experiments with animal models as well as with human beings demonstrated that buckwheat flour may help in the prevention and management of diabetes type 2, obesity, hypertension, hypercholesterolemia and constipation (Li and Zhang 2001).

Thus, despite being more susceptible to staling, the developed multigrain flour tortillas have a favorable nutritional value. Further investigation should be focused on extending their shelf-stability.

Table IX

Calculated nutritional values of the selected multigrain flour tortillas (g per tortilla)

Sample	Crude Protein (g)	Dietary Fiber (g)	α-linolenic acid (g)
Refined Wheat Control	3.4	1.3	ND
Whole White Wheat Control	3.8	3.4	ND
5%Flax 5%Sorghum Bran	3.9	4.0	0.29
5%Flax 15% oat Flour	3.9	3.5	0.29
5% Flax	3.4	3.4	0.29
5%Flax 10% Buckwheat	3.9	3.6	0.29
5%Flax 5% Sorghum Bran5%Oat 5%Buckwheat	3.6	4.4	0.29

CHAPTER V

EFFECTS OF HYDROCOLLOID AND AMYLASE ON MULTIGRAIN TORTILLA CHARACTERISTICS

Hydrocolloid and amylase effects on dough rheology

Based on the previous study whole multigrain tortillas were less shelf-stable than those from refined wheat. Prototypes containing a combination of 5% flax, 5% sorghum, 5% oat and 5% buckwheat are of particular interest because of their excellent nutrient value. Hence, it was chosen to evaluate the effect of various rates of gum and α-amylase on shelf-stability.

Tables X and XI show the effect of different rates of commercial hydrocolloids and α-amylase on dough rheological properties. In general, doughs with shelf-stability improvers were similar. However, compared to the control, 75 ppm dough was significantly softer (2.3) than those with 100 ppm α-amylase (2.3) and 1.5% gum (2.4) were easier to press. These results correlated with objective test data. Control and dough with 0.5 % gum required the highest force to compress (230 N). Treatments that contained 1% gum and 1.5% gum were the softest (160 N and 150 N respectively). Stress relaxation tests were performed, but no significant differences were detected.

Tortilla general characteristics

Neither α-amylase nor hydrocolloids significantly affected thickness of whole multigrain flour tortillas (Table XII). Diameter, however, varied significantly among the samples. Tortillas with α-amylase and 0.5% gum had diameters similar to the control while tortillas with 1% and 1.5% gum had larger diameters. Tortilla diameter increased gradually with increased concentrations of incorporated gum.

Table X

Effect of hydrocolloid and α-amylase on subjective properties of whole multigrain dough

Treatment	Smoothness	Softness	Extensibility	Force to extend	Press rating
5F5S5O5B[1] (control)	3.0^{a}	3.0^{a}	2.2^{a}	2.8^{a}	3.0^{a}
control + 50 ppm	3.0^{a}	2.8^{ab}	2.4^{a}	2.6^{a}	2.8^{ab}
control + 75 ppm	3.0^{a}	2.3^{b}	2.4^{a}	2.5^{a}	2.5^{ab}
control + 100 ppm	3.0^{a}	2.4^{ab}	2.6^{a}	2.5^{a}	2.3^{b}
control + 0.5% gum	3.0^{a}	2.8^{ab}	2.5^{a}	2.8^{a}	2.8^{ab}
control + 1% gum	3.0^{a}	2.4^{ab}	2.3^{a}	2.5^{a}	2.5^{ab}
control + 1.5% gum	3.0^{a}	2.5^{ab}	2.6^{a}	2.4^{a}	2.4^{b}
HSD	0	0.7	0.6	0.6	0.5

Means from five replicates; means in a column followed by the same letter are not significantly different ($p<0.05$).

[1] 5% Flax, 5%Sorghum Bran, 5% Oat, 5% Buckwheat

Table XI

Effect of hydrocolloid and α-amylase on dough rheological properties

Treatment	Compression Force (N)	F20 (N)	F100 (N)	SR% (%)	RT (s)
5F5S5O5B[1] (control)	230^{b}	10.4^{a}	6.7^{a}	12.7^{a}	7.9^{a}
control+50ppm	190^{ab}	10.9^{a}	7.0^{a}	13.4^{a}	8.4^{a}
control+75ppm	190^{ab}	10.4^{a}	6.6^{a}	12.7^{a}	7.9^{a}
control+100ppm	190^{ab}	10.3^{a}	6.6^{a}	12.6^{a}	7.8^{a}
control+0.5%gum	230^{b}	10.9^{a}	7.0^{a}	13.4^{a}	8.4^{a}
control+1% gum	160^{a}	10.4^{a}	6.7^{a}	12.7^{a}	7.9^{a}
control+1.5% gum	150^{a}	10.1^{a}	6.4^{a}	12.4^{a}	7.7^{a}
HSD	49	0.96	0.96	1.19	0.86

Compression force test was performed in triplicates; stress relaxation test in duplicates. Both tests were conducted during each of five processing days

Means from five replicates; means in a column followed by the same letter are not significantly different ($p<0.05$).

