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Sharma, Ekta. Evaluating the Effect of Dietary Fiber Arabinogalactan on the Rheological and Textural Properties of Nonfat Set-type Yogurt

Abstract

Dietary soluble fiber has generated interest amongst researchers and consumers recently as people have started seeking a healthier diet for heart benefits, to prevent obesity, and increase beneficial gut bacteria. Furthermore, yogurt texture is recognized as an important sensory quality that affects consumer perception. The main objective of this research was to evaluate the effect of the prebiotic substrate, arabinogalactan, a soluble fiber, on the rheological and texture properties of nonfat set-type yogurt. Arabinogalactan (1.2% by weight in the first trial and 0.8% in the second trial) was incorporated into milk and made into yogurt. Yogurt from nonfat dry milk was also prepared to generate a standard score to compare the fiber supplemented yogurts. Gel strengths of the yogurts were measured using vane rheometry after one day and after seven days of refrigerated storage. A significant difference ($p \leq 0.05$) in yield stress value between the control yogurt sample, 0.8% arabinogalactan supplemented yogurt, and 1.2% arabinogalactan supplemented yogurt was observed on day 1 as well as on day 7. Fortification with arabinogalactan did not affect rates of fermentation.

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Chapter I: Introduction

Preparation of yogurt takes place through the milk fermentation process with various cultures of bacteria comprising of *streptococcus* subspecies mixed with *lactobacillus delbrueckii* subspecies and *thermophiles* (Barbano, 2009). Yogurt comes in two types, distilled and set, (Augustin, Cheng, Glagovskaia, Clarke, & Lawrence, 2003), in which there is a difference in the yogurt manufacturing process. In the set yogurt, which is inclusive of fruit on the bottom, the fermentation of the lactic acid bacteria generates lactic acid and a structure of continuous gel is formed in the container that is purchased by the consumer. In the processing of the stirred yogurt, the acid gel formation takes place during the stage of maturation in the large tanks for fermentation and then undergoes disruption through the process of stirring in the agitation process (Jaros & Rohn, 2003). After stirring, pumping of the product takes place through a screen in which the product is given a viscous and smooth texture. The physical attributes of the yogurt are inclusive of perceived viscosity and the overall quality and sensory acceptance of the product by the consumers (Cheng et al., 2000).

A clear understanding of the mechanisms through which the yogurt texture is enhanced together with the texture development conditions is essential when it comes to the incorporation of arabinogalactan for improvement of yogurt quality. In order to provide a more clear insight to the effect of introducing arabinogalactan on the yogurt sensory properties, it is important to begin by describing the different yogurt varieties and the process of yogurt manufacturing to the reader.

Yogurt Varieties

In order to ensure that natural sourness is offset, sweetened yogurt has dominated most of the markets in the United States, as yogurt may be flavored or stored in a container with fruit flavor (Serra et al., 2009). In the United States, the yogurt that is stirred before being purchased is referred to as Swiss-style. Most yogurt manufacturers in the United States have a tendency of adding pectin, which is derived from fruits as a thickening agent (Serra et al., 2009). Gelatin is also added to enhance artificial creaminess and thickness at a reduced cost. Other commonly consumed yogurt varieties are referred to as “cream line.” These varieties are manufactured from whole milk that is yet to be homogenized (Chandan et al., 2006). The homogenization process prevents the cream from sinking at the bottom and the fat globules in unhomogenized milk reduce the firmness of the product by interrupting the gel network. Instead of using pieces of raw fruit in fruit yogurts, fruit jam is mainly used to ensure that the yogurt can be stored for weeks (Islenten & Karagul-Yuceer, 2006).

The Physical and Rheological Properties of Yogurt

Yogurt is produced by lactic acid coagulation of milk that brings milk to gelification due to the acid destabilization of the protein system. Texture is one of the essential components of yogurt quality and describes the rheological and structural attributes perceptible by means of mechanical, tactile, and visual receptors (Sodini, Remeuf, Hadda & Corrieu, 2004).

Food rheology involves the study of food materials flow and deformation (Haque, Richardson, & Morris, 2001). The consistency, degree of fluidity, and other mechanical properties are important in understanding how long food can be stored, how stable it will remain, and in determining food texture, which primarily affect the acceptability of the food product by the consumer.

Yogurt exhibits a variety of non-Newtonian effects that include shear-thinning, yield stress, viscoelasticity, and time dependency. Set yogurt is a viscoelastic liquid (Truong & Marshall, 2011). Viscoelastic is an indication that there are some elastic properties in the material and some of the property flow of a viscous fluid. The visoelastic properties are affected by the solids concentration. Furthermore in yogurt, a shear thinning is an effect where a fluid's viscosity (the measure of a fluid's resistance to flow) decreases with an increasing rate of shear stress and is time dependent (Barnes & Nguyen, 2001). Vane rheology is a popular method to determine the flow, deformation, and texture of yogurt.

Arabinogalactan and Dietary Fiber

Currently, the food market has been characterized by adding various dietary fibers claimed to have dietary and health benefits. However, the dietary fibers are relatively limited when it comes to the extent of affecting the digestive tolerance (Richardson & Morris, 2001) and notably many dietary fibers tend to be unstable at low pH. Arabinogalactan is unique in that it has both enhanced digestive tolerance and low pH stability (McKinley, 2005). One of the arabinogalactan varieties is larch arabinogalactan (AG), a non-starch polysaccharide that has received approval as a food additive by the Food and Drug Administration. Taking advantage of arabinogalactan is Larex, Inc., a company based in the United States. This company has taken major steps to ensure that this polysaccharide is extracted and commercialized in a large scale and has capitalized in marketing various studies where arabinogalactan performs the prebiotic role (Charalampopoulos & Rastall, 2009).

Chandan and co-workers established that the benefits to colon microflora may be amplified because of the addition of arabinogalactan (Chandan et al., 2006). Ingestion of arabinogalactan assessed in human subjects resulted in increases of softer stools, fecal masses, and better bowel habits, thus benefiting overall colon health. Therefore, it is apparent that arabinogalactan has uniqueness as a result of low pH stability and digestive tolerance by improving colon health, and may be useful to be integrated in a variety of products and beverages (Chandan et al., 2006).

The Statement of Problem

In recent time, there has been an increase in the popularity of soluble dietary fiber based on the fact that consumption of these fibers has been proven to improve health (Grierson, 1993). From the demonstrations that have been depicted by *in vitro* and *in vivo* studies, the risk of cardiovascular attacks may be reduced by consumption of soluble dietary fiber (Ooi & Liong, 2010). These heart attacks appear to be reduced because of a decline in blood cholesterol, slower digestion of the carbohydrate that decreases postprandial levels of the insulin and blood glucose, and enhanced healthy microflora gut balance (Laws & Marshall, 2001).Thus, a yogurt product supplemented with soluble dietary fiber could decrease risk of cardiovascular events and thus could benefit overall health.

An alarming number of teenagers and children in the United States are increasingly becoming addicted to fruit and soft drinks in addition to other sugar sweetened beverages, which has paralleled a rise in obesity (Serra et al., 2009). It is hence apparent that this trend results in most of these youth drinking less milk. As a result of a decrease in milk consumption, weakening of bones is likely to occur on the long term basis (Katz, 2001). A study conducted in 2002 illustrated that yogurt contains similar nutrients as milk, which are essential for the healthy growth of children (Jaros et al., 2002). Development of yogurt with different flavors, tastes and colon benefits can be one of the ways through which the consumption of this product along with the essential vitamins and minerals for growth and development of children and teens can be boosted. Therefore, if the sensory properties of yogurt are appealing, there is a high likelihood of children developing a favorable association with the product and thereby increasing consumption (Schorsch et al., 2000).

Objective of the Study

The aim of this research was to evaluate the possibility of the development of a yogurt that contains arabinogalactan to improve the functionality of the supplemented yogurt for health. Therefore, the primary study objective was to define the rheological and textural properties of yogurt supplemented with arabinogalactan as measured by yield stress and apparent viscosity using vane rheometry. The secondary objective was to evaluate pH on gel strength and viscosity.

Assumption of the Study

An assumption of the study was that the addition of arabinogalactan would result in desirable rheological and textural properties.

Definition of Terms

The definitions of the following terms are supplied to assist the reader in the understanding of the terminology utilized in the thesis.

Arabinogalactan. A biopolymer consisting of arabinose and galactose monosaccharides. Plant arabinogalactan is a major constituent of many gums, including gum arabic. It is often found attached to proteins and the resulting arabinogalactan protein functions as a signaling molecule between cells and a glue to seal wounds of plants (Kelly, 1999).

Dietary fiber. A fiber comprised of oligosaccharides, polysaccharides, lignin and other related plant substances. Dietary fibers are digestion and absorption resistant in the small intestine with full or part fermentation in the large intestine of humans (DeVries, 2001). Dietary fiber plays an important role to maintain health.

Fermentation process. A process by which carbohydrate components of the food products are converted to alcohol, carbon dioxide, and organic acid by the means of yeast, lactic acid bacteria, or combination of both under anaerobic conditions (Giraffa, 2004).

Food rheology. The study of flow and deformation of food materials (Haque, Richardson & Morris, 2001).

Milk fermentation process. A process by which carbohydrate components in milk are converted to alcohol, carbon dioxide, and organic acid by the means of yeast, lactic acid bacteria, or combination of both under anaerobic condition (Giraffa, 2004).

Prebiotics. The components of food that are indigestible and stimulate the growth of bacteria beneficial to the digestive tract system. (Gibson & Roberfroid, 1995)

Rheology. The study of the deformation or disintegration and flow of food substances (Rao, 1999).

Shear stress. The form of stress that tends to produce cutting rather than stretching or bending.

Shear-thinning. An effect in which viscosity of fluid decreases with increased shear stress rate.

Syneresis. The separation of liquid from the gel as an effect of contraction.

Viscoelasticity. The property of material which indicates that there are some elastic properties in the material and some of the property flow of a viscous fluid.

Viscometer. An instrument by which the viscosity of fluid is measured.

Viscosity. The measure of the internal friction of the fluid. This friction becomes apparent when a layer of fluid is made to move in a reaction to another layer. Viscosity is usually expressed in the centipoise (cP) unit.

Yield stress fluids. Many materials or food products behave like a liquid or solid according to shear stress occurrence. In brief, when the applied stress is small, these behave like an elastic solid, but when the applied stress is sufficiently high, the material behaves like a liquid (Caton & Baravian, 2008).

Yield stress. The applied stress that is needed to make the material flow like a liquid (Caton & Baravian, 2008).Yield stress is usually expressed in the pascal (Pa) unit.

Chapter II: Literature Review

This chapter will discuss a background of yogurt, dietary fiber, and particularly the water soluble fiber, arabinogalactan. This chapter will also discuss yogurt texture and rheological measurements in yogurt as well as the general effect of fortification on the textural properties of yogurt.

Background of Yogurt

The history of yogurt traces back more than 6,000 years ago as the name ‘yogurt’ was derived from the Turkish word “jugurt” (Rasic & Kurmann, 1978). In present day, yogurt is referred to by various names in various parts of the globe: “roba” in Iraq and “fiili” in Finland (Tamime & Robinson, 1985; Tamime & Deeth, 1980). It is believed that an inadequate supply of milk owing to the dry desert environment in the Middle East stimulated the creation of yogurt-like drinks. In Turkey, yogurt was believed to be utilized as a conserved milk product (Akin & Rice, 1994).

By tradition, Greek yogurt has always been produced from ewe's milk, though cow milk is employed in the commercial yogurt production. In Southern Asia, yogurt is known as “dahi,” and it has a soft coagulum, lumpy feel in texture, as well as a placid acidic taste. In India, “raita” is created from “dahi” with the adding of shredded cucumber or bottle gourd, cumin seeds, black pepper, and coriander. Bulgarian yogurt has an exceptional flavor because of special microbial strains used in the yogurt making process. In Indonesia, diverse selections of yogurt known as “dadiah” are made by fermenting milk in a bamboo urn encircled with banana foliage. “Taratur” is a type of yogurt produced in Albania as well as Republic of Macedonia through integration of yogurt with vegetables, garlic, walnuts, oil, and water. “Rahmjoghurt” is a yogurt variety that has a superior milk fat content (of 10%), and is made in Germany and other European nations.

“Matsoni” is an additional type of yogurt product prepared using *Lactococcus lactis,* an inoculate which bestows a unique, thick feel to the yogurt. In Jordan and Palestine, yogurt is known as “Jameed,” and is prepared through the mixing of salt, then dried for conservation (Food Production and Patisserie, 2009).

The Food and Drug Administration identifies yogurt as food created by culturing single or multiple dairy constituents. These constituents include: milk, cream, partly-skimmed milk, and wholly-skimmed milk with a characterizing bacteria culture, which has the lactic acid-generating bacteria, *Lactobacillus delbrueckii subsp. bulgaricus* in addition to *Streptococcus thermophilus* (GPO No. 21 CFR 131.200). In the Code of Federal Regulation 131.200, the Food and Drug Administration (FDA) states that yogurt can incorporate several elective elements such as: concentrated skim milk, buttermilk, nonfat dry milk, lactose, whey, lactoglobulins, lactalbumins, and customized whey, in order to boost the nonfat solids (No. 21). The Food and Drug Administration (FDA) regulations have filed the following conditions for yogurt:

> Yogurt, prior to the adding up of massive flavors, may not have lower than 3.25% of milk fat along with not lower than 8.25% of milk solids that are not fat, and contains a titratable pH of not lower than 0.9% existing as lactic acid. Yogurt can be treated using high temperatures following fermentation in order to annihilate some microorganisms for a more extended shelf life of the same (GPO No. 21 CFR 131.200).

In line with the FDA's Code of Federal Regulations, nonfat yogurt might have lower than 0.5% fat and low-fat yogurt might have between 0.5-2.0% fat (GPO No. 21 CFR 131.206).

The dietary and health-promoting characteristics of yogurt have stimulated copious research and intensive studies in product improvement. Recently, diet knowledge and health education has focused on the extensive endorsement of low-fat yogurt for health characteristics

(McKinley, 2005). Yogurt is a constituent of a balanced diet (Lucey, 2001). Among the most valuable characteristics of yogurt is being easily digested, which makes it extremely pleasing to individuals that have a sensitive stomach, are ill, or recuperative (Adolfsson, Meydani & Russel, 2004). It has been demonstrated that the sugar found in milk, lactose, is not digestible in some individuals. However, in the sour milk, lactose undergoes a chemical transformation and fermentation that in the end can be consumed by individuals that are sensitive to milk sugar. In normal conditions, it takes about four hours to breakdown milk in the digestive system, and just one hour to absorb minerals, vitamins, as well as protein in yogurt.

The calcium content of yogurt being slightly higher than milk is valuable in the diet of elderly individuals, whose bones have thinned leading to easy breakages, who may have pain in the backbone and weakness in the teeth (Deeth & Tamine, 1981). Research has demonstrated that yogurt, high in cholesterol when made using whole milk, has an aspect that stops the creation of cholesterol and to some point decreases the level of cholesterol in the blood (Laye, Karleskind & Morr, 1993). In spite of the debate, which primarily centers on benefits occurring due to the bacterial elements of the yogurt, yogurt is certainly a healthy, nourishing, and digestible food with a pleasing flavor and texture.

Yogurt Texture

The texture of a food can be classified as a flow, deformation, and/or disintegration of the food substance after the application of force according to Jaros and Rohm (2003). The study of the deformation or disintegration and flow of food substances is known as rheology (Rao, 1999). Rheological characteristics of food materials, such as fermented dairy products, are imperative in the blueprint of flow procedures, the control of quality, storage, as well as processing and in foretelling the texture of food substances (Shaker, Jumah, & Abu-Jdayil, 2000). The texture of food products is a representation of all the traits discernible through tactile, mechanical, and when appropriate, visual and acoustic receptors. The texture of food is a central consideration that contributes to the sensory characteristics of food.

Yogurt may be categorized as a pseudo-plastic substance (a substance that has a yield stress that must be surpassed for flow to be set off). This may either be a visco-elastic fluid if the yogurt in question is stirred or designed for drinking, or may be a visco-elastic solid if the yogurt in question is set yogurt. A visco-elastic property shows that the substance in question has a number of the elastic characteristics of an ideal solid as well as a number of the flow traits of an ideal (viscous) fluid. Yogurt, in addition, shows time-bound shear thinning characteristics, although yogurt is not an exact thixotropic substance because shear is not entirely reversible after the shear ends. Texture directly impacts the mouth feel of a food product, as mouth feel is defined by the discernment of feelings on the tongue as well as all through the mouth following the ingestion of a food material. The moving of food in the oral cavity, as well as the feelings perceived by the individual, play a part in the general acceptance as well as liking of the product. Texture is made up of physical traits such as viscosity, density, as well as surface tension.

In regards to rheology, yogurt is held to be a non-Newtonian food, implying that the rate of shear is not proportional to the corresponding stress. The textural traits of yogurt can be generalized by viscosity, syneresis, and strength of the gel (Sodini, Remeuf & Corrieu, 2004). Yogurts are structured substances that act as extremely weak gels (Harte, Clark, & Barbosa-Cánovas, 2007). According to Jaros & Rohm (2003), the examination of the rheological traits of dairy foods is critical in establishing the makeup of the said product. According to Charm (1971) and Tunick (2000), the textural characteristics of yogurt gels are key factors in ascertaining consumer preference as well as production strategies for yogurt. As described by Jaros and

Rohm (2003), the most important factors that affect the rheological and textural properties of yogurt include the makeup and considerations of milk base; homogenization, dry matter fortification, pre-heat treatments, incubation time-temperature, starter culture, and after-incubation treatments.

Texture and Rheological Measurements in Yogurt

Texture is among the most crucial indicators of yogurt quality and therefore gelation is an important process in the production of yogurt (Sandoval-Castilla, Lobato-Calleros, Aguirre-Mandujano, & Vernon-Carter, 2004). The central physical traits that play a part in the general sensory perception, in addition to the functionality of yogurt, are general visual exterior, the microstructure in addition to the rheological traits of the gels. All uninterrupted yogurts appear as visco-elastic substances (McComas & Gilliland, 2003). The formation of yogurt is the result of disulfide bonding involving κ-casein along with de-natured whey proteins as well as the aggregation of caseins as the acidity levels fall to the iso-electric summit of the caseins, i.e., pH 4.6, in fermentation, which results into an unbroken colloidal network. This structure is very weak and can effortlessly be upset if the gel matrix experiences mechanical interruption (Harte, Clark, & Barbosa-Cánovas, 2007).

An important trait of yogurt is the impact of diverse shear rates on the viscosity value (Lee & Lucey, 2006). The product of fermented milk viscosity is commonly seen to diminish with rising shear rates (Lee & Lucey, 2003). This indicates that these products are shear-thinning. In other words, as the disturbance conditions become more vigorous, the fermented product becomes more fluid. This is significant for the mouth feel of the product as shear rates are applied in chewing and swallowing. The rheological categorizations of yogurt gels call for at least two types of measurements to delineate visco-elasticity as well as flow traits. Rheometers that operate in a dynamic manner are employed to compute storage as well as loss modulus, which explains the elastic as well as viscous traits of the gelling structure (Sodini et al., 2004).