[1] 5% Flax, 5%Sorghum Bran, 5% Oat, 5% Buckwheat

Tortilla thickness was not significantly different among the samples. Tortilla weight ranged from 39.2 g (100 ppm α-amylase) to 42.5 g (1.5% gum). Tortillas with 1.5% gum had the highest moisture content; while those with 100 ppm α-amylase had the lowest (33.6% and 31.4% respectively). Tortillas prepared with the commercial hydrocolloid retained more moisture than the control. This was related to the different amount of water used in amylase and gum formulations, and as well as the ability of these additives to increase water holding capacity of tortillas.

Opacity scores (Table XIII) ranged from 50 (0.5% gum) to 56 (1% gum). All the tortillas had unsatisfactory opacity scores. However, treatments prepared with 75 ppm α-amylase, 1% and 1.5% gum were significantly more opaque than other treatments. Neither gum nor amylase addition had any effect on tortilla a* and b*- values.

Rollability score

Rollability scores decreased gradually over time. Control, gum and α-amylase treated tortillas had similar rollability scores after 1 week of storage (Fig. 11). Treatments with 75 ppm and 100 ppm α-amylase had the highest overall dowel scores (4.08 and 4.06 respectively). Tortillas prepared with 0.5% hydrocolloid reached an unacceptable score of 3 on the 12th day of storage. After 16 days of storage tortillas with 75 ppm, 100 ppm of α-amylase and 1.5% gum had rollability score higher than 3.

Texture profile

Tortilla deformation modulus ranged from 0.84 N/mm (0.5% gum) to 0.55 N/mm (75 ppm α-amylase) (Fig. 12). In general, firmness values of tortillas containing 75 ppm of α-amylase were significantly lower than those of the control. Both α-amylase treatments and 1% and 1.5% hydrocolloid addition decreased rate of firmness. Force to rupture tortilla was comparable to the control for the majority of the treatments and did not change significantly over time (Fig. 13). Amylase addition caused a delay in the loss of flexibility. This parameter also decreased gradually during storage. Work to rupture (Fig. 14) was similar for all the samples. Distance to rupture is the distance that the probe traveled to tear a tortilla. It ranged from 8.89 to 10.78 mm (Fig 15). This parameter was not significantly different for the control and the gum treatments.

Sensory evaluation

Tortillas enriched with a composite of 5% flax, 5% sorghum, 5% oat and, 5% buckwheat were prepared without any shelf-extending additives were used for sensory analysis. This treatment was compared with a commercial multigrain tortilla (Mission 6''Fajita Multi-Grain Flour Tortillas) and whole white wheat tortilla made in the laboratory. The commercial multigrain product has whole wheat flour, wheat bran, cracked wheat, rye flakes, wheat flour, barley flakes, triticale flour, corn flour, oat flakes, barley flour, and rice flour. Evaluation of tortillas was done by a 36-member consumer taste panel. Survey ballots, data for consumer panels and demographics data are given in the Appendix.

No significant difference was observed between the three samples for all parameters evaluated (Fig. 16). Comments and opinions about sensory characteristics of the samples are given in Table XIV.

Table XII

Effect of hydrocolloid and α-amylase addition on physical properties of whole multigrain flour tortillas

Treatment	Diameter (mm)	Weight (g)	Thickness (mm)	Moisture (%)
5F5S5O5B[1] (control)	180^{ab}	40.9^{ab}	2.00^{a}	32.3^{ab}
control+50ppm	179^{ab}	41.3^{ab}	1.95^{a}	32.0^{a}
control+75ppm	182^{b}	40.0^{ab}	1.89^{a}	32.1^{a}
control+100ppm	181^{ab}	39.2^{a}	1.88^{a}	31.4^{a}
control+0.5%gum	178^{a}	41.8^{b}	1.90^{a}	32.2^{ab}
control+1% gum	187^{c}	41.8^{b}	1.94^{a}	32.5^{ab}
control+1.5% gum	189^{c}	42.5^{b}	1.95^{a}	33.6^{b}
HSD	3	2.4	0.32	1.44

Means from five replicates; means in a column followed by the same letter are not significantly different ($p<0.05$).