The dynamic reaction of a visco-elastic liquid to oscillatory stimulus results from two factors, namely: the storage modulus G´ and the loss modulus G´´, which is analogous to elasticity plus viscosity (Duboc & Mollet (2001). In addition, compound viscosity as well as the ratio of loss and storage modulus is employed to describe the rheological traits of yogurt products. One key rheological trait is thixotropy, which is the capacity to return to the former structure once the shearing action has ceased (Duboc & Mollet, 2001). The density of the gel can be calculated by the force needed to push a prod into yogurt at a preset deepness of penetration. Yogurt products in addition show a "yield value" which is the point at which the applied pressure surpasses a particular value as well as the liquid deforms/flows (Laws & Marshall, 2001).

General Effect of Fortification on Textural Properties of Yogurt

Scholars have illustrated that fortification with various substances such as skim milk powder or whey powder will advance the physical as well as textural traits of yogurt. According to Trachoo and Mistry (1998), nonfat along with low-fat set yogurt made through fortification using buttermilk powder at a protein level of 3.7% was comparatively smoother than those made with the adding of skim milk powder at a 4% protein level. Pereira, Matia-Merino, Jones and Singh (2006) also found low-fat yogurt prepared with buttermilk powder was found to be a little smoother than that prepared with skim milk powder. Guzman-Gonzalez et al. (1999) reported finding no divergence in the quality between yogurts that were fortified using skim milk powder or condensed skim milk. Substitution of skim milk powder with whey powder at 4.2% protein generated more density and viscosity, and better flow traits in yogurt products than the control set with equal level of skim milk protein powder (Gonzalez-Martinez, Chafer, Albors, Carot, &

Chiralt, 2003). In studies by Augustin et al. (2003), Remeuf, Mohammed, Sodini, and Tissier, (2003), and Cheng, Augustin and Clarke, (2000) when skim milk was substituted with whey protein concentrates, the yogurts demonstrated a rise in water-retention ability as well as a cutback in syneresis.

In addition, according to Sandoval-Castilla et al. (2004), a low-fat yogurt created with the adding of 1% micro-particulated whey protein resulted in a sensory shape parallel to that of full-fat yogurt. Guirguis, Versteeg, and Hickey (1987) established a rise in the firmness as well as a reduction in the whey expulsion in yogurt that was made by reverse osmosis of skim milk as opposed to yogurt that was made by the adding milk powder. On the other hand, yogurt that has extra caseinate was found to have higher gel firmness as well as viscosity (Remeuf et al., 2003; Guinee, Mullins, Reville & Cotter, 1995; Tamine, Kalab & Davies, 1984; Rohm, 1993). However, decreased silkiness and rougher texture occurred with extra caseinate in comparison to yogurt created by the addition of skim milk powder (Modler, Larmond, Lin, Froelich, & Emmons, 1983; Remeuf et al., 2003).

Dietary Fiber

The American Association of Cereal Chemists defines dietary fiber as a safe to eat component of plants or similar carbohydrates (DeVries, 2001). Dietary fibers are digestion and absorption resistant in the small intestine with full or partial fermentation in the large intestine of humans (DeVries, 2001). Dietary fiber supports healthy bowel movements, in addition to supporting healthy blood cholesterol and blood sugar levels. The distinctive trait of dietary fiber is its inability to be digested or absorbed in the small intestine (Whitney & Rolfes, 2005). Following its movement via the small intestine, dietary fiber passes undigested into the large intestine, wherein it is partially or fully fermented. It is believed that this fermentation has a constructive effect on the regulation of bowel movement, colonic pH levels, as well as on the creation of the byproducts that may have constructive physiological benefits. Dietary fiber is comprised of oligosaccharides, polysaccharides, lignin, and other related plant substances. Polysaccharides make up the major cluster of dietary fiber and consist of such compounds as hemicellulose and cellulose, arabinogalactansm polyfructose and arabinoxylans, oligofructans and inulin, along with galacto-oligosaccahrudesm gums, pectins and mucilages (DeVries, 2001).

Arabinogalactans

Arabinogalactans are extended, heavily branched, and water-soluble polysaccharides of molecular mass varying from sixteen thousand to one hundred thousand. Arabinogalactans originate from plants, bacteria, and fungi (Kelly, 1999). Common dietetic consumption of arabinogalactans is obtained from foods such as: leek seeds, radishes, carrots, beans, black gram dal (lentil like beans), pears, maize, red wine, wheat, Italian ryegrass, ragweed, tomatoes, sorghum, coconut meat, bamboo grass, and milk (Kelly, 1999). Arabinogalactans, a naturally occurring polymer, can be found highly concentrated in the *Larix* species of trees. Arabinogalactans function not only as a prebiotic fiber but also hold moisture, provide bulk, boost the immune system, improve mouth feel, and extend shelf strength (Klimis-Zacas, 2006).

Due to the arabinogalactans’ low-viscosity characteristic, along with emulsification boosting traits, its most common uses include inclusion in refrigerated as well as non-refrigerated drinks (Furia, 1972). Interest to use arabinogalactan in snack foods, processed cereals, bars, baked goods and yogurt/dairy products is on the rise. Commercially obtainable arabinogalactans-containing products include drinks and nutrition bars.

Arabinogalactans not only add nutritional beneficial fibers, but offer practical advantages in food processing. For instance, it has been confirmed that the addition of arabinogalactans enhance white pan bread structure, exterior evenness, and interior grain scores (Salvador & Fiszman, 2004). In addition, fat-free flour tortillas with arabinogalactans demonstrated enhanced taste and aroma compared to the control tortillas. Lamoreux and others have also identified arabinogalactan as a low-fat additive for non-natural or synthetic sweeteners that offers the mouth feel, flavor, as well as bulking characteristics similar to sugar (Lamoreux, Roy, & Gauthier, 2002). In confectionery and baked goods, arabinogalactans have been found to diminish water activity, support taste, and preserve oil (Ullrich, 2009). Other applications for arabinogalactans include browning raw foods, in seasoning powders to enhance flow and diminish hygroscopicity, and in foods that contain starch in order to reduce swelling.

A recent clinical study on larch arabinogalactans was performed at the University of Minnesota by Joanne Slavin and employed Larex's ImmunEnhancer’ and FiberAid brands of arabinogalactan (Schultz, Johnson, Currie & Bacic, 2000). This half-year, double blind and placebo-controlled research tracked one hundred adult subjects that were on a self-selected diet. The research confirmed arabinogalactans’ prebiotic and immune-enhancing effects. The outcomes of the study demonstrated considerable rises in total gut anaerobes that included useful gastro-intestinal bacteria. More notably, the research established a striking decrease in the levels of cholesterol in the hyperlipidemic subjects. Furthermore, *in vitro* cell studies have shown that arabinogalactan is the dynamic immune stimulatory complex in echinacea, and larix arabinogalactans arouses the human immune response better than echinacea alone (Gaspar, Johnson, McKenna, Bacic, & Schultz, 2001).

Two human feeding studies carried out at the University of Minnesota, along with Southwest College Research Institute, showed how the immune spur that coincides with feeding arabinogalactan impacts cells (Gibson, 2006). The consuming of larch arabinogalactan resulted in the augmented immune function of white blood cells, in particular monocytes, and greatly complemented the immune system.

The physiological advantages of arabinogalactan as established in human and animal studies have been found at reduced levels as low as 1.5 g per day or as great as 20 mg/kg of body weight (Chapman, Blervacq, Vasseur & Hilbert, 2000). Arabinogalactan has been established as a completely harmless food ingredient. On average, products that have a bare minimum of 60 mg/kg of body mass or approximately 4.5 g per day is advised for use of arabinogalactan as a food ingredient (Deis, 2000). The utility of supplementing arabinogalactan in food products such as yogurt on the rheological properties such as gel strength and viscosity of the yogurt gels using vane rheomety should provide data of the utility of arabinogalactan additions in yogurt. Thus, the health benefits of arabinogalactan could be utilized as well as improving the calcium consumption of certain US populations.

Chapter III: Methodology

This chapter provides a comprehensive discussion on the effect of arabinogalactan fiber on the rheological characteristic of yogurt. In this chapter, the methodology and formulation of the yogurt preparations are provided. Chapter 3 also provides a description of the methods through which the yogurt textural characteristics were measured through the use of vane rheometry.

This experiment incorporated four main ingredients: (a) arabinogalactan from the distributor, Food Science of Vermont (Vermont, USA) (b) nonfat dry milk (NFDM) from Fresno's Dairy America, Inc. (California USA), (c) Lactic DVS culture from Dairy Connections Inc. (Madison, Wisconsin, USA), and (d) distilled water.

Instrumentation

Brookfield Viscometer. In this experiment, The Brookfield DV-III ultra programmable rheometer (Brookfield Engineering Lab Inc., Massachusetts, USA) was used to determine the yield stress value and the viscosity of the yogurt samples.

Stephan Mixer. In this experiment, a Stephan mixer (Stephanplatz 2-31789, Hamein, Germany) with jacketed kettle was used for the pasteurization of all prepared milk bases.

Preparation of Milk Base

This experiment involved preparation of three various milk bases: 0.8% by weight of arabinogalactan base, 1.2% by weight arabinogalactan base, and the control base (Table 1). The preparation of these bases was enhanced by combining commercial NFDM powder and low heat together with the distilled water. This process did not incorporate additional protein milk concentrate. In the control base that contained 12% of total solids, preparation was enhanced through gradual addition of 120 g NFDM to 880 mL distilled water that was in a 2 liter capacity beaker. At 800 rpm, agitation was performed continuously by use of a magnetic stirrer. After covering the beaker, the mixing of the base lasted for thirty minutes to completely ensure that the nonfat dry milk powder was completely hydrated. The next step involved preparation of a 0.8% arabinogalactan yogurt base with total solids amounting to 12%. This preparation took place in a similar manner through the use of 112 g NFDM together with 8 grams of arabinogalactan in 880 mL distilled water. In preparation of the last yogurt base, which contained 1.2% arabinogalactan, arabinogalactan amounting to 12 grams together with 108 grams of NFDM were added to the distilled water by following the same mixing procedure. This resulted in a base that contained 12% of total solids. All three mixes were developed to contain 12% of total solids.

Table 1

Formulas for Composition of Milk Base used in Yogurt Manufacturing.

Ingredients	Control	0.8% Arabinogalactan	1.2% arabinogalactan
Distilled water (mL)	880	880	880
NFDM (g)	120	112	108
Arabinogalactan (g)	-	8	12
Total solids (%)	12	12	12

Yogurt Culture Preparation

In the experiment, DC1612, Direct Vat Culture Set (DVS) (Dairy Connection, Inc., Madison, Wisconsin) was used to acidify the milk during the process of manufacturing the yogurt. In this culture set, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* were the commercial strains used and represent the strains that have commonly been used in the industry. Before use, the culture was maintained at a temperature of -16 degrees Celsius in a flaky form. In order to ensure that the yogurt bases were consistently inoculated, there was a preparation of a standard culture. Preparation of a milk base was performed by addition of NFDM (80 grams) into 450 milliliters of distilled water. The ingredients were then mixed using a magnetic stirrer for a period of 40 minutes. The heating of this base took place at a temperature of 90 degrees Celsius for a period of three minutes through immersing in a water bath containing hot circulating water. At a temperature of 35 degrees Celsius in the jar, the prepared milk base was mixed with the 135 mg of DC1612. The sealing of the jar was followed with incubation for a period of 9.5 hours at 35 degrees Celsius. As the pH approached 4.6, the fermentation process was terminated through refrigeration to 5 degrees Celsius. The subsequent culture was incorporated for the fermentation step as an inoculum.

The Process of Pasteurizing the Yogurt Mix

Through pasteurizing, microorganisms and the enzymes found in milk are deactivated (Sodini et al, 2004; Lee & Lucey, 2004). This process, which also involves denaturing of the whey proteins, was accomplished in a Stephan universal machine (Stephanplatz 2-31789, Hamein, Germany). The heating of this machine was enhanced through circulation of a water bath (Julabo, Pennsylvania). Holding of all the bases followed for a period of 30 minutes at 85 degrees Celsius. Using the Stephen machine, which is a jacketed kettle with agitation, uniform heating was achieved on the milk bases (Lucey, 2001; Bangari, 2011). Once pasteurization had taken place, the heated milk was transferred into a glass beaker. A plastic lid was used to cover this glass beaker, followed immediately by refrigeration at a temperature of 5 degrees Celsius. The bases that had been pasteurized were put in storage overnight to ensure that the proteins underwent a complete process of hydration coupled with minimization of any foam that might have been generated in the process of cooling and heating.

Sample Preparation, Fermenting and Storing

After pasteurization, the stored milk mix was reheated to a temperature of 42 degrees Celsius. After the milk temperature reached a temperature of 42 degrees, addition of the mother culture was initiated at a 2% inoculation rate followed with agitation of the mixture. Replicates measuring 200 mL were transferred to the plastic cups (250 mL). The cups were covered with lids, immediately followed by the transfer of the cups to an air incubator (Model 12-140, Quincy Lab, Inc, Illinois, USA). The temperature of air incubator was maintained at 42 degrees. For each of the three bases, five replicates were generated. The onset of the incubation was followed by recording of time in intervals of one hour. Upon obtaining a pH of 4.6, the cooling of the cups immediately followed to 5 degrees Celsius. Evaluation of the pH and gel strength was carried out after 24 hours.

Data Analysis

pH determination. The pH measurement was conducted hourly for the entire process of the experiment for each of the variables of the milk base. For each yogurt sample, pH was measured through insertion of pH probe into the sample followed by lightly shaking for a standardized period of time before making the readings. Also in each of the samples, the pH was determined and documented at the onset of the incubation and at intervals of one hour until when the pH reached 4.6. This is the time when the termination of the fermentation took place. Measurements were also carried out for the pH values of all the samples that had been stored at temperature of 9 degrees Celsius. This measurement took place after 24 hours and seven days after the onset of the experiment.

Brookfield Viscometer. The yield values of the prepared samples of yogurt were determined through the use of Brookfield DV-III ultra programmable rheometer. The DV-III’s operating principle involves driving a spindle which is inserted into the sample using a calibrated spring (Sapan, 2011). A spring deflection enhances measurement of the food sample viscous drag alongside the spindle. Through a transducer, the spring deflection is measured. The calculation of the viscosity is done from the shape and size of the spindle, the spindle speed, the container of the sample in which the rotation of the spindle is taking place, and the full scale torque of the calibrated spring (Sapan, 2011). Calculation of all the measurements of shear stress, shear rate together with the torque takes place in compliance with the SI (International System of Units) or CGS (Centimeter-Gram and Second) system.

Yield Measurement: The yield strain and stress of the static shear test samples were determined for each sample after 24 hours and on the seventh day of the storage using the Brookfield DV-III ultra rheometer. In this study, a four bladed vane rotor, no. 73, attached to a viscometer was used for the texture analysis of yogurt. A cup of yogurt was placed on a platform and the vane was inserted into the yogurt sample. Stress and strain data for the sample were collected. Two values of the yields readings were collected from every sample. During the analysis, there was also a recording of the temperature of the sample. As a time function, there was also a recording of the torque that was required to uphold a fixed rotation. The calculations of the yield strain, yield stress, and torque data were recorded. Having completed the process, the figures were saved and then were converted into MS Excel format.

Viscosity Measurement: The viscosity of the samples at temperature 21˚C was also determined using the Brookfield viscometer on the seventh day of the sample storage. In this study, a four bladed vane rotor no.73 attached to Brookfield viscometer was used for viscosity measurement of yogurt. A cup of yogurt was placed on a platform and the vane was inserted into the yogurt sample. Viscosity data for the samples were collected at a constant shear rate of 100 rpm with increasing time intervals. The spindle was carefully cleaned with water after taking the viscosity reading of each sample.

Statistical Analysis

The yield stress data for all samples were analyzed using analysis of variance (ANOVA), SPSS, and the level of significance was present at $p \leq 0.05$. The Brookfield viscometer was linked with the laptop having software which can convert and save all yield stress data and the viscosity readings to a MS Excel sheet.

Chapter IV: Results

The main objective of this research was to evaluate the effect of the prebiotic substrate, arabinogalactan, a soluble fiber, on the rheological and texture properties of nonfat set-type yogurt. Arabinogalactan (1.2% by weight in the first trial and 0.8% by weight in the second trial) was incorporated into milk and made into yogurt with a total of 12% solids. Yogurt from nonfat dry milk (solids of 12%) was also prepared to generate a standard score to compare the fiber supplemented yogurts. Gel strengths of the yogurts were measured using vane rheometry after various times of refrigerated storage.

Yield Stress

The quality of dairy products is determined by rheological properties. Yield stress is one of the measures used to examine rheological properties. In this experiment the yield stress values of the prepared samples of yogurt were determined through the use of Brookfield DV-III ultra programmable rheometer on day 1 and day 7. It is clear that addition of 0.8% and 1.2% of the arabinogalactan resulted in a significant increase in the average yield stress value and the standard deviation of day 1 and day 7, compared to the control (Table 2).

The results reveal that the addition of 0.8% arabinogalactan increased the average yield stress value from 87.03 to 90.05 on the day 1. The yield stress also changed with the time. This is shown by the increase in stress level from 90.05 (day 1) to 104.47 (day 7). Additionally, addition of 1.2% of the arabinogalactan increased the yield stress from 90.05 to 113.32 on day 1 and from 104.47 to 127.73 on day 7 (Table 2).

Table 2

Average Yield Stress Value for Control Samples, 0.8%, and 1.2% Arabinogalactan Supplemented Yogurt Samples on Day 1 and Day 7

Samples	Yield Stress (Pa) Day 1	Yield Stress (Pa) Day 7	Std. Deviation
Control	87.03	100.14	9.27
0.8% Ag	90.05	104.47	10.20
1.2% Ag	113.32	127.73	10.19

Analysis of variance (ANOVA) showed that there was a significant difference ($p \leq 0.05$) in average yield stress values between the control yogurt samples, the 0.8% arabinogalactan supplemented yogurt, and 1.2% arabinogalactan supplemented yogurt on day 1 (Table 3). It was apparent that the addition of arabinogalactan significantly increased the yield stress of the yogurt samples on day 1.