[1] 5% Flax, 5%Sorghum Bran, 5% Oat, 5% Buckwheat

Table XIII
Effect of gum and α-amylase on opacity scores and color values of whole multigrain flour tortillas

Treatment	**Opacity (%)**	**L***	**a***	**b***
5F5S5O5B[1] (color)	51^{a}	53.7^{ab}	6.4^{a}	14.7^{a}
color+50ppm[2]	51^{a}	53.7^{ab}	6.5^{a}	14.8^{a}
color+75ppm[3]	54^{b}	54.1^{ab}	6.2^{a}	14.8^{a}
color+100ppm[4]	51^{a}	53.7^{ab}	6.4^{a}	14.7^{a}
color+0.5%gum[5]	50^{a}	53.4^{a}	6.4^{a}	14.9^{ab}
color+1% gum[6]	56^{b}	54.8^{b}	6.5^{a}	15.4^{b}
color+1.5% gum[7]	53^{ab}	54.8^{b}	6.4^{a}	15.3^{ab}
HSD	3.6	1.5	0.4	0.5

Means from five replicates; means in a column followed by the same letter are not significantly different ($p<0.05$).

[1] 5% Flax, 5%Sorghum Bran, 5% Oat, 5% Buckwheat

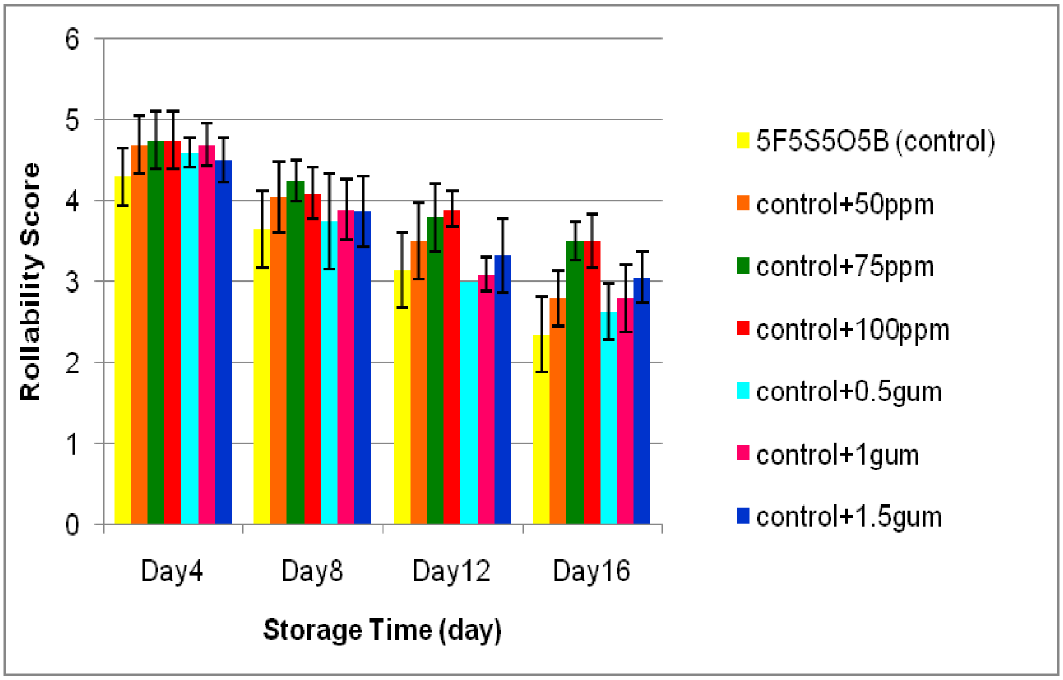

Fig. 11. Effect of additives on the rollability score of whole multigrain flour tortillas.

Error bars represent standard deviations. Test was performed in duplicates on five processing days

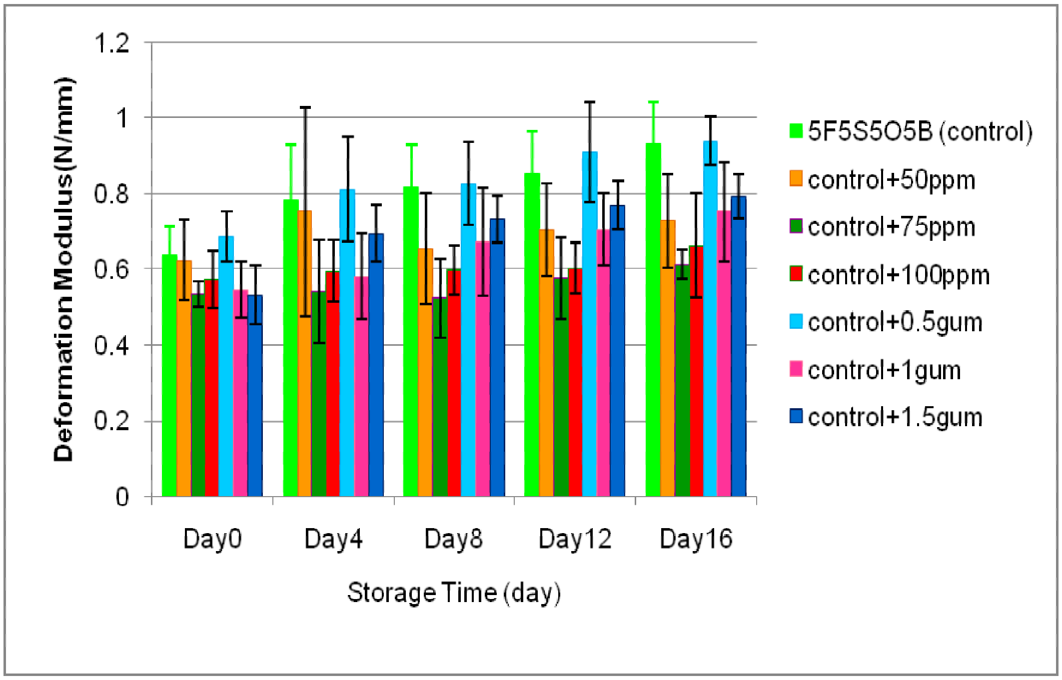

Fig. 12. Effect of α-amylase and hydrocolloid on deformation modulus of whole multigrain flour tortillas.

Error bars represent standard deviations. Test was performed in duplicates for five processing days

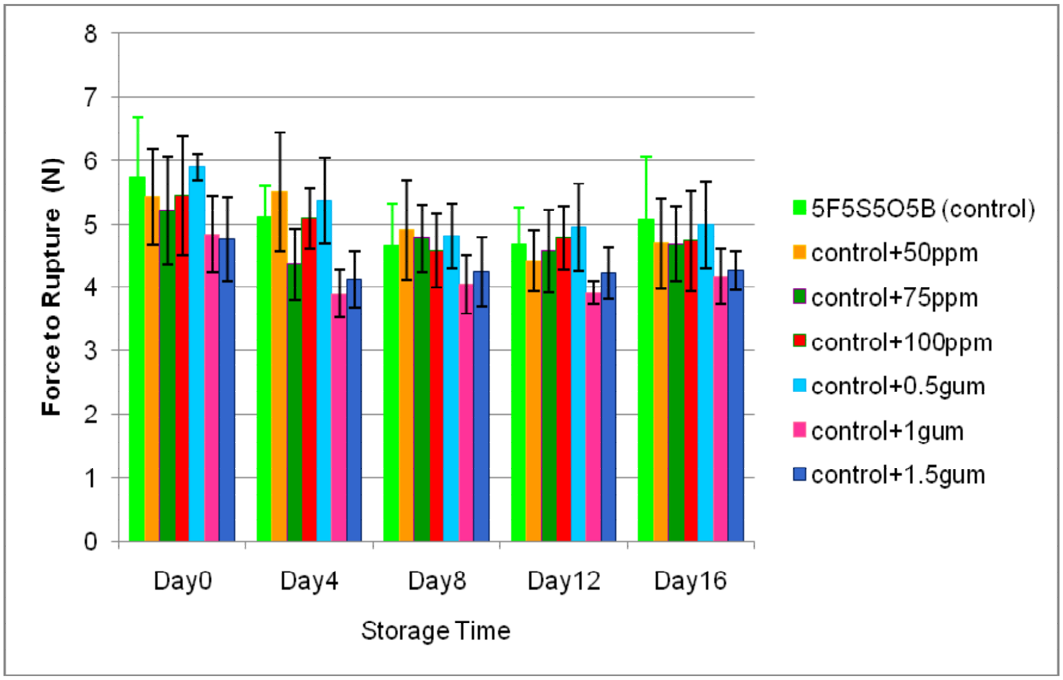

Fig. 13. Effect of α-amylase and hydrocolloid on force to rupture of whole multigrain flour tortillas.

Error bars represent standard deviations. Test was performed in duplicates for five processing days