Table 3

ANOVA Analysis for the Average Yield Stress Value of Control Sample, 0.8%, and 1.2% Arabinogalactan Supplemented Yogurt Samples on Day 1

Samples	N	Mean	Std. Deviation
Control	3	87.03^{a}	0.84
0.8% Ag	3	90.05^{b}	1.14
1.2% Ag	3	113.32^{c}	1.07

$*^{a,\ b,\ c}$ Means with different subscripts are significantly different at $p \leq 0.05$ level

Analysis of variance (ANOVA) showed that there was a significant difference ($p \leq 0.05$) in average yield stress value between the control yogurt samples, the 0.8% arabinogalactan supplemented yogurt, and 1.2% arabinogalactan supplemented yogurt on day 7 (Table 4). It was apparent that the addition of arabinogalactan significantly increased the yield stress of the yogurt samples on day 7.

Table 4

ANOVA Analysis for the Average Yield Stress Value of Control Samples, 0.8%, and 1.2% Arabinogalactan Supplemented Yogurt Samples on Day 7

Samples	N	Mean	Std. Deviation
Control	3	100.14^{a}	1.78
0.8% Ag	3	104.47^{b}	1.10
1.2% Ag	3	127.73^{c}	1.11

*^{a,b,c} Means with different subscripts are significantly different at $p \leq 0.05$ level

Viscosity

The graphs in figures 2, 3 and 4 depict the three trials which explored viscosity of the samples. Each graph indicates that the arabinogalactan did not have an effect on the final viscosity properties of the supplemented yogurts as compared to the control. The initial viscosity levels varied based on the percentage of the arabinogalactan used. The higher the percentage of the arabinogalactan used, the greater the viscosity level of the yogurt in the beginning. It is likely that the structural arrangement of the arabinogalactan must be responsible for the initial viscosity properties of the yogurt.

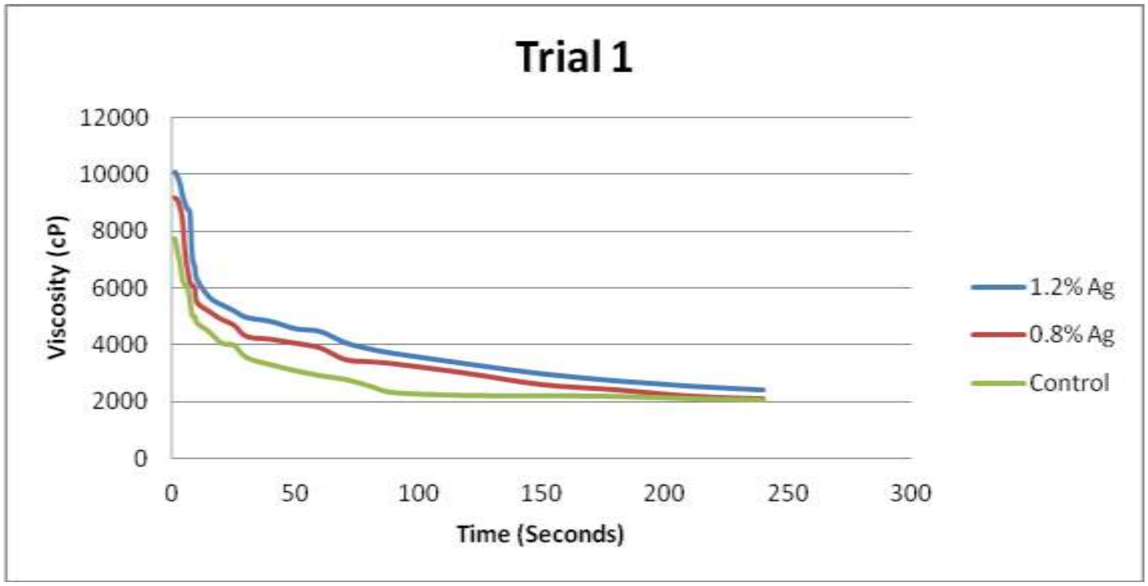

Figure 1. Viscosity of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 1 on day 7

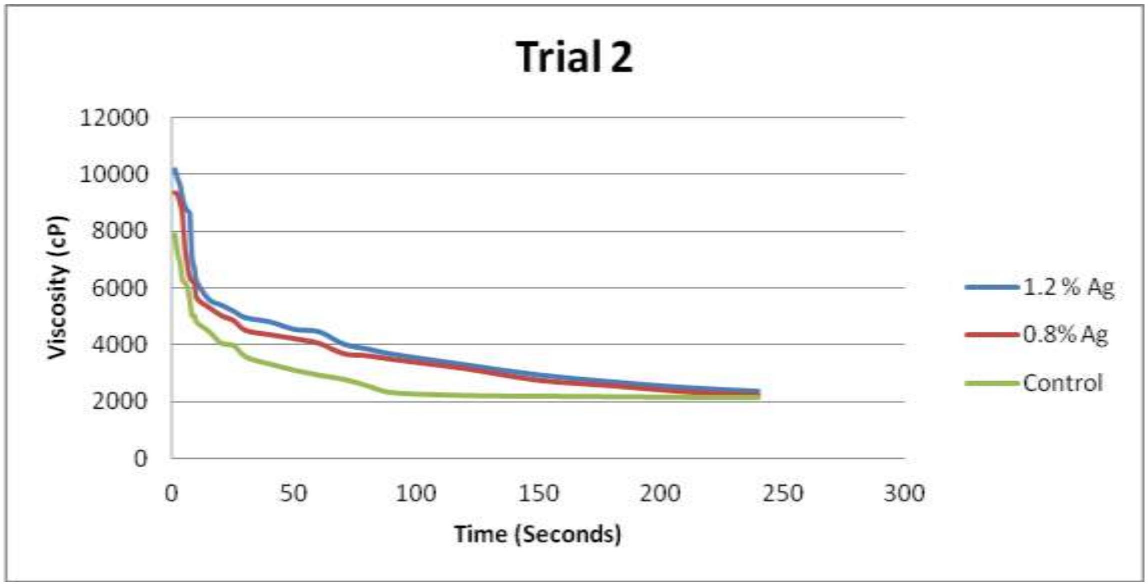

Figure 2. Viscosity of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 2 on day 7

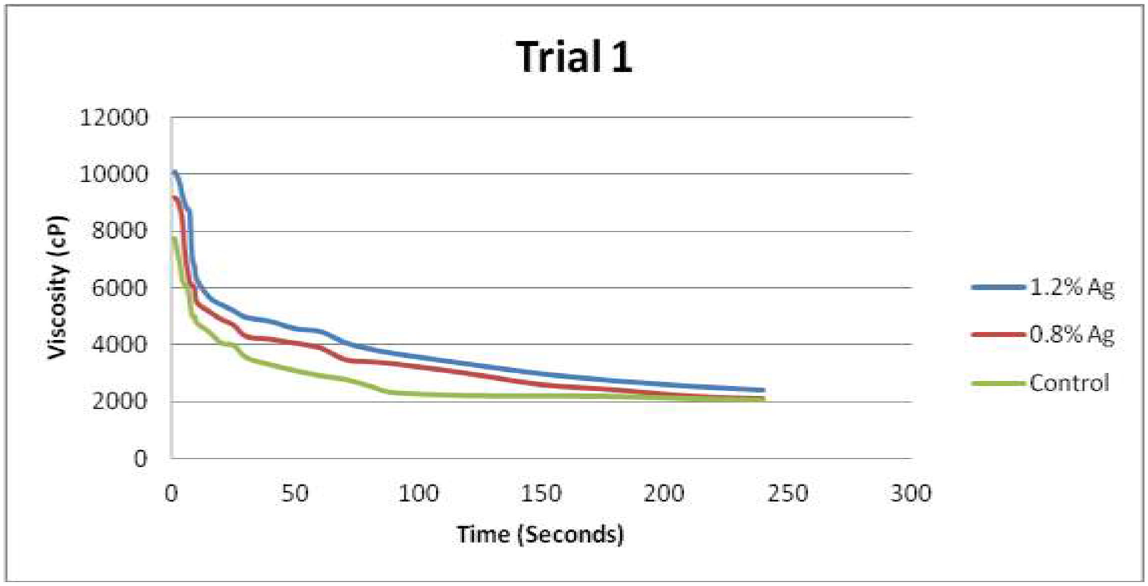

Figure 1. Viscosity of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 1 on day 7

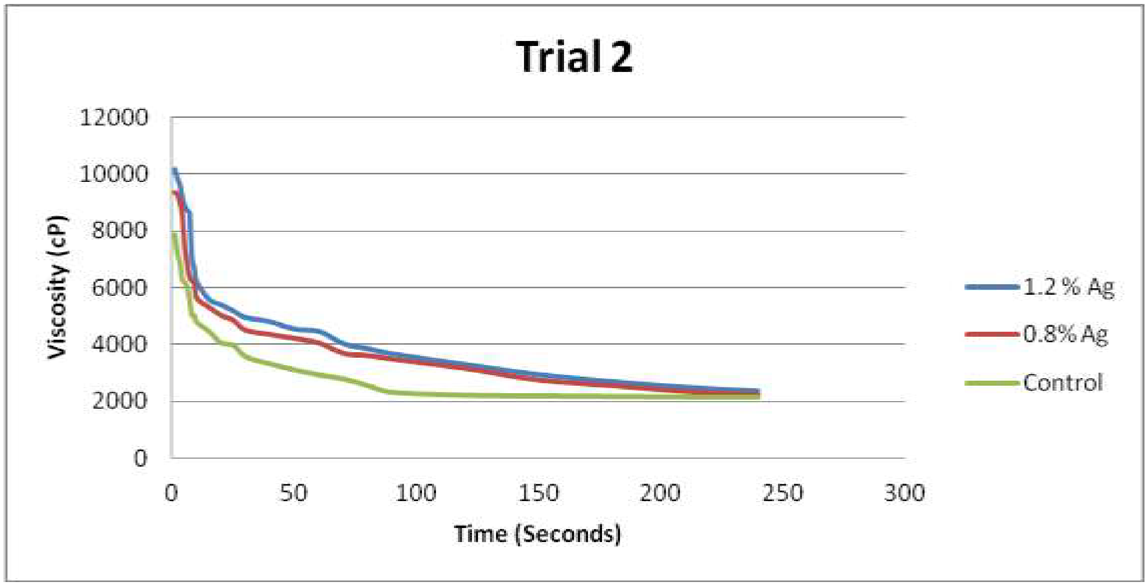

Figure 2. Viscosity of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 2 on day 7

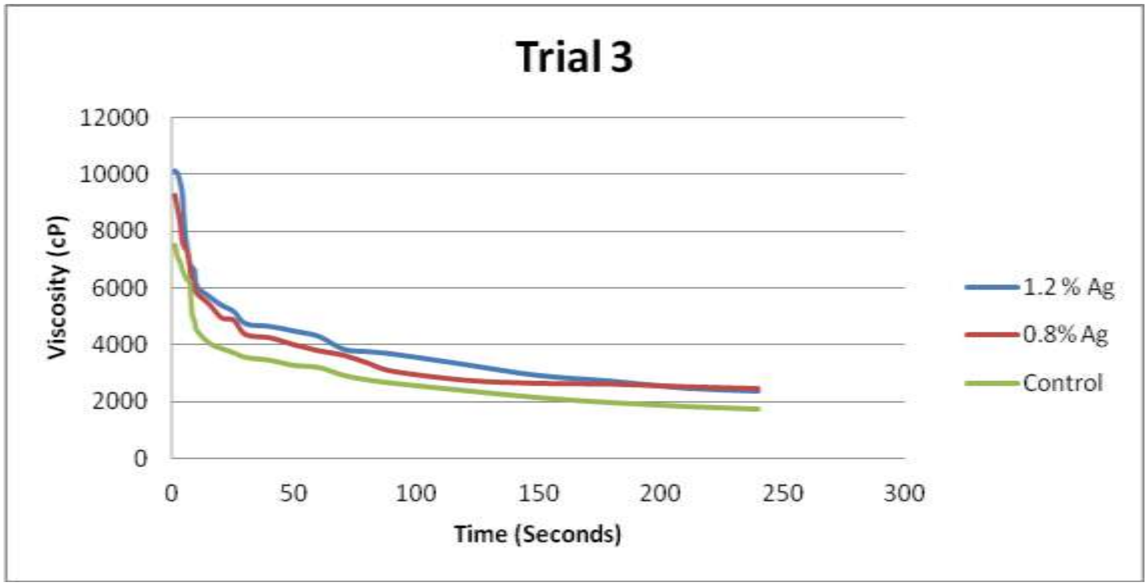

Figure 3. Viscosity of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 3 on day 7

ph Measurement

The pH was measured at intervals of one hour during the fermentation process for the control and each of the supplemented yogurts until the pH decreased to 4.6, which occurred at 6 hours. The graphs in figures 5, 6 and 7 illustrate that the arabinogalactan had no effect on the pH properties of the yogurt. The control, 0.8% arabinogalactan, and 1.2% arabinogalactan had similar pH profiles. The addition of fiber did not affect the fermentation time for the different supplemented yogurts to reach pH 4.6, thus there were no differences in the gelation time of the fortified yogurts.

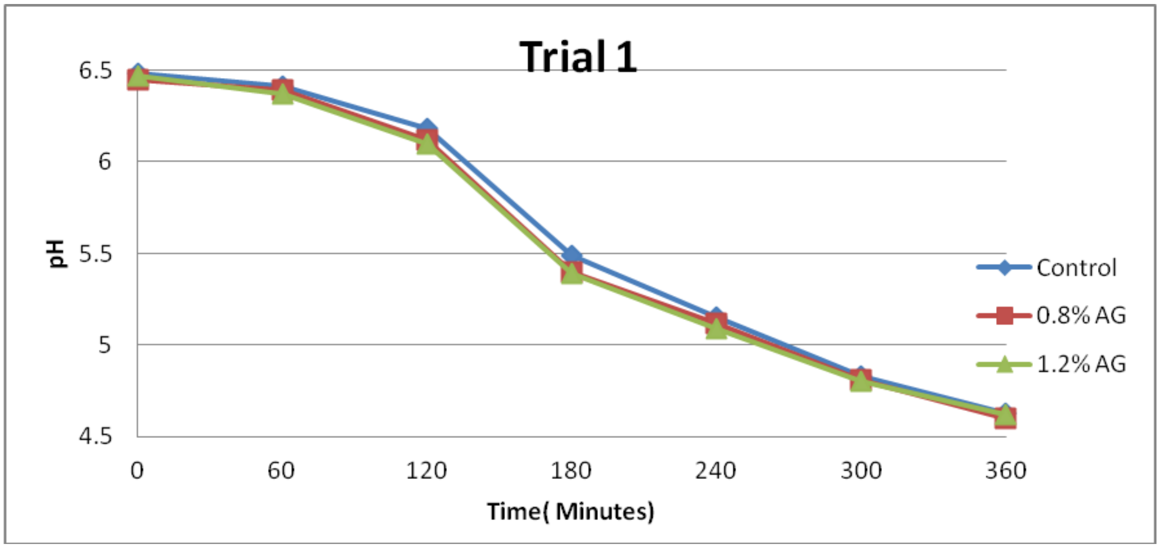

Figure 4. pH values of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 1

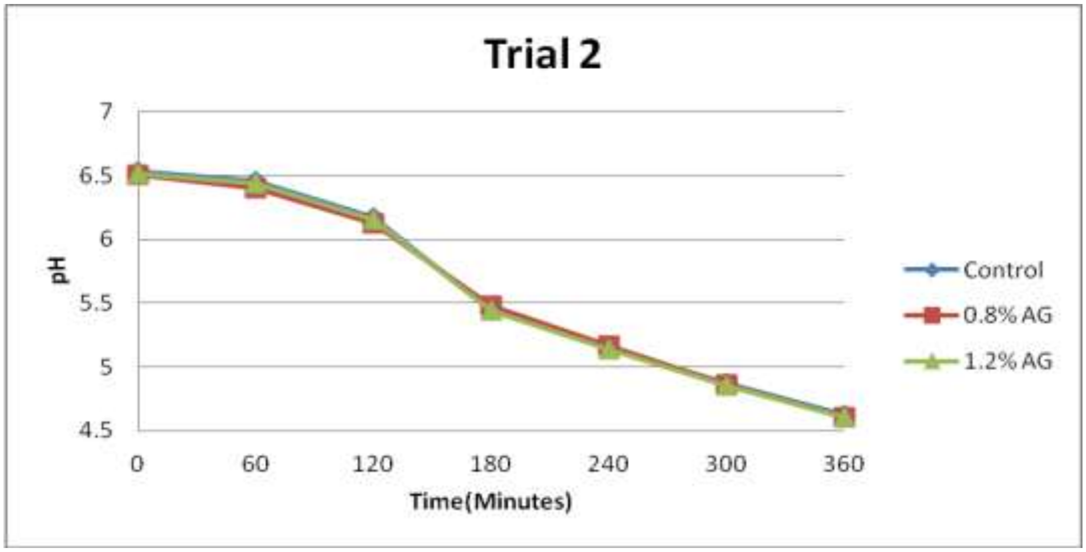

Figure 5. pH values of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 2

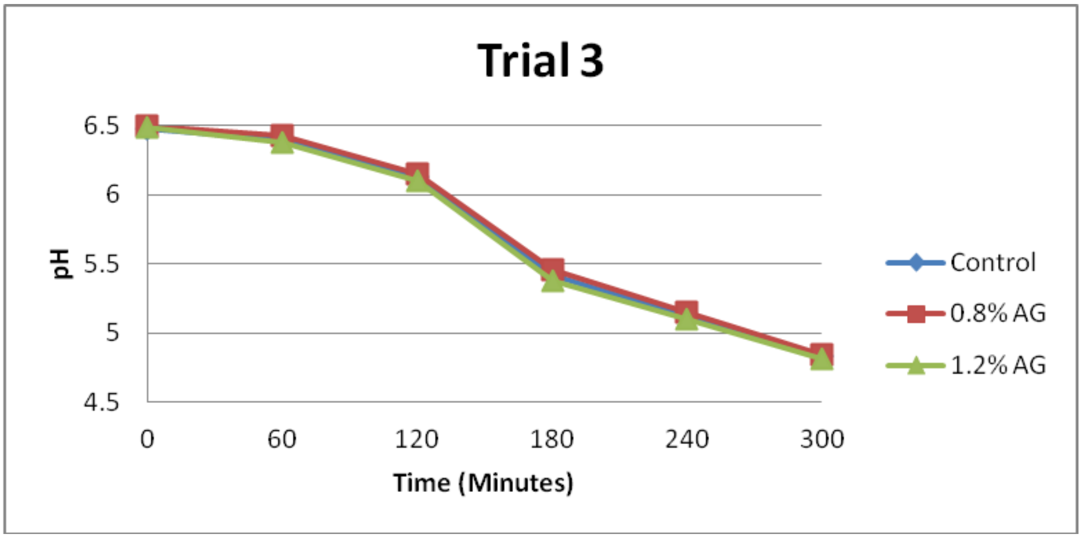

Figure 6. pH values of control sample, 0.8% arabinogalactan yogurt sample and 1.2% arabinogalactan yogurt sample in trial 3

In summary, this experiment found a statistically significant difference in yield stress between the control yogurt sample, 0.8% arabinogalactan supplemented yogurt, and 1.2% arabinogalactan supplemented yogurt on day 1 as well as on day 7. Initially, viscosity of the fortified samples on day 7 was higher in comparison to the control sample; however, this difference was not apparent at the end of the viscosity measurements. The addition of arabinogalactan did not affect the fermentation time for the different treatments of yogurts to reach pH 4.6. The significance of these findings will be discussed in Chapter 5.