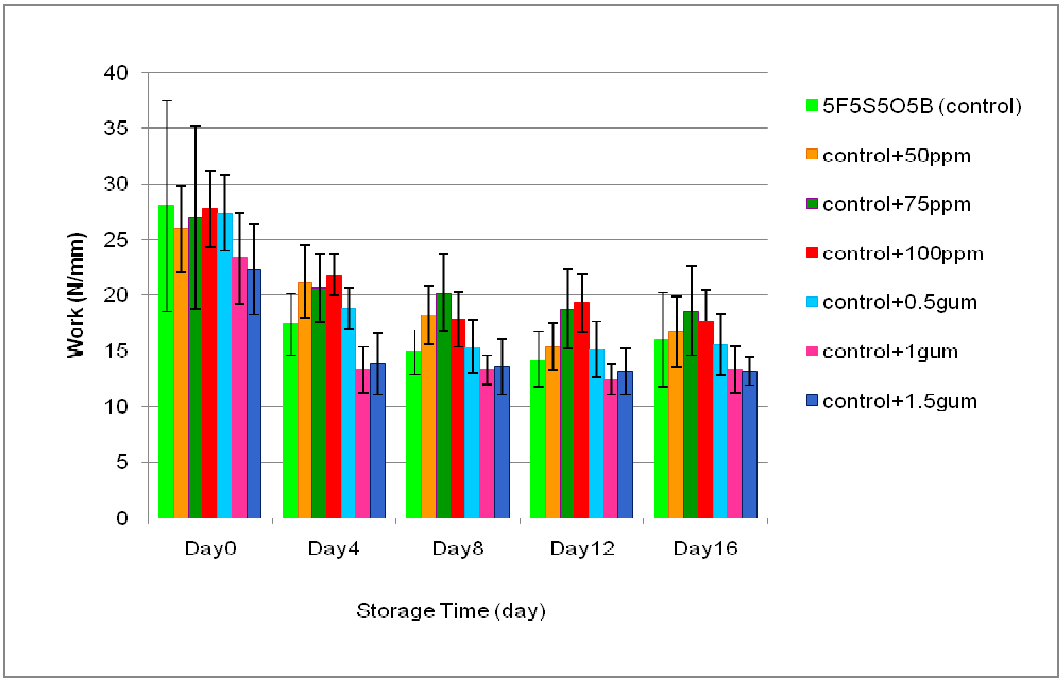

Fig. 14. Effect of α-amylase and hydrocolloid on work to rupture of whole multigrain flour tortillas.

Error bars represent standard deviations. Test was performed in duplicates for four processing days

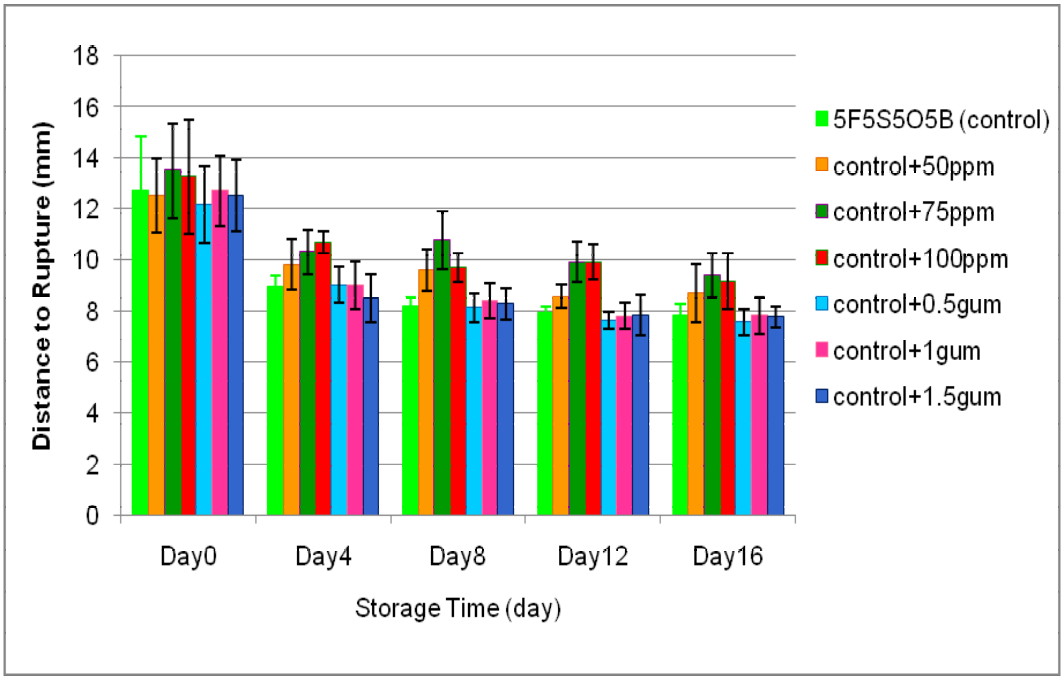

Fig. 15. Effect of α-amylase and hydrocolloid on distance to rupture of whole multigrain flour tortillas.

Error bars represent standard deviations. Test was performed in duplicates for four processing days.

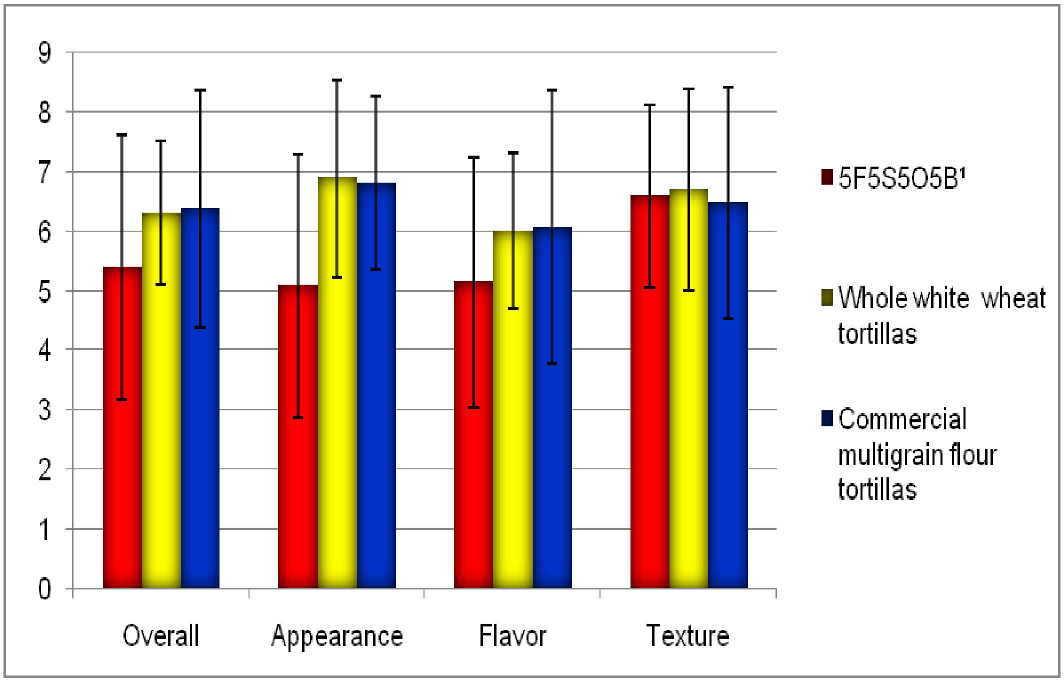

Fig. 16. Sensory scores of whole multigrain flour tortillas.

Error bars represent standard deviations
[1] 5% Flax, 5% Sorghum Bran, 5% Oat, 5% Buckwheat

Table XIV

Subjective Comments of Consumer Taste Panel for Whole Multigrain Flour Tortilla

Treatment	**Comments**[a]
5F5S5O5B	nice , best, yummy, weird color, bitter aftertaste, astringent, dry in mouth
Whole Wheat Flour Tortilla	bland, rancid odor, good color, aftertaste, needs more salt
Commercial Brand	creamy, nutty, bitter, too tough, dry, too sweet, bad.

[a] More than 50% of the panelists did not choose to comment on the tortillas

Discussion

The goal of the second part of the research was to evaluate the effects of amylase and hydrocolloid on physical properties, shelf-stability and texture of the whole multigrain flour tortillas.

Addition of α-amylase and hydrocolloids improved tortilla dough to some extent. Subjective dough evaluation revealed that the majority of the parameters were similar among the treatments. However, tortillas with 75 ppm amylase were significantly softer than control dough, and dough with 100 ppm amylase and 1.5% gum required significantly less force to press. Objective compression test showed that addition of gum at 1% and 1.5% gave softer doughs. These results were expected, since the mechanism of action of α-amylase and hydrocolloids in bakery products has been investigated. Rossell at al (2001) stated that the addition of hydrocolloids changes dough rheological properties, dough firmness, and extension resistance.

Ribbota and associates (2005) explained this is due to the ability of hydrocolloid to form hydrophilic complexes with gluten proteins, bind water and decrease moisture migration in the dough.

Amylases also affect the consistency of the dough, but through a different mode of action. Damaged starch granules absorb more water than intact granules. When amylase is added to the system, it decreases starch's water absorption capacity. Since the ability to immobilize water is reduced, the damaged granules release free water, which softens the dough (Hegenbart 1994).

Tortilla physical characteristics were also affected by amylase and hydrocolloid addition. Tortillas that contained hydrocolloids were significantly heavier than the control or amylase treatments. Similarly, gum containing tortillas accumulated and retained moisture better than the control or tortillas prepared with α-amylase. The main function of hydrocolloids in tortillas is their ability to bind water. Thus, addition of hydrocolloids to the tortilla formulation yields larger tortillas. Similar results were obtained by Arora (2003), who compared the effect of different commercial enzymes on tortilla properties.

The α-amylase acts on damaged starch granules and reduces their ability to absorb water. Tortilla thickness was not affected by α-amylase or by gum addition which contradicts the data of other researchers. Arora (2003) observed that the addition of 0.05 units of the bacterial α-amylase adversely affected tortilla thickness. Anton and associates (2008) concluded that addition of certain hydrocolloids led to an increase in tortilla thickness. Treatments prepared with 75 ppm α-amylase, 1% and 1.5% gum were more opaque than the control sample.