Chapter V: Discussion/Conclusion

Rheological properties are the means to determine the quality of dairy products. Most consumers rely on the texture of the dairy products when deciding the best product to buy. Consequently, the knowledge of the rheological properties as well as the effects of compounds upon the rheological properties is paramount in product development (Chronakis, 1997). Pavia et al. (1999) suggested that arabinogalactan has a structural feature capable of binding milk particles within the yogurt structure and hence increasing the yield stress (Pavia et al., 1999). This present report analyzed the effect of arabinogalactan on the rheological properties of set-type yogurt.

Texture is related to the structure and microstructure of the product. Products such as fiber increase the microstructure of the yogurt and hence can lead to changes in the rheological properties. Arabinogalactan constitutes one of the fibers that can impact the rheological properties of dairy products (Halmos, 1997) as was seen to occur in this experiment investigating 0.8% arabinogalactan and 1.2% arabinogalactan supplemented yogurt.

Yield Stress

Yield stress was one of the measures used to examine the rheological properties of yogurt in this study. There was a statistically significant difference in yield stress between the control yogurt sample, 0.8% arabinogalactan supplemented yogurt, and 1.2% arabinogalactan supplemented yogurt on day 1 as well as on day 7. Addition of 0.8% arabinogalactan increased the average yield stress value from 87.03 to 90.05 on day 1, which further increased over time from 90.05 (day 1) to 104.07 (day 7). Additionally, addition of 1.2% of the arabinogalactan increased the yield stress from 90.05 to 113.32 on day 1 to 127.73 on day 7. This confirms the research done by Suwonsichon and Peleg (1999) and others (Bullens, 1994) which reported that

that the plant compound arabinogalactan increased the yield stress of dairy products such as ricotta and cheddar cheese.

Yield stress is very important during the processing of the dairy products such as yogurt. In this experiment, yogurt enriched with arabinogalactan had relatively higher yield stress than non-enriched yogurt. Yield stress constitutes one of the factors that consumers consider. Consequently, most of the dairy industries are currently using fibers such as inulin, carrageenan, and guar gum to enhance the yield stress of the yogurt to meet customers' needs. With additional research on human sensory properties, arabinogalactan could join this list of useable fibers.

Viscosity

It is likely that the structural arrangement of the arabinogalactan must be responsible for the viscosity properties of dairy products such as ricotta cheese, as reported by Suwonsichon and Peleg (1999) and reduced-fat cheddar cheese, as reported by Bullens (1994). Research conducted by Surowka (1997) revealed a close relationship between the arabinogalactan and the viscosity of cheese.

Initially, the viscosity of the yogurt stored for 7 days was higher in the yogurts fortified with the arabinogalactan, but at-the end of the measurements, there was no difference in the viscosity. As the spindle was continuously rotating at the same point, we can conclude that the similarity of viscosity of control and fortified samples at the end of the measurements was due to the sample structure break down, syneresis effect, or whey separation.

pH Measurement

The control, 0.8% of arabinogalactan, and 1.2% arabinogalactan had similar pH profiles and the addition of fiber did not affect the fermentation time for the different treatments of yogurts to reach pH 4.6. There were no differences in the gelation time, which was 6 hours.

Similar results were found in literature. Guven et al (2005) reported that the fortification of yogurt with inulin fiber did not significantly affect the pH values. This was also found in this investigation using arabinogalactan at 0.8 and 1.2% levels.

Conclusion

From the above experimental results, it is clear that arabinogalactan influences the rheological properties of yogurt. Arabinogalactan is an insoluble fiber obtained from the cell surface of most of flowering plants. Arabinogalactan falls into a class of compounds called proteoglycans that are composed of the protein and glucose molecules linked together. Work performed by Breuil and Meullenet (2000) revealed that the arabinogalactan is composed of a meshwork of protein and glucose molecules where the milk particles are sandwiched. This explains why the arabinogalactan increases the initial viscosity as well as increases the yield stress of the yogurt.

However, identifying the ideal concentration of arabinogalactan may be of importance to develop a product with consistent yield stress. As the percentage of the arabinogalactan was increased in this study, the yield stress seemed to fluctuate as evidenced by the larger standard deviations of the products containing arabinogalactan than the control yogurt sample between day 1 and day 7 (Table 2). The exact or best concentration of arabinogalactan was not determined in this research. This experiment indicates that there is a certain concentration of the arabinogalactan that could effectively and uniformly increase the texture and the rheological properties of the yogurt which could be the subject of further investigations.

In addition to usefulness in food processing, clinical studies have shown the advantages of arabinogalactans to gastrointestinal health and immunity (Domb & Kumar, 2011), and also a significant lessening of serum cholesterol, insulin, and glucose concentrations. This opens the door to potential FDA approved heart healthy label claims and provides an option to consumers looking for foods beneficial in terms of controlling body weight, blood glucose, or blood insulin levels (Odonmazig, Ebringerova, Machova, & Alfoldi, 1994).

Recommendations for Further Study

Further research is recommended to evaluate and compare micro textural and human sensory analysis of the yogurts prepared with arabinogalactan. The exact concentration of arabinogalactan to achieve uniform yield stress needs to be determined. Additionally, sensory testing to determine if addition of flavors, sweeteners, or fruits would improve the characteristics of arabinogalactan fortified yogurt might be of value. Additionally, exploring the proper amounts of combinations of different types of fibers with arabinogalactan might improve the consumer acceptance of the final product.

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Appendix A: *Raw Data for Viscosity Readings in Centipoise for Control, 0.8%, and 1.2% Arabinogalactan Supplemented Yogurt Samples for Trials 1, 2, and 3*

Trial 1

Time (Seconds)	1.2% Ag Viscosity (cP)	0.8% Ag Viscosity (cP)	Control Viscosity (cP)
1	10100	9200	7747
2	9945	9116	7276
3	9700	8860	6891
4	9300	8446	6292
5	9000	7319	6115
6	8800	6720	6012
7	8700	6249	5589
8	7104	6117	5012
9	6758	6004	5008
10	6296	5506	4768
15	5683	5189	4451
20	5417	4910	4054
25	5204	4709	3980
30	4973	4313	3552
40	4830	4214	3296
50	4573	4077	3082
60	4476	3911	2910
70	4085	3502	2782
80	3863	3426	2548
90	3703	3351	2312
120	3330	3011	2211
150	2984	2617	2200
180	2737	2437	2180
210	2549	2214	2100
240	2415	2115	2045

Trial 2

Time (Seconds)	1.2% Ag Viscosity (cP)	0.8% Ag Viscosity (cP)	Control Viscosity (cP)
1	10180	9347	7887
2	9865	9262	7262
3	9640	9005	6915
4	9208	8589	6323
5	8896	7456	6196
6	8739	6854	6032
7	8639	6381	5617
8	7066	6248	5037
9	6686	6135	5033
10	6224	5634	4792
15	5611	5315	4473
20	5419	5035	4062
25	5205	4859	3988
30	4973	4513	3583
40	4829	4364	3325
50	4562	4227	3110
60	4485	4061	2938
70	4052	3702	2796
80	3878	3626	2561
90	3696	3501	2324
120	3322	3172	2222
150	2965	2767	2198
180	2724	2574	2180
210	2524	2364	2161
240	2393	2248	2147

Trial 3

Time (Seconds)	1.2% Ag Viscosity (cP)	0.8% Ag Viscosity (cP)	Control Viscosity (cP)
1	10120	9296	7514
2	10028	8831	7104
3	9746	8369	6929
4	9291	7650	6643
5	8051	7438	6429
6	7392	7314	6286
7	6874	6807	6214
8	6729	6114	5074
9	6604	6110	4827
10	6057	5822	4497
15	5708	5441	4059
20	5401	4965	3869
25	5180	4876	3717
30	4744	4362	3552
40	4653	4255	3450
50	4485	3998	3266
60	4302	3792	3197
70	3852	3638	2918
80	3769	3358	2759
90	3686	3074	2645
120	3312	2753	2379
150	2929	2640	2131
180	2731	2616	1955
210	2485	2520	1821
240	2377	2454	1725

Appendix B: ***Data for pH Measurements for Control, 0.8%, and 1.2% Arabinogalactan Supplemented Yogurt Samples for Trials 1, 2 and 3***

Trial 1

Time(Mins)	Control	0.8% Ag	1.2% Ag
0	6.48	6.45	6.46
60	6.41	6.39	6.37
120	6.18	6.12	6.1
180	5.49	5.4	5.39
240	5.15	5.12	5.09
300	4.83	4.81	4.8
360	4.63	4.6	4.62

Trial 2

Time(Mins)	Control	0.8% Ag	1.2% Ag
0	6.53	6.5	6.51
60	6.46	6.4	6.44
120	6.17	6.12	6.15
180	5.44	5.48	5.44
240	5.15	5.17	5.14
300	4.87	4.86	4.85
360	4.63	4.61	4.61

Trial 3

Time(Mins)	Control	0.8% Ag	1.2% Ag
0	6.48	6.5	6.49
60	6.4	6.43	6.38
120	6.13	6.15	6.1
180	5.42	5.46	5.38
240	5.12	5.15	5.1
300	4.83	4.84	4.81
360	4.62	4.63	4.6