Aguilera and Stanley (1999) stated that texture of a food product is based on its structural organization. Thus any change in food structure leads to corresponding texture changes. Starch and gluten are the main components of the wheat dough. Any treatment that results even in slight alteration of the functionality of the starch will cause a profound effect on tortilla texture (Alviola and Waniska 2008). Addition of amylase (75 ppm and 100 ppm) and gum (1% and 1.5%) to the formulation led to longer retention of tortilla flexibility.

Rheological data showed that both 1% and 1.5% of gum and 75 ppm and 100 ppm of amylase improved tortilla texture. These results are similar to the data of Shalini et al. (2007) who evaluated the effect of guar gum addition on chapatti quality. They found that hydrocolloids improved extensibility of fresh and stored chapatti. In the present study, the beneficial influence of gum on multigrain tortilla flexibility may be caused by the increased water holding capacity which helps to prevent staling. It can also signify that commercial hydrocolloid hold structure together, effectively compensating for the weak structure caused by substituting of wheat flour with multigrain blends of grains without gluten.

Amylase applied in the amount of 75 ppm and 100 ppm caused significant improvement in tortilla shelf-stability. Similar results were obtained by

Alviola and Waniska (2008). They concluded that hydrolytic action of amylase changed starch properties which caused significant improvement in tortilla flexibility. Amylase acts on damaged starch granules of tortillas and hydrolyses dispersed amylose. It prevents reassociation of amylose molecules and therefore reduces rate of staling (Alviola and Waniska 2008). Hegenbart (1994), analyzing antistaling properties of amylase, concluded that by hydrolyzing the amylopectin into smaller units, bacterial α-amylase can maintain softness and improve shelf-stability.

Sensory evaluation showed no significant difference in consumer acceptability of the three samples evaluated. The samples were not differentiated partly because of the high variability in scores. The relatively limited number of respondents and their being untrained contributed to this. The participants were randomly selected and not without specifically selecting those who regularly consume tortillas (particularly multigrain tortillas), thus the wide range of preferences. The multicultural environment of Texas A&M University where the sensory analysis was conducted may explain the different sensory scores. People leading a healthy diet tend to pay attention to the food nutritional composition. They also prefer products that have characteristics commonly associated with healthy products such as: darker color, chewy texture, unusual notes in flavor. The multigrain tortilla developed has all of these qualities. Thus, if sensory evaluation was conducted taking into consideration life style of the panelists, tortillas enriched with 5% flax, 5%sorghum bran, 5% oat and 5% of buckwheat might have received higher scores.

CHAPTER VI

CONCLUSION

Acceptable whole white wheat tortillas substituted with different ratios of non-wheat cereal grains were prepared using the hot press procedure. The tortillas had improved nutritional values. The tortillas containing the multi grain mix of 5% flax, 5% sorghum bran, 5% oat flour and 5% buckwheat flour contained about 4.4 g of dietary fiber and 0.29 g α-linolenic fatty acids per tortilla. It makes them a good alternative for health conscious people. The added grains gave the tortillas a pleasant dark color that is commonly associated with healthy products.

The challenge in this study was to create a healthy product that would have a good taste, and acceptable shelf-stability. To achieve this goal, the various multigrain flours were blended and substituted for whole white wheat flour. The addition of the composite flours affected dough and tortilla characteristics along with nutritional value.

A stiffening of the dough was subjectively observed with the replacement of whole wheat by multigrain flours. This condition was confirmed by objective dough tests. Multigrain doughs were less extensible, less smooth and soft and required significantly more force to compress than refined wheat flour tortilla doughs.

Multigrain tortillas were thinner, more translucent and were of larger diameter than refined wheat flour tortillas. They were also firmer and less flexible than refined wheat tortillas. At the 16th day of storage, the majority of the multigrain treatments had unacceptable rollability scores of “3”.

Hydrocolloid and α-amylase significantly improved dough rheology, shelf stability and some physical properties of multigrain tortillas. Addition of 75 ppm and 100 ppm α-amylase and 1% and 1.5% of gum helped to improve flexibility of multigrain tortilla, which was demonstrated by the dowel test and objective measurements. The treatments, except 1% gum, had rollability scores of more than “3” till the end of the storage period.

Since one of the main problems in tortilla quality is the deterioration of texture with time because of staling (Waniska 1999), these additives were more beneficial to multigrain tortilla shelf stability.

There are many market opportunities for new types of whole multigrain flour tortillas in the North American market. Due to its non-traditional flavor and color, “wrap” is a more appropriate name for the new product. This name implies lots of possibilities for incorporating specialty cereals into the traditional wheat flour tortilla formulation, resulting in healthier products. Although it seems that multigrain tortillas could attract health-conscious consumers, more research must be done in this area for the achievement of appropriate formulations for the preparation of high quality products on a large scale.