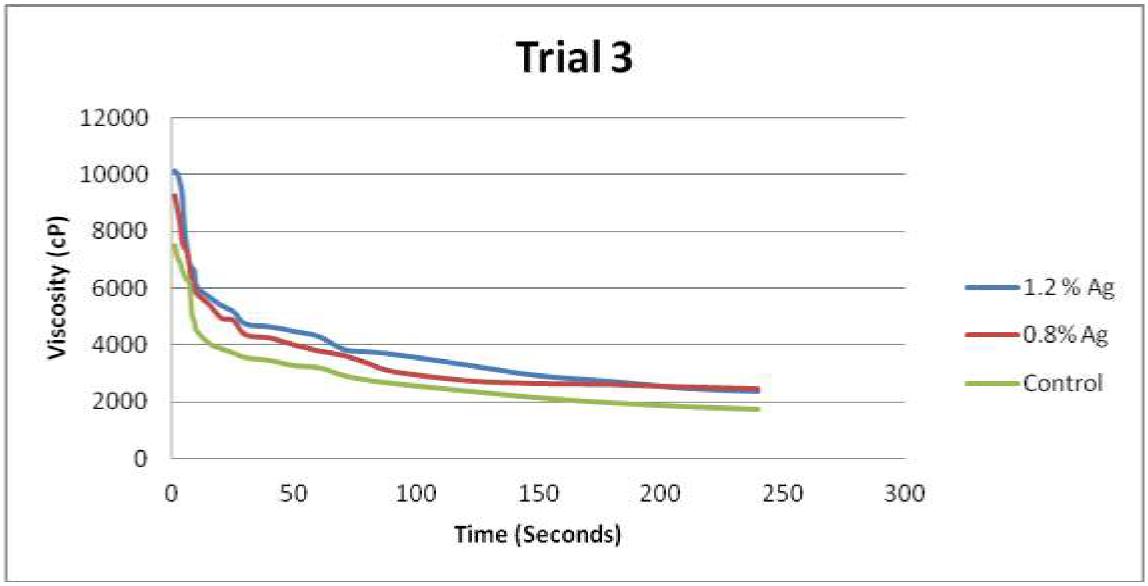

Figure 3. Viscosity of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 3 on day 7

ph Measurement

The pH was measured at intervals of one hour during the fermentation process for the control and each of the supplemented yogurts until the pH decreased to 4.6, which occurred at 6 hours. The graphs in figures 5, 6 and 7 illustrate that the arabinogalactan had no effect on the pH properties of the yogurt. The control, 0.8% arabinogalactan, and 1.2% arabinogalactan had similar pH profiles. The addition of fiber did not affect the fermentation time for the different supplemented yogurts to reach pH 4.6, thus there were no differences in the gelation time of the fortified yogurts.

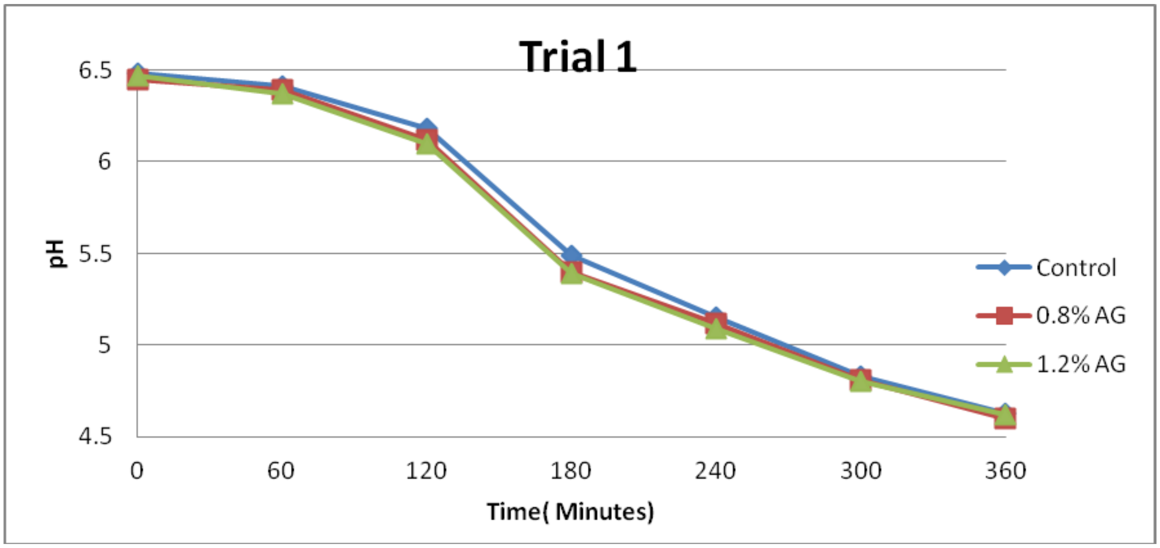

Figure 4. pH values of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 1

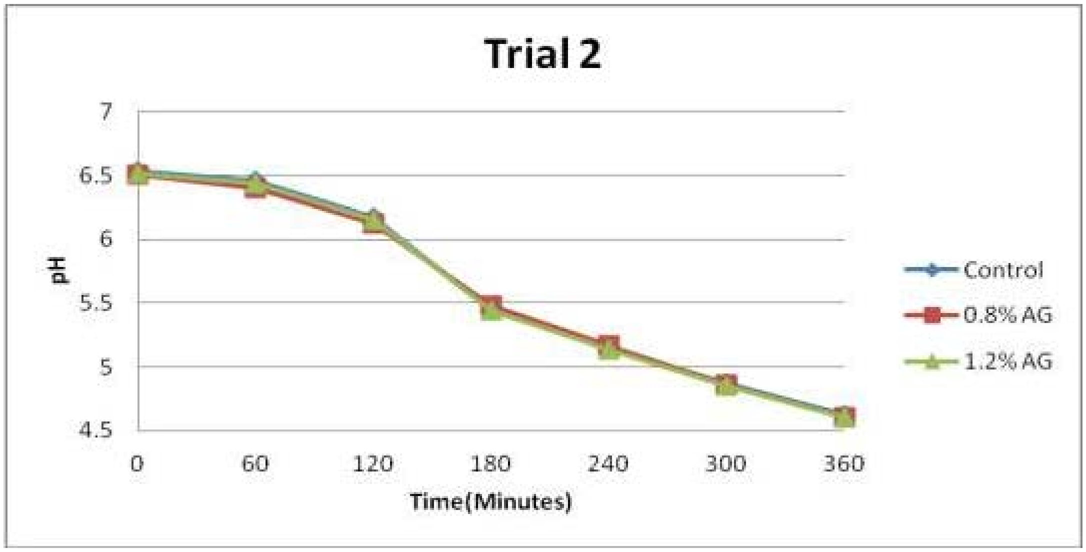

Figure 5. pH values of control sample, 0.8% arabinogalactan yogurt sample, and 1.2% arabinogalactan yogurt sample in trial 2

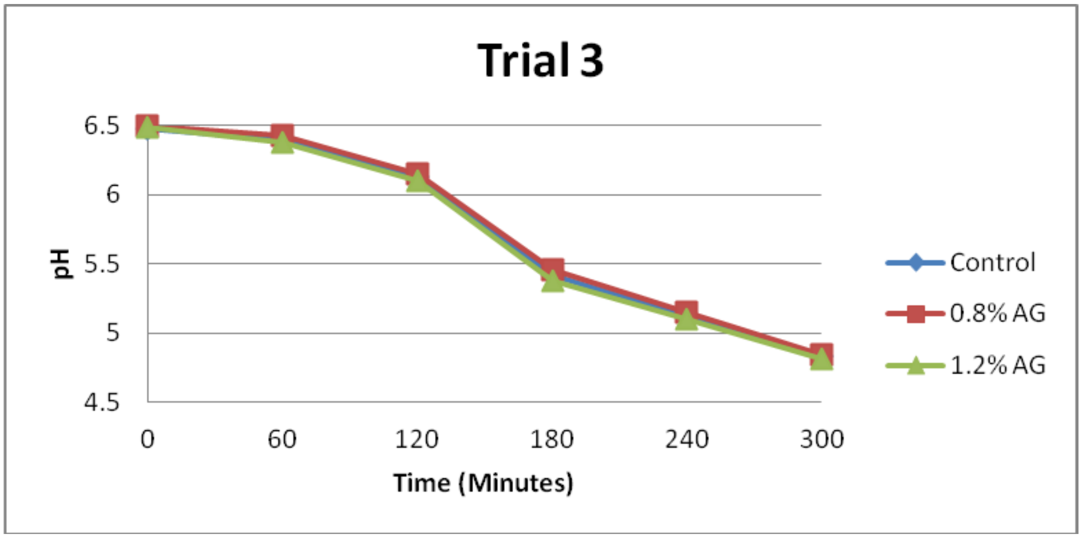

Figure 6. pH values of control sample, 0.8% arabinogalactan yogurt sample and 1.2% arabinogalactan yogurt sample in trial 3

In summary, this experiment found a statistically significant difference in yield stress between the control yogurt sample, 0.8% arabinogalactan supplemented yogurt, and 1.2% arabinogalactan supplemented yogurt on day 1 as well as on day 7. Initially, viscosity of the fortified samples on day 7 was higher in comparison to the control sample; however, this difference was not apparent at the end of the viscosity measurements. The addition of arabinogalactan did not affect the fermentation time for the different treatments of yogurts to reach pH 4.6. The significance of these findings will be discussed in Chapter 5.