Future research

More work should be done to improve the properties of multigrain wheat flour tortillas. Studies on characterization of multigrain flours used in the tortilla formulation will explain their effects on quality. These should include studies of flour particle distribution and degree of starch damage. The effect of multigrain flours on tortilla dough water absorption is important. Adjustments in multigrain flour tortilla formulations and actual nutritional analysis of the prepared tortillas should be performed including how much antioxidant activity is lost during processing and how much is retained in tortillas. In order to get more precise data regarding consumer acceptance of the new product it would be very useful to conduct consumer study with a large number of participants. The effect of incorporated shelf extenders on sensory characteristics of the multigrain tortillas should be evaluated. To achieve the optimum shelf-stability of multigrain tortillas the combination of different rates of both α-amylase and commercial hydrocolloid can be studied.

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APPENDIX

CONSUMER PANEL QUESTIONNAIRE

Please complete the information below:

Age:

☐☐ 18-25 ☐☐ 26-30

☐☐ 31-35 ☐☐ 36-40

☐☐ 41-45 ☐☐ 46-50

☐☐ 51-55 ☐☐ 56-60

☐☐ 61-70 ☐☐ 71-80

Gender:

☐☐ Male ☐☐ Female

Ethnicity

☐☐ Caucasian

☐☐ African American

☐☐ Hispanic

☐☐ Asian

☐☐Native American

☐☐Other

About how often do you eat flour tortillas? (soft tacos, burritos, wraps, etc.)

☐☐ Every Day

☐☐ At least once a Week

☐☐ Once every Two Weeks

☐☐ Once a Month

☐☐ Once a Year

☐☐ Never

Do you suffer from any food allergies?

☐☐ Yes

☐☐ No

If you have any food allergies, you cannot participate in this study. Thank you for your willingness to help.

Instructions:

You will be testing three samples of tortillas. Samples are presented in the order to be tasted. Make sure to use the ballot with the sample number that matches the number of the sample. Please be sure to answer the questions completely and honestly. Check the box that best describes your answer. Take a drink of water and a bite of cracker before you start and as needed throughout testing.

Please check only one box that represents your response (X)

SAMPLE: ___

Please check one box that represents your response

1. Please rate your OVERALL ACCEPTABILITY of this sample

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely	Neither like nor dislike	Like Extremely

2. How much do you like or dislike the APPEARANCE of this sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely	Neither like nor dislike	Like Extremely

3. How much do you like or dislike the FLAVOR (taste and aroma) of this sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely	Neither like nor dislike	Like Extremely

4. How much do you like or dislike the TEXTURE (mouthfeel) of this sample?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely	Neither like nor dislike	Like Extremely

Additional Comments:

____

Consumer Panel Data

SAMPLE	Overall	Appearance	Flavor	Texture
5F5S5O5B	5.4±2.2	5.1±2.2	5.1±2.1	6.6±1.5
Whole wheat control	6.3±1.2	6.8±1.7	6±1.3	6.7±1.7
Commercial Brand	6.4±1.9	6.8±1.5	6.1±2.3	6.5±1.9

Consumer Demographic Data

Panelist	Age	Gender	Ethnicity	Frequency of the tortilla consumption
1	18-25	male	Hispanic	Once every two weeks
2	18-25	male	African American	At least once a week
3	26-30	male	Caucasian	At least once a week
4	51-55	female	Caucasian	At least once a week
5	56-60	female	Caucasian	At least once a week
6	18-25	female	Caucasian	At least once a week
7	51-55	female	Caucasian	Once every two weeks
8	18-25	male	Caucasian	Everyday
9	26-30	male	African American	At least once a week
10	18-25	female	Hispanic	Everyday
11	18-25	female	Hispanic	At least once a week
12	18-25	female	Caucasian	At least once a week
13	18-25	female	Caucasian	Once every month
14	18-25	female	Caucasian	At least once a week
15	18-25	female	Caucasian	At least once a week
16	36-40	female	Caucasian	Once every two weeks
17	51-55	male	Caucasian	Once every month
18	51-55	male	Hispanic	Once every month
19	18-25	male	Hispanic	Once every month
20	18-25	male	Asian	Once every month
21	51-55	female	Caucasian	At least once a week
22	26-30	female	Caucasian	At least once a week
23	26-30	male	Caucasian	At least once a week
24	31-35	male	African American	Once every month
25	26-30	male	Hispanic	Once every two weeks
26	18-25	female	Hispanic	Once every month
27	51-55	female	Caucasian	At least once a week
28	18-25	female	Hispanic	At least once a week
29	18-25	female	Hispanic	At least once a week
30	26-30	female	Other	At least once a week
31	36-40	female	Hispanic	Everyday
32	56-60	female	Caucasian	Once every two weeks
33	36-40	female	Hispanic	Once every two weeks
34	36-40	male	Hispanic	Once every two weeks
35	36-40	female	Caucasian	Once every two weeks
36	36-40	female	Hispanic	Once every two weeks

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